CROP WEATHER RELATIONSHIP IN RICE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Crop weather relationship in rice**" is a bona fide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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We, the undersigned members of the Advisory Committee of **Mr.Sunil, K.M.** a candidate for the degree of **Master of Science in Agriculture** with major in **Agricultural Meteorology**, agree that the thesis entitled "**Crop weather relationship in rice**" may be submitted by Mr.Sunil, K.M. in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Rice (*Oryza sativa.* L.) is the staple food of more than half of the world's population. It grows well under widely varying climatic conditions ranging from the tropical to the sub tropical warm temperate climates (40°N to 50°S). It is cultivated as an important crop in 89 Nations. The total rice cultivated area all over the world extends to about 149 million hectares with a production of 550 million tonnes. By the year 2000, global paddy production should go up to 560 million tonnes in order to meet the requirement of the world's population (Swaminathan, 1989). The scope of extending area under rice is very much limited, therefore, the only way for increasing production is through intensive cultivation.

In India, rice cultivation extends between 8°N to 35°N latitudes. It occupies about 42 million hectares, which comes to about 23.5% of India's total agricultural area. The average rice productivity in the country is about 1.9 tonnes per hectare.

In Kerala, area under rice is to the tune of 2.23 lakh hectares with an annual production of about 3.88 lakh tonnes (Table 1). There is a wide gap between potential and actual grain yield of paddy in the State. Primarily it is due to the physical environment constraints, most of which are either uncontrollable by man or require excessive cost for their removal. The other reasons are biological constraints and socio–economic constraints that are controllable, if appropriate technologies are available. The major problem facing Kerala is the diminishing area under rice cultivation.

Table 1. Area, production and productivity of rice in different seasons over Kerala (1965 to 1998)

Year	Autumn			Winter			Summer		
	Area '000 ha	Product-ion '000 t	Producti-vity kg/ha	Area '000 ha	Product-ion '000 t	Producti-vity kg/ha	Area '000 ha	Product-ion '000 t	Producti-vity kg/ha
1965-'66	398.0	521.8	1311	327.8	389.8	1188	76.4	85.8	1122
1970-'71	394.7	538.8	1365	381.9	566.9	1484	98.0	192.1	1960
1975-'76	397.2	585.0	1473	383.7	588.8	1534	104.0	190.1	1836
1980-'81	349.2	553.7	2431	354.1	548.5	2357	98.3	169.7	2627
1985-'86	279.7	461.9	2514	313.4	526.9	2559	85.1	184.0	3290
1990-'91	236.1	463.0	2985	258.6	480.7	2829	64.8	142.8	3356
1995-'96	186.7	344.2	1844	224.6	458.1	2039	59.8	150.7	2519
1997-'98	69.3	138.6	3045	114.4	238.0	3173	48.6	11.4	3470

From the Table (1) it was clear that in 1965-'66 the total area under rice cultivation was 8.01 lakh hectares; while in 1997-'98 it was only 2.32 lakh hectares. The annual rice production of Kerala decline from 9.97 lakh tonnes (1965-'66) to 3.88 lakh tonnes (1997-'98).

The growth and yield of rice largely depend on the various weather factors like temperature, rainfall, solar radiation and relative humidity that prevail during the growing season. The optimum temperature range for rice is between 20-30^{0}C (Owen, 1971). Temperature beyond 35°C can affect grain filling. Sato (1972) observed highest rice yield in Japan, when sum of sunshine hours in the last two months of the crop was more than 400. Phenology of rice crop, particularly flowering is influenced by relative humidity regime. Flowering is inhibited at relative humidity below 40% and is best at 70-80% (Angladette, 1966).

Crop production involves a complex interaction between crop genotype, soil and aerial environment, and the crop management practices. Information generated about the various components of production system and their interactions has been used to develop crop growth simulation models. These models are effective tools for evaluating the consequences of different management strategies and its response to the environment leading to better crop production. Thus, a scientifically prepared simulation model will be very much helpful in improving the rice productivity.

Hence, the present investigation was taken up with the following objectives:

1. To study the effect of weather on the growth and yield of rice.

2. To develop regression equations between growth, phenology and yield of rice, and weather.

3. To generate the "Minimum Data Set" of weather, soil and crop to validate the rice model developed by the International Benchmark Sites Network for Agrotechnology Transfer.

Review of Literature

REVIEW OF LITERATURE

Interactions between crop and weather are the backbone for the productivity and stabilized yield. The growth and yield of any crop is highly associated with environmental factors. In the case of rice, these factors play a vital role because rice is highly sensitive to weather.

The present study was carried out to evaluate the influence of various weather parameters on the growth and yield of rice variety 'Kanchana' in three major rice growing seasons in Kerala i.e. *virippu*, *mundakan* and *puncha*. The study was also aimed at generating the 'Minimum Data Set' (MDS) on soil, weather and crop to validate the rice modal developed by International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT). The literature pertaining to the present study is reviewed in this chapter.

2.1 WEATHER AND RICE

2.1.1 Vegetative stage

2.1.1.1 Temperature

Among the different weather factors that affect the growth and yield of rice, temperature has got paramount importance. Growth processes in different development stages responded differently to the same temperature conditions (Ishizuka *et al.*, 1973).

Unlike in other crops, both water and surface air temperatures were important for rice. For upland rice, the optimum air temperature for germination was 30°C (Hall, 1966) while the lower limit was 20°C (Downey and Wells, 1974). According to Sreedharan (1975), a minimum air temperature of 25-26°C was ideal for shoot and root growth in rice. Robertson (1975), reported that optimum temperatures for elongation and leaf emergence were 25°C and 30°C respectively.

Kang and Heu (1976) reported that lower temperature during nursery period resulted in higher plant height.

Temperature affected the internode length in deep-water rice (Gomosta and Vergara, 1988). Internode elongation increased as temperature increased from 15°C to 30°C, then decreased at 35°C. Water temperature affected growth by regulating carbohydrate and N metabolism in the plants. According to Goto and Hoshikawa (1989), the rate of increase in tiller number on a time basis increased with temperature, but the rate of increase in leaf number decreased with temperature. Differences in growth rate between the main stem and 2nd order tillers decreased with temperature and between stem and 3rd order tillers were higher at 24/19 than at 30/25°C.

Plant height and length of first three leaves were high at 27-28°C and low at 20-22°C. Stem dry weight per cm decreased as plant height increased. Further increase in temperature at the early stage gave further increases in plant height and the length of the 1st and 2nd leaves (Chiba, 1990). According to Tsai and Lai (1990), tiller number in rice, decreased as shading increased and the decrease was greater at higher temperatures. The reports of Yang and Heilman (1990) indicated that temperature influenced the length-breadth ratio in rice, which in turn affected the leaf area. Kakizaki (1991) stated from experiments with ten different temperature treatments that tiller number was higher in the 15°C treatment. Tiller emergence was inhibited by the 33°C treatment. With the 33°C treatment, emergence of secondary tillers ceased completely in Zosan No.1, whereas six secondary tillers were formed in Norin No.1. Tillers which emerged under 15°C base temperature were inhibited when the temperature was switched to 33°C, and those which were inhibited under 33°C developed again when switched back to 15°C.

In a comparison of rice grown in water at 30 and 35°C, Sasaki (1992) had shown that high water temperature (HWT) decreased the length and width of the leaf blade. HWT at the emergence of a particular leaf markedly decreased the blade length of the subsequent leaf and the blade width of the leaf after that. Sheath length was unaffected by temperature. Temperature influenced the leaf appearance rate, the leaf number, panicle emergence and development (Ellis *et al.*, 1993). The rate of leaf appearance was no greater at 28°C than at 24°C, the optimum being about 26°C.

Various germination regimes were tested in order to evaluate 23 cultivars for germinability under unfavourable environmental conditions similar to those in northern Italy (Quagliotti *et al.*, 1995). Germination at 10°C for 5 days followed by 18°C for 15 days gave the best results for vigour evaluation.

2.1.1.2 Rainfall

Rainfall affects the rice crop at different stages of vegetative growth period. Variability in rainfall affects stand, establishment and the growth duration of rice. Chandler (1963) reported that many rice varieties responded better to nitrogen in dry season than in wet season. According to Chatterjee (1970), tillering in a number of rice varieties continued up to 42-45 days in rainy season, whereas it was up to 50-55 days in dry season.

2.1.1.3 Solar radiation

Radiation has been reported to influence tillering during vegetative phase and fertilizer response during flowering. The solar radiation requirement of rice crop differs from stage to stage.

Low light intensity during the vegetative phase slightly affected the yield and yield components of rice (Yoshida, 1973; Yoshida and Parao, 1976). According to Sreenivasan and Banerjee (1978) at Aduthurai, sunshine during flowering was 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 were conducive for better yield.

Sreedharan and Vamadevan (1981) reported that Leaf Area Index (LAI) reduced to a great extent in plants shaded either from planting to panicle initiation or from flowering to harvest. Shading also caused death of many lower leaves.

In deep-water rice, with increase in light intensity, the length of elongated internodes decreased and dry matter content increased. Internode length was the highest in red light followed by yellow or green light and blue or white light and least in far-red light (Gomosta and Vergara, 1988).

Rice was grown under full solar radiation or shaded to 78 per cent of solar radiation from panicle formation to heading. Samples taken showed reduced root length and density in shaded plots. Total root length was 3,81,000 km ha^{-1} in shaded plots and 4,92,000 km ha^{-1} in unshaded plots (Mawaki *et al.*, 1990). According to Tsai and Lai (1990), rice was grown at normal light, 25 and 75 per cent shading. Tiller numbers decreased as shading increased and the decreased was greater at higher temperatures. Shading delayed tillering and decreased tillering rate. There was an interaction between the effects of light and temperature on tillering.

At low light intensity (5 Kilo Lux), photosynthetic rates of the three cultivars from the higher elevations were lower than that from lower elevations, the opposite effect was seen at higher light intensity i.e. 70 Kilo Lux (Xia, 1991).

2.1.1.4 Relative Humidity

Rice crop required a fairly high degree of humidity for proper growth (Ghosh, 1961). According to Sreedharan (1975), RH of 80-85 per cent is ideal for shoot and root growth.

According to Lin-Meng Huei *et al.* (1994), rice growth was significantly affected by the NE monsoon with an average monthly wind speed of 4.7ms^{-1}. Strong winds caused leaf breakage and delayed crop maturity.

2.1.2 Reproductive stage

Weather parameters have got much more significant effect on rice crop during reproductive phase than that in the vegetative phase.

2.1.2.1 Temperature

In North India low temperature caused high yield reduction due to cold injury. Due to this, a 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 (Hayase, 1969).

Nishiyama *et al.* (1969) reported that the critical low temperature for inducing sterility is 15-17°C in highly cold tolerant varieties. A 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 were reported by De-Datta and Zarate (1970). . According to Satake and Hayase (1970), the stage most sensitive to coolness is the young microspore stage after meiotic division at anthesis.

Satake and Yoshida (1978) reported that high temperature induced sterility in rice and heading time was the most sensitive stage to high temperature. For spikelet sterility, high temperature was the second detrimental factor before anthesis but it was the most detrimental factor during anthesis. It had got a little effect after anthesis on spikelet sterility.

Low temperature treatment (19°C) of rice from boot stage to heading delayed heading, shortened stems and panicles and decreased grain fertility and yield potential. Low temperature treatment also resulted in low pollen density per anther and increased pollen sterility (Kim *et al.*, 1989). According to Tsuno *et al.* (1989) low night temperature decreased photosynthesis and transpiration by 3-46 per cent by increasing stomatal resistance

Transferring rice growing from 27/22°C to a range of day/night temperatures (24/19° to 30/25°) after heading resulted in little variation in grain dry weight. There was a significant drop in grain dry weight with a further increase in temperature to 33/28° and 39/24° (Tashiro and Wardlaw, 1991a). They also reported that sterility and parthenocarpy were most evident when temperature treatments commenced at heading and were greatest at the highest temperature (39/34°C). It was suggested that temperature greater than 27/22° could interfere with the early stages of cell division and development in the endosperm (Tashiro and Wardlaw, 1991b).

According to Baker *et al.* (1992) grain yield was decreased by an average of about 7-8 per cent per 1° rise in temperature from the 28/21/25°C to 34/27/31°C (day time dry bulb air temperature/night time dry bulb air temperature/paddy water temperature) temperature treatment.

Chauhan (1994) reported that at high temperatures (37/27° C of day/night temperatures) 1000-grain weight was reduced but the main cause of the yield decrease was much reduced spikelet fertility (36% compared to 86% in controls).

Four rice cultivars were grown at temperatures of 21-25°C, 24-28°C and 27-31°C. The number of spikelets per panicle varied with cultivar and tended to decrease with increasing temperature (Kitagawa *et al.*, 1995). Increasing day/night temperature to 36/29°C resulted in a significant reduction in both plant biomass and grain yield at harvest. At a constant day temperature of 29°C, increasing night temperature did not significantly alter growth and yield, however increasing night temperature at a day temperature of 33°C, resulted in a significant decline in grain yield, primarily due to reduced seed set. This suggests that higher night time temperature could increase the susceptibility of rice to sterility with a subsequent reduction in seed set and grain yield (Ziska and Manalo, 1996).

2.1.2.2 Rainfall

Rainfall affected the rice crop at the reproductive stage. Variability in rainfall was associated with an untimely cessation at the reproductive and ripening stage, the yield reduction was severe. The number of panicles was more (500/m^2) in *rabi* compared to *kharif* (400/m^2) season, thus being responsible for high yield in the former (Venkateswarlu *et al.*, 1976).

Moraes (1978) reported that a drought of 5 to 20 days duration adversely affected the upland rice and often caused severe damage at the reproductive and ripening stages.

Ebata and Ishikawa (1989) reported that wind damage to rice crop at the reproductive phase was triggered by temporary water stress in the panicle spikelet and the injury was less when wind was accompanied by rain.

In South Konkan, for an average productivity of 2.32 t ha^{-1}, rainfall distribution pattern of 27, 34, 23.5, 12 and 28 per cent of the mean total of 3501 mm during seedling, establishment, tillering, flowering and maturity phases, respectively was required. But in North Konkan, the corresponding rainfall pattern for an average productivity of 2.34 t ha^{-1} was 22.6, 33, 27.3, 14.3 and 3.3 per cent of the mean total rainfall of 2066.3 mm respectively (Patil, 1995).

2.1.2.3 Solar radiation

Wada *et al.* (1973) and Yoshida and Parao (1976) reported that solar radiation and temperature during the reproductive stage (before flowering) had the greatest influence on rice yield because they determine the number of spikelets per square metre. According to Stansel (1975), the most critical sunlight requiring period was around the heading stage. During this period, a mean yield reduction of 6.5 per cent was observed for every 1 per cent reduction in solar radiation.

Dry matter production and yields were highly dependant on solar radiation and it was the major factor governing photosynthesis. The low light intensity up to flowering in *kharif,* imposed a ceiling on tillering and reduced dry matter production as compared to *rabi* season (Venkateswarlu *et al* 1977). Vijayalakshmi *et al.* (1991) reported that the productivity of October sown rice crop was relatively low (1.2 t ha^{-1}) as compared to that of January sown *rabi* crop. This reduced productivity was due to the insufficient solar radiation during *kharif.*

Seasonal influence and varietal variation in solar energy utilization (Eu%) in 8 lines were assessed. Eu per cent for biological yield (BY) over the whole growth period was highest (1.3m) in the August planted crop which experienced low cumulative radiation of 24 k cal cm^{-2} and lowest in the December planted crop which was exposed to maximum total incident radiation of 48 k cal cm^{-2}. The Eu per cent for BY showed an inverse relationship with total incident radiation received by the crop and was higher in the wet season than in the dry season crops (Sahu *et al.*, 1989).

According to Vijayalakshmi *et al.* (1991), yield reduction due to shading (50%) was 11-14 per cent in the shade-tolerant cultivars and 29-34 per cent in the susceptible ones compared to 100 per cent sunlight. Corresponding reductions in total dry matter accumulation were 8-13 and 23-25 per cent respectively. The shade

Wind speed of 43-80 kmh^{-1} in Brazil, caused whitened panicles, which were upright, suggesting that an interruption occurred in the spikelet filling process. Analysis of the reproductive organs showed that the anthers and ovaries were absent or were desiccated in empty spikelets. (Marchezan *et al.*, 1993).

2.1.3 Ripening stage

2.1.3.1 Temperature

Generally, grain yield was higher when temperature during ripening stage was relatively low, an effect attributed to a more favourable balance between photosynthesis and respiration. Temperature influenced the ripening of rice in two ways - first, low temperature favoured an increase in grain weight and second, low daily mean temperature increased the length of ripening period (Nagato and Ebata, 1966).

Higher grain yield in temperate countries than in tropics could have generally been attributed to the lower temperature during ripening, which extended the ripening period, so more time grain filling. At low temperature, translocation of photosynthates to grain took place at a slower rate and thus maturity period got delayed (Boerma 1974).

In tropics, where the daily mean temperature ranged from 23-30°C, duration of ripening became about 30 days after the beginning of panicle emergence (Yoshida and Hara, 1977).

According to Kwon *et al.* (1989), low temperature treatment reduced ripening ratio and yield while fertilizer application reduced low temperature injury. The effective heat sum and base temperature (BT) for specific stages of the reproductive phase were analysed. BT for panicle emergence and flowering of cv. Sasamishiki were 12.1 and 11.5°C respectively. During ripening, BT showed its highest value of 9.4-10.1°C at the earliest stage and declined to 4-5°C at the latest stage of ripening (Ebata, 1990).

Grain thickness in rice was most reduced by high temperature commencing 12 days after heading, but grain length and width were most sensitive to high temperature at early stages of development. (Tashiro and Wardlaw, 1991b).

2.1.3.2 Rainfall

According to Sahu and Murthy (1976) reported that dry matter production and grain yield were invariably lower by about 50 and 54 per cent respectively in wet (July-October) season than in dry season (January-May). The report of Balakrishna Pillai and Prabhakaran (1978) indicated that, at Pattambi, at least one third of variablity in yield of *Virippu* could be explained through fluctuations in monthly rainfall.

Sikder and Gupta (1979) noticed an overall reduction of 44.5 per cent in grain yield during *Kharif* season compared to *rabi* in West Bengal. Viswambharan *et al.*, (1989) reported a negative correlation between yield and number of rainy days during maturity stage. The degree of association between rainfall pattern in individual years and the average distribution pattern during various growth phases dictated rice productivity (Patil, 1995).

According to Reddy and Reddy (1997), grain yield was negatively correlated with number of rainy days and humidity during the vegetative stage and with maximum temperature and humidity during the reproductive stage, but was positively correlated with sunshine hours during the pre- and post-flowering stages.

2.1.3.3 Solar radiation

Studies at IRRI revealed that the quantity of solar radiation had profound influence on rice yield, particularly during the last 30-45 days of ripening period (Moonaw *et al.*, 1967). Sreedharan (1975) reported that the yield attributes such as panicles per square metre, grain yield etc., recorded a positive correlation with solar energy during reproductive and ripening phases.

According to Yoshida and Parao (1976), low solar radiation during ripening phase reduced the grain yield considerably, because of the decrease in percentage of filled grains. Krishnakumar (1986) reported that panicles per square metre, grains per square metre, degree of ripening and grain yield were positively correlated with solar energy during ripening period.

Usha (1985) reported that the increase in grain yield was attributed to more Utilisation of solar energy with uniform exposure to sunlight.

Reports of Pamplona *et al.* (1995) clearly showed that grain yield in rice was highly correlated with solar radiation and minimum temperature. High yield observed especially during the dry season was not due mainly to higher solar radiation but also due to lower minimum temperature.

Low temperature and reduced solar radiation decreased both vegetative and reproductive growth and inhibited panicle heading, particularly in September (Lee-Tiann Feng and Lee, 1997).

2.1.3.4 Relative Humidity

High Relative Humidity (RH) at the time of harvest posed problems of seed germination in case of varieties which lack seed dormancy.

Photosynthetic rate at 22, 28 and 34°C, increased with increased humidity and vice versa (Hirai *et al.*, 1989).

Relative humidity was the most significant meteorological factor affecting spikelet fertility in rice followed by mean temperature at 3 days after heading. Spikelet fertility was reduced with increasing RH (Shi and and Shen, 1990).

2.1.3.5 Wind

Viswambaran *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.

Fertilization in rice was inhibited by wind speed more than 4 ms^{-1}. Brown grain discolouration was caused by wind at flowering and the occurrence of white grain was increased by wind at 14-21 days after heading.

Wind speed of 43 -80 kmh^{-1}, together with high temperature (25-32°C) and low RH (55-65%) caused whitened panicles, due to an interruption occurred in the spikelet filling process. Analysis of the reproductive organs showed that the anthers and ovaries were absent or were desiccated in empty spikelets (Marchezan *et al.*, 1993).

Rice growth was significantly affected by the NE monsoon with an average monthly wind speed of 4.7 ms^{-1}. Strong winds caused leaf breakage and delayed crop maturity, 1000-grain weight and yield (Lin-Merg-Huei *et al.*, 1994).

2.2 DATES OF PLANTING

Experiments conducted at Pattambi (KAU, 1980) showed that all varieties gave maximum yield for sowing done on 3rd May during *virippu* season. During *mundakan* season, all varieties gave poor yield when the nursery was raised in the second week of October. During *puncha,* for Jyothi, sowing in last week of January produced maximum grain yield. Similar results were reported in an experiment conducted at Agricultural research station, Mannuthy (KAU, 1983).

Report of KAU (1985) showed that early planting (last week of August) of second crop gave maximum yields and delayed plantings were severely affected by pest attack. According to Sreelatha (1989) transplanting in the first week of July in *virippu* and third week of October in *mundakan* season can give higher grain yield for variety Jaya.

At Regional Agricultural Research Station, Pilicode, the grain yield was higher when planted on 8th June, followed by crops planted on 22nd June (Rao, 1994). He also reported that low yield was attributed to high rainfall received during the early and flowering stages of crop.

2.3 WEATHER AND PESTS & DISEASES

Weather parameters have got profound influence on the incidence of pest and diseases in rice. Some weather conditions are highly congenial for the pests and diseases whereas some conditions protect the crop. By knowing that, we can modify the weather conditions to suit the requirements of rice crop.

Singh *et al.* (1986) reported that sheath rot of rice (*Sarocladium oryzae*) was becoming an important disease in rainfed low land rice, especially in delayed plantings. The occurrence was high in 50 days old seedlings. In general, photoperiod sensitive tall varieties were more resistant than photoperiod insensitive ones. Dhal and Choudhary (1987) reported that the disease incidence was high in delayed plantings due to low temperature accompanied by low RH during reproductive stage. At low temperatures, nymphs of brown plant hopper (*Nilaparvata lugens* Stal.) that moulted successfully and emerged as adults with in 1-2 days. They also suggested that a temperature of around 10°C was critical for the survival and development of *Nilaparvata lugens* (Yang and Chu, 1988).

In Tamil Nadu, the activity of the parasitoid *Tetrastichus schoenobii* attacking rice yellow borer (*Scirpophage incertulas*) was reduced as temperature and wind velocity increased (Chandramohan and Chelliah, 1990). According to Viajante and Saxena (1990), for optimum hatchability and larval survival of rice yellow borer, egg mass storage should not exceed 10 days at 15°C. According to the reports of Ramakrishnan and Venugopal (1991), 50 per cent of the variation in dead heart, due to the attack of rice stem borer infestation was attributed to weather.

The entire vegetative growing stage of rice was suitable for the population growth of rice gall midge. Humidity was the main factor influencing the reproduction of the cecidomycid. An average humidity of more than 78 per cent at the early to middle stages of rice tillering, the rate of reproduction increased by more than 7 times from the previous generation to the following generation (Pan *et al.*, 1993).

Peak occurrence of green leafhopper (*Nephotettix virescens*) on rice was recorded during September and October in Tamil Nadu. Influence of weather parameters on green leafhopper population for spring, autumn and winter seasons showed positive correlation with RH and negative correlation with minimum temperature (Raju *et al.*, 1997).

Maximum percentage of rice blast (*Pyricularia oryza)* occurrence was recorded in the second fortnight of October followed by the first fortnight of November when the maximum and minimum temperature varied between 31.5 and 18.1-16.6°C and RH 90-40 per cent. (Tripathi *et al.*, 1997).

2.4 CROP WEATHER MODELS

Crop growth model is an effective tool for evaluating the consequences of different management strategies on its response to the environment leading to better crop production.

A simulation model of the growth of irrigated rice cv. IR 36 in relation to radiation, temperature and nitrogen status of above ground biomass was described by Angus and Garcia (1989). The model was modified to simulate the growth of rainfed rice by incorporating a water balance component.

A function of substrate utilization of rice was formulated to simulate the functions of the enzyme system which manipulated the partitioning of substrate in rice. Based on the carbon balance rule and the Michaelis-Menten Law, numerical simulation models were set up to describe the relationship between weather factors, vegetative growth and yield formation of rice (Zhan, 1989).

The CERES-RICE-N model, which models the effects of weather, soil properties and crop management on nitrogen dynamics and crop growth was described by Godwin *et al.* (1990).

A demographic model for rice growth and development as affected by temperature and solar radiation under non-limiting water and nutrient conditions was presented by Graf *et al.* (1990). The distributed delay model was used to describe the dynamics of tiller production and culm, leaf, root and grain growth.

The MACROS model simulated physiological and physical processes by which meteorological variables affected the growth and development of rice (Herrera-Reyes *et al.* 1990). Crop parameters, weather variables and management factors are inputs in the model.

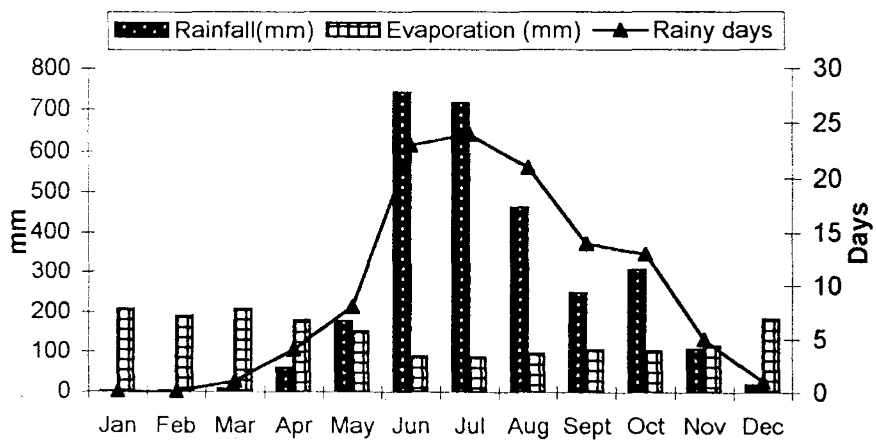
A dynamic model (SIMRIW) for simulating rice growth and yield in relation to weather and climate was developed by Horie (1991). The model did not predict the actual yield, but gave potential yield that may be expected under a given climate from the physiology of a given cultivar grown under optimal conditions.

Feng and Wang (1992) proposed a model for the growth of late rice in which the weight of panicles and the total above ground weight were predicted from meteorological data only. In 1989 the actual measurements agreed closely with the calculation based on the model. The meteorological measurements used were temperature and sunlight.

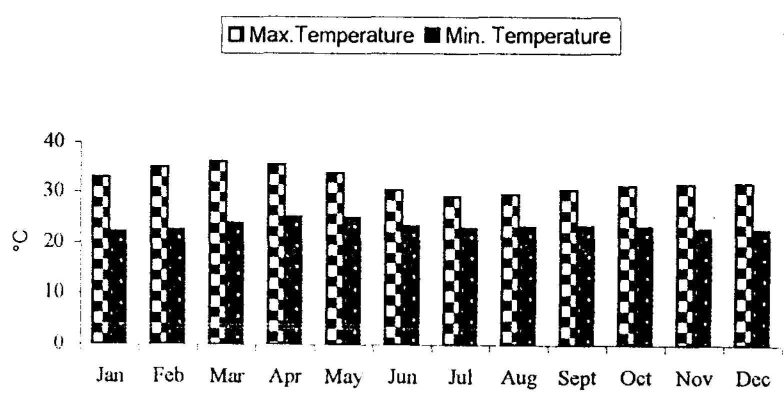
The regression model showed that the daily minimum temperature had a more significant effect on development than the daily maximum temperature (Yin, 1994).

The ORYZA 1 model was used to estimate rice potential production using daily weather data. Increasing Co_2 alone increased simulated yields but temperature increases of 1, 2 and 4°C decreased yields by 6.7, 14.1 and 29.4 per cent respectively (Mathews *et al.*, 1995).

Fig. 1. Climate of the locality



Rainfall (mm), Evaporation (mm) and Rainydays



Monthy Mean Maximum and Minimum temperatures(^{0}C)

Fig.2. Layout of the field

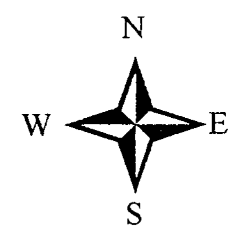
	First crop season			Second crop season			Third crop season		
R III	T_1	T_3	T_2	T_4	T_6	T_5	T_8	T_7	T_9
R II	T_3	T_1	T_2	T_5	T_6	T_4	T_8	T_9	T_7
R I	T_3	T_2	T_1	T_6	T_5	T_4	T_7	T_9	T_8

TREATMENTS

T_1 - June Ist
T_2 - June 15th
T_3 - June 30th

T_4 - October 1st
T_5 - October 15th
T_6 - October 30th

T_7 - January 1st
T_8 - January 15th
T_9 - January 30th



3.3.1.5 Leaf area index

Leaf area index was computed at weekly intervals. Two sample hills were randomly selected in each plot and number of tillers was counted in each hill. The length and maximum width of leaves in the middle tiller of the sample hills were measured separately and leaf area was computed based on length- width method.

$Leafarea = L \times W \times K$, where

K is the Adjustment factor (0.75), L is the length and W is the width (Gomez, 1972). The leaf area index was calculated using the following formulae.

$$Leaf\ area\ \ per\ hill\ = Total\ leaf\ area\ of\ middle\ tiller \times Total\ number\ of\ tillers$$

$$\text{LAI} = \frac{\text{Sum of leaf area per hill of "n" sample hill (cm}^2\text{)}}{\text{Area of land covered by "n" hills (cm}^2\text{)}}$$

3.3.1.6 Maximum leaf area index

Leaf area index of the plant was calculated at different stages of plant growth using the above equation. The highest value recorded by each planting was taken as the maximum leaf area index.

3.3.1.7 Final leaf number

Total number of leaves present per hill at the time of harvest were counted and recorded.

3.3.1.8 Time of flowering

Number of days taken for 50 per cent flowering after transplanting was noted and recorded.

3.3.2 Yield components

3.3.2.1 Number of panicles/plant

Number of panicles/plant was recorded.

3.3.2.2 Number of filled grains/panicle

The number of filled grains per panicle was recorded at harvest.

3.3.2.3 1000 grain weight

One thousand grains were counted from the cleaned produce from each plot and the weight was recorded in grams.

3.3.2.4 Grain chaff ratio

$$\text{Grain chaff ratio} = \frac{\text{Grain yield}}{\text{Chaff content}}$$

3.3.2.5 Grain yield

The grain harvested from each plot was dried to 14 per cent moisture, and was cleaned, winnowed, weighed and expressed in t ha^{-1}

3.3.2.6 Straw yield

The straw from each net plot was dried uniformly, weighed and expressed as t ha^{-1}.

3.3.2.7 Harvest index

Harvest index for different treatments was calculated using the equation

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.3.3 Chemical analysis

3.3.3.1 Plant analysis

The crop samples collected at different stages and at harvest were dried at 80°C separately in a hot air oven to constant weight, powdered well in a willy mill and respective samples were analyzed for nitrogen, phosphorus and potassium content.

The methods used for analysis

1. Nitrogen : Microkjeldhal method (Jackson, 1958).
2. Phosphorus : Vandomolybdate method (Jackson, 1958).
3. Potassium : Hydrochloric Acid extract method using Flame Photometer (Jackson, 1958).

3.3.3.2 Soil analysis

Soil samples were collected before planting and continued at 30 days interval till the harvest.

The samples were dried separately powdered well in a mortar and respective samples were analyzed for pH, CEC and organic matter content.

The method used for analysis

1. pH : 1: 2.5 soil –water suspension p^H meter
2. CEC : Kjeldahl Distillation method.
3. Organic carbon : Walkley and Black method

3.3.4 Weather data

The daily data on the different weather elements were recorded from the Agro met observatory of College of Horticulture, Vellanikkara. The daily data on maximum temperature, minimum temperature, bright sunshine hours, rainfall, relative humidity, wind speed and evaporation were used for the study.

3.4 Statistical analysis

The data obtained from experiments were analyzed statistically as per the methods suggested by Panse and Sukhatme (1985).

Correlation and regression analysis were done between the growth and yield characters with the weekly mean/total values of rainfall, maximum temperature, minimum temperature, relative humidity and sunshine hours to determine the effect of weather elements on the growth and yield of rice. Regression equations were worked out from these observations.

3.5 Growing degree days (GDD)

The growing degree days (GDD) were worked out during the crop period and attempted to relate the same with crop duration as well as grain yield. The GDD were calculated using the following formula. The base/threshold temperature is assumed as 10°C for rice, as its growth ceases if it is below this optimum of 10°C.

$$GDD = \sum_{i=1}^{n} \frac{T\ maximum + T\ minimum}{2} - T\ base$$

where

$\sum_{i=1}^{n}$ = Period in days from sowing date till the last date of harvesting

Results

RESULTS

The results of the experiment entitled "crop weather relationship in rice" are presented in this chapter. The data on different observations were subjected to statistical analysis and results are presented below:

4.1 Weather during the crop period

The daily meteorological elements viz., maximum and minimum temperatures, rainfall, morning and afternoon relative humidity, wind speed and sunshine recorded at principal agromet station, College of Horticulture were used for the study and the weekly mean of weather variables are depicted in Table 3.

4.1.1 Rainfall

An amount of 2255.2 mm of rainfall was received during the first crop season (June-September) while it was 592.2 mm during second crop season (October-January) of 1998-'99. The total amount of rainfall received during the third crop season (January-April 1999) was only 49 mm. It indicated that the third crop requires irrigation depending upon rainfall distribution for successful cultivation of paddy in and around Thrissur region. It is true to some extent during second crop also.

Among the different treatments, June 15th planted crop received the highest amount of rainfall (1850.8 mm), followed by crop planted on June 30th (1789.8 mm). However, the ripening period (August) received the highest amount of rainfall (601.7 mm) and resulted in poor yield when transplanted on 30th June 1998. The lowest amount of rainfall (22.8 mm) was received by the crops planted on January 1st and January 15th.

Table 3. Weekly distribution of weather parameters

Std Week	Rain fall (mm)	Rainy days	Evapor ation (mm)	Max.T °C	Min.T °C	Mean T °C	Sunshine hours	RH1 (%)	RH2 (%)	Wind speed (km/h)
22	24.4	1	9.3	34.4	25.2	29.8	8.8	86	63	3.2
23	65.7	5	3.8	32.0	23.9	27.9	6.4	92	71	3.1
24	118.0	5	3.1	30.0	23.1	26.6	2.2	94	81	2.0
25	257.3	7	2.3	29.0	22.4	25.7	3.0	96	79	2.5
26	368.7	7	2.1	27.8	23.2	25.5	0.3	95	89	3.4
27	250.6	7	2.4	29.0	23.8	26.2	2.5	96	81	2.6
28	140.1	6	2.6	29.2	24.0	26.6	2.4	95	81	2.2
29	116.2	5	2.9	29.8	24.1	26.9	4.9	96	77	2.4
30	151.6	7	2.4	29.2	23.4	26.3	3.0	96	84	2.8
31	80.0	6	8.2	30.3	24.4	27.4	4.6	97	76	3.1
32	80.9	6	2.8	29.2	23.8	26.5	2.1	95	80	2.5
33	12.7	2	3.1	30.5	24.5	27.3	4.6	94	73	2.2
34	274.7	5	2.1	28.5	23.5	26.0	2.5	95	84	2.9
35	129.9	3	3.4	30.2	23.6	26.9	5.4	94	72	2.4
36	184.4	6	2.7	30.7	23.7	27.2	3.8	96	82	1.8
37	169.4	7	2.9	28.4	22.9	25.7	3.2	95	80	2.2
38	29.9	4	3.4	30.2	23.3	26.8	6.8	95	72	2.2
39	63.0	5	2.4	28.6	23.1	25.9	2.4	95	77	1.6
40	51.8	6	2.8	29.3	23.1	26.2	3.8	93	79	1.5
41	319.4	6	1.9	27.8	23.0	25.4	1.5	95	91	2.7
42	70.2	5	3.1	29.8	22.6	26.2	4.8	94	73	1.8
43	10.8	1	3.5	31.1	22.5	26.8	8.2	92	66	2.0
44	6.9	1	2.8	31.1	23.2	27.2	5.5	94	68	1.6
45	86.0	5	2.6	30.8	23.6	27.2	4.1	93	70	1.8
46	16.9	3	3.5	31.9	22.8	27.4	8.9	94	63	1.9
47	0.0	0	3.2	31.7	22.8	27.3	9.0	93	58	1.3
48	4.8	1	3.3	32.2	23.0	27.6	7.9	88	58	1.7
49	1.4	0	4.5	31.3	23.8	27.6	6.1	78	60	6.0
50	27.0	3	2.9	29.7	23.4	26.5	3.3	82	71	7.1
51	0.0	0	4.2	31.4	22.4	26.9	8.6	79	57	4.3
52	0.0	0	5.1	31.1	22.0	26.6	8.2	76	40	6.7
1	0.0	0	5.1	31.1	22.0	26.6	8.2	76	40	6.7
2	0.0	0	5.0	32.5	21.9	27.2	9.5	79	43	5.1
3	0.0	0	6.9	32.2	22.8	27.5	10.0	70	40	9.8
4	0.0	0	5.9	82.5	19.5	26.0	7.9	74	32	5.5
5	0.0	0	4.5	33.9	22.1	28.0	10.1	83	39	3.6
6	22.8	1	5.1	34.0	23.4	28.7	9.2	80	44	4.3
7	0.0	0	6.3	34.7	23.2	29.0	10.0	79	39	5.3
8	0.0	0	7.6	34.2	24.5	29.4	6.9	70	33	7.9
9	0.0	0	7.6	36.4	22.2	29.3	10.4	74	33	5.0
10	0.0	0	5.8	36.5	23.8	30.2	9.9	92	34	3.1
11	0.0	0	4.9	35.2	25.0	30.1	8.4	89	54	2.8
12	0.0	0	4.5	34.8	25.0	29.9	8.4	91	55	2.4
13	0.0	0	4.9	34.9	25.1	30.0	7.5	89	54	2.4
14	26.2	1	5.7	34.9	24.5	29.7	7.8	90	55	3.0
15	0.0	0	4.6	33.2	25.8	29.5	7.4	86	59	3.3

4.1.2 Temperature

A decreasing trend (34.4°C to 30.7°C) was noticed in mean weekly maximum temperature during the first crop season of 1998 from transplanting to maturity (June-September). In contrast, the mean weekly maximum temperature gradually increased during second crop season (October- January) of 1998-99 from 29.3°C at transplanting to 32.5°C at maturity. While it was 31.1°C to 33.2°C in third crop season (January-April, 1999), indicating a similar trend as in the case of second crop.

During the first two crop seasons the minimum night temperature decreased from transplanting to harvest. It was 25.2°C to 23.7°C in the first crop while it was 23.1°C to 21.9°C during the second crop season. Unlike the first two crop seasons, it varied from 22.0°C to 19.5°C during vegetative phase (January-February) indicating a decreasing trend and thereafter a gradual increase (from 22.1°C to 25.8°C) was noticed during reproductive phase of third crop season.

4.1.3 Sunshine

A glance at the availability of solar radiation in terms of bright sunshine during all the three cropping seasons revealed that, the first crop season received least amount (455.3 hours) of radiation compared to second and third crop seasons (905.7 and 1022.7 hours respectively). It indicated that the bright sunshine was not a limiting factor during the second and third season crops, while it was not so in the case of first crop season (117.9 hours) as it required an optimum of 200 hours during 30 days before harvest.

4.1.4 Relative humidity

During the first crop season, the crops experienced fairly high (92-97%) relative humidity during the entire growing period. In the case of second crop season, the relative humidity remained high (92 – 95 %) for the first 7 weeks (October 1st to November 18th) and then decreased gradually from 97 to 79 per cent. During the third crop season (January-April, 1999), relative humidity was low (75-80%) during initial weeks (January 1st to February 4th) and then increased (79-89%).

4.1.5 Wind speed

During the first crop season, the average wind speed at vegetative phase (June- July) was 2.7 km hr^{-1}. Second crop season recorded the lowest average wind speed at vegetative period (1.8 km hr^{-1}). The average wind speed during third crop season was high during vegetative period (6.03 km hr^{-1}). In the case of reproductive phase also, a similar trend was noticed. The average wind speed remained same for the first crop season (2.7 km hr^{-1}) and the second crop season recorded the lowest (2.2 km hr^{-1}). The third crop season recorded the highest wind speed (5.3 km hr^{-1}) during reproductive period.

4.2 Biometric observations

4.2.1 Plant height

The mean plant height (cm) at 15, 30, 45, 60 and 75 days after planting are given in Table 4. At 15 days after planting, crop planted on June 15th was significantly superior, recorded the maximum height of 46.8 cm. In the case of 30, 45, 60 and 75 days after transplanting June 1st recorded the highest of 59.1, 89.1, 100.9 and 104.3 cm respectively. As expected, all the treatments recorded the maximum height at 75 DAP. Crop planted during January 30th recorded the lowest plant height (65.6cm). The crop transplanted during the first fortnight of June (1st and 15th June) recorded the maximum height of 99.3 and 104.3 cm. It was significantly superior among all the treatments. It revealed that the time of transplanting had a significant influence on plant height.

Table 4. Times of transplanting and plant height (cm) at 15 days interval

Time of planting	Transplanting	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP
June 1	18.8^{ab}	42.6^{b}	59.1^{a}	89.1^{a}	100.9^{a}	104.3^{a}
June 15	18.5^{ab}	46.8^{a}	52.7^{b}	77.3^{b}	90.2^{b}	99.3^{a}
June 30	15.4^{c}	31.7^{cc}	42.2^{cd}	59.1^{cd}	66.1^{cde}	85.3^{b}
October 1	16.5^{bc}	34.9^{c}	46.2^{c}	60.4^{c}	72.3^{cd}	76.7^{cd}
October 15	20.1^{a}	33.0^{cd}	47.7^{bc}	66.3^{bc}	73.9^{c}	80.9^{bc}
October 30	18.1^{ab}	29.6^{e}	44.5^{c}	66.6^{c}	72.2^{cd}	81.5^{bc}
January 1	16.9^{bc}	24.0^{f}	37.4^{de}	46.7^{e}	60.5^{ef}	72.9^{d}
January 15	17.5^{bc}	24.7^{f}	34.0^{ef}	49.2^{e}	64.4^{de}	78.3^{cd}
January 30	12.2^{d}	19.1^{g}	28.3^{f}	42.2^{e}	54.3^{f}	65.6^{e}
SE(m)±	0.73	0.98	1.92	2.22	2.51	2.03
LSD	2.19	2.93	5.86	6.66	7.56	6.11

4.2.2 Number of tillers

The number of tillers per hill varied between 5 and 10 among the different treatments (Table 5) at 75 days after planting. Like plant height, the number of tillers was also inferior (only 5) when planted on 30th January. Interestingly, the number of tillers produced per hill was high (8-10) when the crop was taken up during October and they were superior along with June 1st transplanted crop. It showed that the number of tillers was high when planted on June 1st, October 1st, 15th and 30th.

4.2.3 Biomass

As a whole, the total biomass was high during the first and second crop seasons except on June 30th. However, crops planted on October 1st and 15th showed superiority (25.17 and 27.77 g/plant) over other treatments. As evident in the case of plant height and number of tillers, the biomass was also poor (11.23g/plant) when crop planted on 30th January (Table 6).

4.2.4 Leaf number

During transplanting stage the crop planted on June 1st, June 15th and October 15th recorded the highest number (4 nos./hill) of leaves. Like biomass, crops planted during first and second crop seasons recorded the highest number of leaves/hill except in the case of June 30th planted crop. The highest number of leaves/ hill (53) was recorded by October 1st planted crop at beginning of grain filling stage. January 30th crop recorded the lowest leaf number in all the growth stages (Table 7).

4.2.5 Leaf area index (LAI)

During transplanting and active tillering stages, crops planted on June 1st, June 15th, October 1st, October 15th and October 30th were found superior to other treatments and on par with each other. June 1st and June 15th planted crops recorded the highest LAI in all the growth stages except during beginning of grain filling. At

Table 5. Times of transplanting and number of tillers at 15 days interval

Time of planting	Transplanting	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP
June 1	1	7^{a}	8^{bc}	11^{a}	9^{ab}	9^{a}
June 15	1	5^{b}	6^{cde}	7^{b}	7^{bc}	6^{bc}
June 30	1	2^{d}	4^{e}	4^{c}	6^{bc}	6^{bc}
October 1	1	3^{cd}	10^{ab}	10^{a}	10^{a}	8^{ab}
October 15	1	5^{b}	11^{a}	12^{a}	10^{a}	10^{a}
October 30	1	4^{bc}	8^{bc}	11^{a}	10^{a}	10^{a}
January 1	1	3^{cd}	7^{cd}	6^{bc}	5^{cd}	6^{bc}
January 15	1	3^{d}	8^{bc}	6^{b}	7^{bc}	6^{bc}
January 30	1	3^{d}	5^{de}	5^{bc}	4^{d}	5^{c}
SE(m)±	0	0.382	0.795	0.769	0.804	0.848
LSD	NS	1.48	2.39	2.30	2.41	2.54

Table 6. Times of transplanting and biomass per plant at different stages of plant growth

Time of planting	Transplanting	Active tillering	Panicle initiation	Heading	Beginning of grain filling	Maturity
June 1	0.06^{a}	4.27^{ab}	5.70^{b}	10.17^{a}	18.93^{a}	23.30^{bc}
June 15	0.06^{a}	2.63^{cd}	7.40^{a}	8.03^{abc}	14.83^{b}	24.67^{b}
June 30	0.03^{c}	2.33^{cd}	3.97^{c}	7.60^{abc}	10.03^{c}	14.30^{d}
October 1	0.05^{b}	3.60^{bc}	5.60^{b}	9.60^{a}	17.27^{ab}	25.17^{ab}
October 15	0.05^{b}	5.40^{a}	5.83^{b}	10.23^{a}	19.37^{a}	27.77^{a}
October 30	0.05^{b}	4.30^{ab}	6.90^{ab}	8.83^{ab}	14.83^{b}	21.07^{c}
January 1	0.03^{c}	1.40^{d}	3.57^{c}	5.57^{c}	8.17^{c}	12.30^{de}
January 15	0.03^{c}	1.60^{d}	3.57^{c}	6.43^{bc}	9.13^{c}	13.67^{de}
January 30	0.03^{c}	1.33^{d}	3.30^{c}	5.47^{c}	7.27^{c}	11.23^{e}
SE(m)±	0.003	0.475	0.450	0.943	0.890	0.913
LSD	0.005	1.42	1.35	2.02	2.67	2.74

Table 8. Times of transplanting and leaf area index at different stages of plant growth

Time of planting	Transplanting	Active tillering	Panicle initiation	Heading	Beginning of grain filling	Maturity
June 1	0.09^{a}	4.43^{a}	6.90^{a}	7.73^{a}	6.53^{b}	6.97^{a}
June 15	0.10^{a}	4.33^{a}	7.17^{a}	7.43^{a}	6.90^{ab}	7.13^{a}
June 30	0.05^{bc}	3.20^{bcd}	3.73^{c}	4.70^{cd}	4.40^{c}	4.60^{c}
October 1	0.10^{a}	4.03^{ab}	5.13^{b}	5.70^{bc}	7.73^{a}	6.17^{b}
October 15	0.10^{a}	3.93^{ab}	5.03^{b}	5.97^{b}	7.20^{ab}	6.57^{ab}
October 30	0.09^{a}	3.63^{abc}	4.90^{b}	6.30^{b}	7.17^{ab}	6.23^{b}
January 1	0.04^{c}	2.53^{de}	3.03^{cd}	4.27^{d}	3.70^{cd}	3.70^{d}
January 15	0.05^{bc}	3.00^{cde}	3.33^{cd}	4.43^{d}	4.03^{cd}	3.77^{d}
January 30	0.04^{d}	2.17^{e}	2.63^{d}	3.87^{d}	3.20^{d}	3.13^{d}
SE(m)±	0.003	0.28	0.29	0.34	0.28	0.23
LSD	0.005	0.84	0.86	1.03	0.84	0.68

the beginning of grain filling, crop planted on October 1st recorded the highest LAI. The first and third crop seasons recorded their Maximum LAI during heading stage, whereas second crop season recorded maximum at beginning of grain filling stage. The Maximum LAI was recorded by crops planted on June 1st(7.73) and October 1st (7.73). They were on par with crops planted on June 15th, October 15th and October 30th. Crop planted on January 30th recorded the least LAI at all the crop growth stages (Table 8).

4.2.6 Maximum leaf area index

Maximum LAI was observed during the heading stage for the first and third season crops. But in the case of second crop season, maximum LAI was observed at the beginning of grain filling stage. June 1st and 15th, October 1st, 15th and 30th were on par with each other and showed highest Maximum LAI. The lowest value of maximum LAI was (3.87) recorded by January 30th planting. For getting higher yields (more than 4 t ha^{-1}), the Maximum LAI should be above four (Table 9).

4.2.7 Final leaf number

Final leaf number also showed a similar trend as that of maximum leaf area index. The highest value (38.3) was recorded by October 15th planted crop. It was followed by crops planted during October 1st (36.7), June 15th (34.7), June 1st (34) and October 30th (33.7). The least final leaf number (25) was recorded in the January 30th planted crop (Table 9).

The variations in morphological character of 'Kanchana' with the time of transplanting indicated that its effect was significant. The early transplanted crops on June 1st and 15th along with October plantings were superior when compared to that of the other treatments. It is also evident that the behaviour of the crop was inferior when the crop was transplanted on January 30th. As a whole, the behaviour of the

Table 9. Times of transplanting on maximum leaf area index and final leaf number

Time of Planting	Maximum leaf area index	Final leaf No.
June 1	7.73[a]	34.00[abc]
June 15	7.43[a]	34.70[abc]
June 30	4.70[b]	27.00[de]
October 1	7.73[a]	36.70[ab]
October 15	7.17[a]	38.30[a]
October 30	7.10[a]	33.70[abcd]
January 1	4.27[b]	29.00[cde]
January 15	4.43[b]	31.00[bcde]
January 30	3.87[b]	25.00[e]
SE(m)±	0.35	2.1
LSD	1.04	6.28

crop during first and second crop season except on June 30th planting was much better when compared to that of the third crop.

4.3 Yield characters

4.3.1 Panicles number

Highest number of panicles/hill (9) was recorded by October 1 planting. However it was on par with June 1st, 15th, October 15th and 30th planted crops and they significantly differ from all other treatments (June 30th, January 1st, 15th and 30th). A minimum of four panicles/hill value was recorded by crop planted on January 30th (Table 10).

4.3.2 Number of filled grains/panicle

The highest number of filled grains/panicle was 108 in crop planted on October 1st. There was no significant difference between crops planted on June 15th, October 1st, October 15th and October 30th. The minimum number recorded was 70.3 in crop planted on 30th January. January 1st and January 30th plantings recorded low values of 83.3 and 70.3 (Table 10).

4.3.3 Thousand grain weight

It ranged from 25.13 to 28.5 g among the different treatments. October 1st, 15th and January 15th were on par with each other and recorded comparatively higher values of 1000 grain weight. The first season crops planted during June showed relatively lower grain weight and they form a homogeneous group (Table 11). Quite interestingly the 1000 grain weight was inferior (25.13 to 25.63) during the first crop season in all the transplanted crops.

Table 11. Times of transplanting and thousand grain weight

Time of Planting	1000 grain weight (g)
June 1	25.13^{e}
June 15	25.63^{de}
June 30	25.23^{e}
October 1	26.57^{cd}
October 15	28.47^{a}
October 30	27.70^{ab}
January 1	27.10^{bc}
January 15	27.57^{abc}
January 30	27.13^{bc}
SE(m)±	0.34
LSD	1.24

4.3.4 Grain-chaff ratio

The grain-chaff ratio was 17.87 and 15.07 in crops planted on October 15th and 30th and they were on par. Crop transplanted on June 30th recorded the lowest Grain Chaff ratio and was significantly differed from all other treatments (Table 12).

4.3.5 Grain yield

The highest grain yield (6.2 t ha^{-1}) was obtained from October 15th planted crop while the lowest (2.1 t ha^{-1}) on January 30th planted crop. October 1st and 30th had comparatively high grain yield and they were on par with each other. The third crop planted during January (*puncha*) recorded low grain yield and was inferior to all other treatments (Table 13). It indicated that the grain yield was significantly superior during the second crop transplanted during October when compared to that of first and third crops.

4.3.6 Straw yield

The maximum straw yields were 10.36 t ha^{-1} and 9.72 t ha^{-1} in crops planted on 15th June and 30th June, respectively and they were on par with each other. Crop planted in January recorded low straw yields and they were significantly differed from all other treatments. The lowest value (2.75 t ha^{-1}) was recorded by January 30th planted crop (Table 13). In contrast to the grain yield, the straw yield was significantly superior when transplanted on June 15th.

In the case of total yield (grain + straw yield) crop planted on June 15th recorded the maximum yield (14.95) and it was significantly superior when compared to other treatments.

Table 13. Times of transplanting on grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index and total yield (t ha^{-1})

Time of Planting	Grain yield	Straw yield	Harvest index	Total yield
June 1	4.20^{d}	7.15^{b}	0.35^{g}	11.35^{c}
June 15	4.59^{c}	10.36^{a}	0.35^{g}	14.95^{a}
June 30	3.40^{de}	9.72^{a}	0.25^{h}	13.12^{ab}
October 1	5.60^{b}	6.07^{b}	0.46^{a}	11.67^{c}
October 15	6.20^{a}	7.13^{b}	0.46^{a}	13.33^{ab}
October 30	5.80^{b}	6.77^{b}	0.39^{e}	12.59^{bc}
January 1	3.00^{e}	3.17^{c}	0.41^{c}	6.17^{de}
January 15	2.74^{ef}	3.98^{c}	0.40^{d}	6.72^{d}
January 30	2.06^{f}	2.75^{c}	0.37^{f}	4.81^{e}
SE(m)±	0.2	0.50	0.01	0.52
LSD	0.39	1.5	0.005	1.005

4.3.7 Harvest Index

In the case of harvest index also, there was a significant difference between the treatments. The maximum harvest index was noticed in October 1st and 15th planted crops (0.46) and the minimum (0.25) was found in June 30th planted crop (Table 13).

The yield and yield attributes varied widely with times of transplanting. The crop planted on June 1st and 15th along with October plantings were superior when compared to other treatments. In case of grain chaff ratio, 1000 grain weight, grain yield and harvest index October planted crops were superior to all other treatments, but straw yield was maximum in June planted crops. The number of filled grains/panicle and number of panicles/hill in first and second crop seasons were on par with each other.

4.4 Crop weather relationship

Simple linear correlations between important morphological, yield characters and mean weekly weather parameters like maximum, minimum mean and its range of surface air temperature, relative humidity (morning, afternoon, mean and difference between morning and afternoon relative humidity), wind speed, bright sunshine, were carried out and the coefficients have been presented in ables 15 and 16.

4.4.1 Weather and morphology of rice

Morphological characters like maximum LAI, tillers at 45 days after planting and biomass accumulation from 15 to 45 days after transplanting were correlated with above mentioned weather parameters.

Table 15. Correlation coefficients between weather and phenological and morphological characters of rice - Kanchana

Weather Element	Days TP-PI	Tillers at 45 DAP	BM accu 15-45DAP	Maximum LAI
Maximum Temperature	-0.774* (3-4)	N.S	N.S	-0.718* (2-6)
Minimum Temperature	0.702* (1-3)	N.S	N.S	N.S
Mean Temperature	-0.755* (3-4)	N.S	N.S	-0.731* (3-6)
Temperature Range	-0.691* (2-4)	N.S	N.S	-0.673* (1-6)
Wind Speed	N.S	N.S	N.S	-0.827** (1-6)
RH1 (Morning)	0.704* (1-4)	N.S	0.811** (1-5)	0.755* (1-6)
RH2 (Afternoon)	0.742* (1-4)	N.S	0.750* (2-6)	0.737* (1-6)
Mean RH	0.737* (1-4)	N.S	0.746* (1-5)	0.748* (1-6)
RH1-RH2	-0.734* (1-4)	N.S	N.S	-0.696* (1-6)
Bright Sunshine Hours	-0.757* (2-4)	N.S	N.S	N.S

Figures in parentheses indicate period in weeks from transplanting

* Significant at 5%
** Significant at 1%

4.4.3 Weather and yield characters of rice

4.4.3.1 Grain yield

Wind speed, minimum temperature and mean temperature during flowering to maturity had a significant negative correlation with grain yield while the morning relative humidity and mean relative humidity during transplanting to panicle initiation stage had a significant positive influence on ultimate grain yield (Table 16).

4.4.3.2 Straw yield

Decrease in wind speed, mean temperature, temperature range, RH1-RH2 and solar radiation during vegetative phase had significantly increased the straw yield as there was a negative correlation between them. Maximum temperature during beginning of grain filling to maturity stage also had a negative correlation with straw yield. But increase in minimum temperature, mean relative humidity, morning and afternoon relative humidity during transplanting to flowering stage was significantly increase the straw yield as there was a positive correlation (Table 16).

4.4.3.3 Harvest index

The only weather parameter which had a significant correlation with harvest index was minimum temperature. An increase in minimum temperature during booting to beginning of grain filling stage had decreased the harvest index as there was a negative correlation between them (Table 16).

4.4.3.4 Number of panicles per plant

Increase in maximum temperature and mean temperature during active tillering to heading stage had significantly decrease the number of panicles/plant as there was a significant negative correlation between them.

Table 16. Correlation coefficients between weather and yield attributes of rice - *Kanchana*

Weather Element	Grain Yield	Straw Yield	Harvest Index	Panicle Number	No. of grains / panicle	Grain / Chaff ratio
Maximum Temperature	N.S.	-0.911** (7-11)	N.S.	-0.689* (3-6)	N.S.	N.S.
Minimum Temperature	-0.905** (6-11)	0.674* (1-5)	-0.820** (5-8)	N.S	N.S	-0.911** (5-8)
Mean Temperature	-0.744* (6-11)	-0.836** (1-6)	N.S	-0.720* (2-6)	N.S	N.S
Temperature Range	N.S	-0.948** (1-6)	N.S	N.S	N.S	N.S
Wind Speed	-0.854** (4-7)	-0.739* (1-6)	N.S	-0.795** (1-6)	N.S	N.S
RH1 (Morning)	0.748* (1-5)	0.890** (1-7)	N.S	0.725* (2-6)	N.S	N.S
RH2 (Afternoon)	N.S	0.921** (1-7)	N.S	0.703* (1-6)	N.S	N.S
Mean RH	0.681* (1-4)	0.913** (1-7)	N.S	0.714* (1-6)	N.S	N.S
RH1-RH2	N.S	-0.921** (1-7)	N.S	-0.674* (1-6)	N.S	N.S
Bright Sunshine Hours	N.S	-0.922** (1-6)	N.S	N.S	N.S	N.S

Figures in parentheses indicate period in weeks from transplanting

* Significant at 5%
** Significant at 1%

Table 17. Mean meteorological parameters prevailed during vegetative period

Time of planting	Max. Temperature °C	Min. Temperature °C	Relative Humidity I (%)	Relative Humidity II (%)	Sunshine Hours	Temp. Range °C	Wind Speed (km/h)
June 1	32.1	24.1	90.6	71.7	5.8	8.1	2.8
June 15	28.9	22.9	95.0	83.0	1.8	6.0	2.6
June 30	28.7	23.5	95.3	83.7	1.7	5.2	2.7
October 1	29.0	22.9	94.0	81.0	3.4	5.7	1.9
October 15	30.7	22.8	93.3	69.0	6.2	7.9	1.7
October 30	31.3	23.2	93.7	67.0	6.2	8.1	1.8
January 1	32.2	22.2	74.7	42.7	9.6	10.0	7.4
January 15	32.9	21.6	75.7	37.0	9.3	11.3	6.3
January 30	34.2	22.9	80.7	40.7	9.8	11.3	4.4

Table 18. Mean meteorological parameters prevailed during reproductive period

Time of planting	Max. Temperature °C	Min. Temperature °C	Relative Humidity I (%)	Relative Humidity II (%)	Sunshine Hours	Temp. Range °C	Wind Speed (km/h)
June 1	28.6	22.96	96	83	1.9	5.6	2.8
June 15	29.1	23.66	96	80	3.3	5.5	2.4
June 30	29.6	23.83	96	79	4.2	5.7	2.8
October 1	31.0	23.10	93	68	5.9	7.9	1.8
October 15	31.8	23.06	93	64	7.3	8.4	1.7
October 30	31.7	23.2	86	59	7.7	8.5	3.0
January 1	33.5	21.76	79	38	9.1	11.7	4.7
January 15	34.3	23.7	76	39	8.7	10.6	5.8
January 30	35.7	23.5	79	33	9.1	12.2	5.3

Table 19. Mean meteorological parameters prevailed during ripening period

Time of planting	Max. Temperature °C	Min. Temperature °C	Relative Humidity I (%)	Relative Humidity II (%)	Sunshine Hours	Temp. Range °C	Wind Speed (km/h)
June 1	29.4	23.9	96	80	3.4	5.6	2.6
June 15	29.5	24.0	95	80	3.4	5.6	2.7
June 30	29.5	23.8	95	78	3.7	5.8	2.4
October 1	31.3	23.2	87	62	7.1	8.2	3.6
October 15	31.1	22.9	80	58	6.8	8.2	5.2
October 30	31.3	22.3	78	52	7.8	9.1	6.1
January 1	35.4	23.7	81	38	9.1	11.5	4.8
January 15	35.6	24.2	87	46	8.9	11.3	3.1
January 30	34.6	25.0	89	55	7.9	9.5	2.8

During transplanting to heading period, morning and afternoon relative humidity and mean relative humidity had a positive relationship with number of panicles per plant, whereas wind speed and RH_1-RH_2 had a negative correlation (Table 16).

4.4.3.5 Grain chaff ratio

Increase in minimum temperature during booting stage to beginning of grain filling had decreased the grain chaff ratio significantly. All other weather parameters showed no significant relationship with grain chaff ratio (Table 16).

4.5 Regression equations developed

Regression analysis was carried out to select the critical variables, which contributed to yield, morphological characters and phenological variables.

In rice, heading to maturity stage is the most critical phase for grain yield. Among all the weather parameters, minimum temperature and wind speed had the maximum influence on ultimate grain yield. A multiple regression equation was developed based on minimum temperature and wind speed for estimation of grain yield. The estimate and the actual grain yields are given in Table 20.

4.5.1 Grain yield

$$Y = -1.5062\ T\ min - 0.39712\ WS + 41.1736. \quad (R^2 = 0.931)$$

Y = Grain yield ($t\ ha^{-1}$)

T min = Minimum temperature (Heading to maturity) (°C)

WS = Wind speed (booting to beginning of grain filling) ($km\ h^{-1}$)

4.5.2 Straw yield

Weather parameters during vegetative phase had a good relationship with straw yield. Among them, morning and afternoon relative humidity, wind speed, $RH_1 - RH_2$ and bright sunshine hours had shown the best relationship. The following is the regression equation for estimating straw yield.

$$Y = -0.4386\ RH_1 - 1.4524\ WS + 0.509\ RH_1 - RH_2 - 3.3\ SSH + 57.244 \quad (R^2 = 0.971)$$

Y = Straw yield (t ha^{-1})

RH_1 = Morning relative humidity (Transplanting to flowering)

WS = Wind speed (Panicle initiation to flowering) (km h^{-1})

$RH_1 - RH_2$ = Difference between morning and afternoon relative humidity (Transplanting to flowering)

SSH = Bright sunshine hours (Transplanting to heading).

The estimated and actual observed straw yields are given in Table 21.

4.5.3 Maximum Leaf Area Index

The maximum LAI was greatly influenced by the weather parameters during the period of transplanting to heading. The maximum LAI had a profound influence on grain yield. Considering the above fact, a multiple regression equation was developed and it is as follows:

$$Y = -2.3756\ WS - 0.5102\ \text{Mean RH} - 0.6198\ RH_1 - RH_2 + 0.9316\ \text{T range} + 61.1366 \quad (R^2 = 0.981)$$

Y = Maximum LAI

WS = wind speed (kmh^{-1})

Mean RH = Mean relative humidity (%)

$RH_1 - RH_2$ = Difference in morning and afternoon humidity (%)

T range = Temperature range (°C)

The estimated and actual observed values were in good agreement and accounted for 98%(Table 22).

4.5.4 Duration of vegetative phase (Transplanting to Panicle initiation)

Multiple regression equation with four weather parameters viz., sunshine, temperature range, minimum and mean temperature resulted in a reasonably better predictor of vegetative phase (days taken from transplanting to panicle initiation). The regression equation is as follows:

$$Y = 5.1618\ T\ min - 1.799\ SSH + 2.7386\ T\ range - 2.9522\ T\ mean - 22.595$$

$R^2 = 0.972$

Y = Duration of vegetative phase

SSH = Bright sunshine hours (h day^{-1})

T range = Temperature range (^{0}C)

T min = Minimum temperature (^{0}C)

T mean = Mean temperature (^{0}C)

The deviation of estimated vegetative phase varied between 0.1 and 2.11 days, which was in good agreement with the observed values. The equation accounts for 97% in estimated vegetative phase (Table 23).

4.6 Minimum Data Set for IBSNAT Model

4.6.1 Experimental details

a) Experimental name	: Crop weather relationship in rice.
b) Location	: ARS, Mannuthy.
c) Gross plot area	: 30 m^2
d) Rows per plot	: 40
e) Plot length	: 6 m
f) Plot spacing	: 15 x 10 cm

Table 22. Actual and estimated maximum leaf area index

Time of planting	Maximum LAI		
	Actual	Estimated	Residual
June 1	7.73	7.63	0.994
June 15	7.43	7.03	0.3924
June 30	4.70	4.91	-0.2054
October 1	7.73	8.00	-0.2722
October 15	7.17	7.19	0.0125
October 30	7.10	7.15	-0.0383
January 1	4.27	4.62	-0.3032
January 15	4.43	4.25	0.1505
January 30	3.87	3.70	0.1641

Table 23. Actual and estimated duration of vegetative phase (transplanting to panicle initiation)

Time of planting	Duration of vegetative phase		
	Actual days	Estimated days	Residual
June 1	36	35.42	-0.196
June 15	32	31.36	1.32
June 30	26	29.89	-0.93
October 1	30	28.55	-0.89
October 15	28	26.11	0.04
October 30	28	26.45	0.71
January 1	24	25.77	0.17
January 15	23	23.1	0.25
January 30	23	23.38	-0.47

g) Harvest area : 30 m^2

h) Harvest row number : 40

i) Harvest row length : 6 m

j) Harvest method : Manual

4.6.2 Cultivars

a) Cultivar code : RI

b) Cultivar name : Kanchana

4.6.3 Fields

a) Weather station : Kerala Agricultural University, Thrissur.

b) Slope : 3°

c) Obstruction to sun : 0

d) Drainage type : Surface furrows

e) Surface stones : Abundant

f) Soil texture : Sandy clay loam

g) Soil depth : 115 cm

4.6.4 Soil analysis

a) Depth of base layer : 15 cm

b) Bulk density : 1.54 g m^{-3}

c) Organic carbon : 0.67%

d) Total nitrogen : 0.17%

e) Available phosphorus : 87 kg ha^{-1}

f) Available potassium : 218.4 kg ha^{-1}

4.6.5 Planting details

a) Planting date : 01/06/98

b) Planting method : Transplanting

c) Planting distribution : Row

d) Row spacing : 15 cm

e) Planting depth : 5 cm

f) Planting material weight : 40 kg ha^{-1}

g) Transplanting age : 18 days

h) Plants per hill : 2-3

4.6.6 Fertilizers

a) Fertilization date : At transplanting and 30 days after transplanting

b) Fertilizer application : Broadcasting

c) Amount of nitrogen : 70 kg ha^{-1}

d) Amount of phosphorus : 35 kg ha^{-1}

e) Amount of potassium : 35 kg ha^{-1}

4.6.7 Chemical application

a) Chemical material : Phosphamidon

b) Application method : Foliar spray

4.6.8 Weather data

a) Solar radiation : MJ $m^2 day^{-1}$

b) Maximum temperature : °C

c) Minimum temperature : °C

d) Precipitation : mm

e) Dew point temperature : °C

f) Wind run : Km day^{-1}

g) PAR : Moles m^{-2} day^{-1}

DISCUSSION

The present investigation was taken up with a view to determine the effect of various weather elements on growth and yield of rice variety "Kanchana". The results of the experiments detailed in the previous chapter are discussed here under.

5.1 Biometric observations

5.1.1 Plant height

The results indicated that the plant height at 15, 30, 45, 60 and 75 days after transplanting was significantly influenced by times of planting (Fig.3). It showed a gradual decreasing trend from first crop (June – September) to third crop (January – April). This is in agreement with findings of Misra and Khan (1973), Majid and Ahmed (1975) and Lathif (1982). The diurnal temperature range during reproductive (panicle initiation to beginning of grain filling) and ripening (beginning of grain filling to maturity) phase had a negative correlation with plant height indicating that rice crop may require moderate day (30°C) and night temperatures (22°C) for proper growth. High temperature of more than 32°C may also decrease plant height. This is in confirmity with the findings of Lin (1976), Kang and Heu (1976).

5.1.2 Number of tillers

The effect of times of sowing on tiller production was found to be significant (Fig.4). Crop planted on June 1st, October 1st, October 15th and October 30th recorded the highest number of tillers per plant (11,10,12, and 11 respectively). High maximum temperature of 32°C and above prevailed throughout the crop growth period may decrease 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).

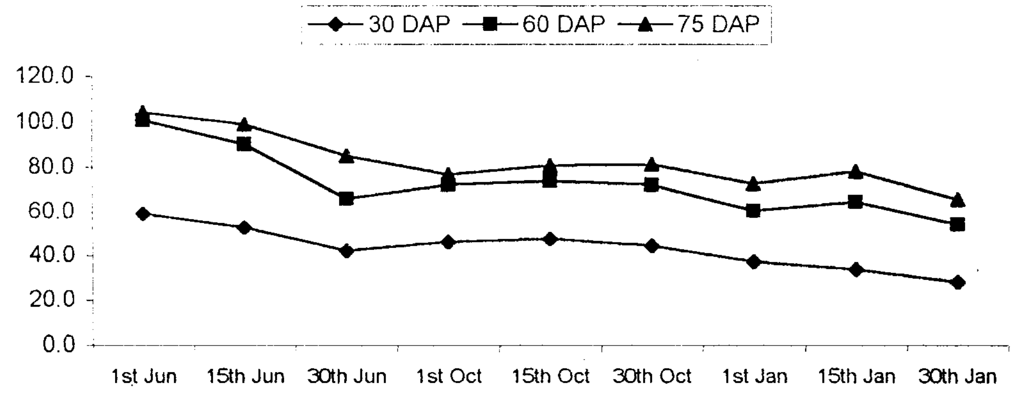


Fig.3. Effect of times of planting on plant height at 30, 60 and 75 DAS

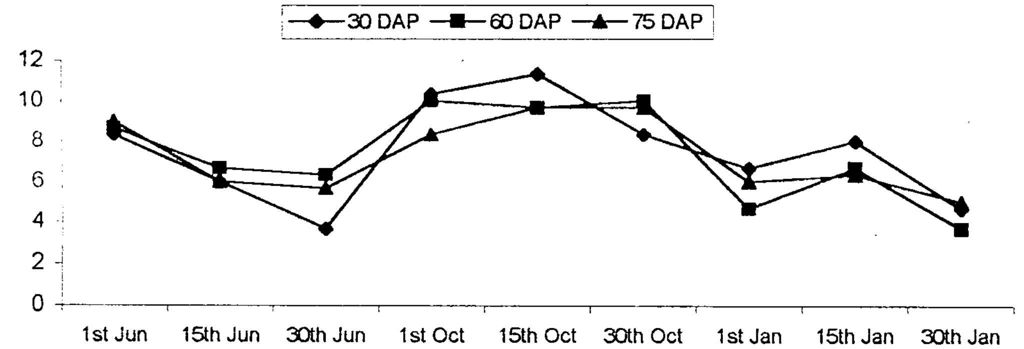


Fig. 4. Effect of times of planting on number of tillers at 30, 60 and 75 DAS

5.1.3 Biomass

The results indicated that the biomass per plant at different stages varied significantly with time of planting (Fig.5). The crops transplanted during the first and second crop seasons recorded significantly higher biomass during all stages of crop growth. The maximum temperature (28°C to 32°C) and relative humidity (80-90%) during entire crop growth period favoured the high biomass per plant. This is supported by findings of Hirai *et al.* (1992) and Sreedharan (1975).

5.1.4 Leaf number

Crop planted on June 1st, June 15th, October 1st, October 15th and October 30th recorded the highest leaf number at panicle initiation stage (46, 49, 47 and 41). The lowest number (31) was recorded when crop transplanted on January 30th. Low solar radiation and high relative humidity during vegetative period positively influenced the number of leaves per plant. This was supported by studies of Janardhan and Murthy (1980), Ghosh (1961), Yoshida (1973), Yoshida and Parao (1976).

5.1.5 Leaf Area Index (LAI)

The seasonal effect on LAI at various growth stages was significant (Fig.6). Crop planted during June 1st, June 15th, October 1st, October 15th and October 30th showed the highest LAI. (7.73, 7.43, 7.73, 7.20 and 7.17 respectively). This was due to high amount of relative humidity (80-90%) and low light intensity during the entire growth period. The Maximum LAI was recorded in heading stage when crops were planted during first and third crop seasons. But in the case of second crop season, Maximum LAI was recorded during beginning of grain filling stage. These are in agreement with findings of Mandal and Chatterjee (1973) and Janardhan *et al.* (1980).

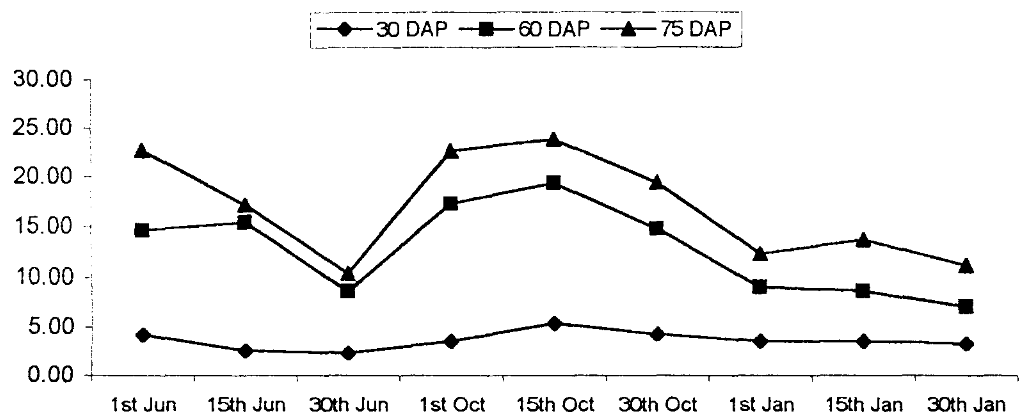


Fig. 5. Effect of times of planting on biomass at 30, 60 and 75 DAS

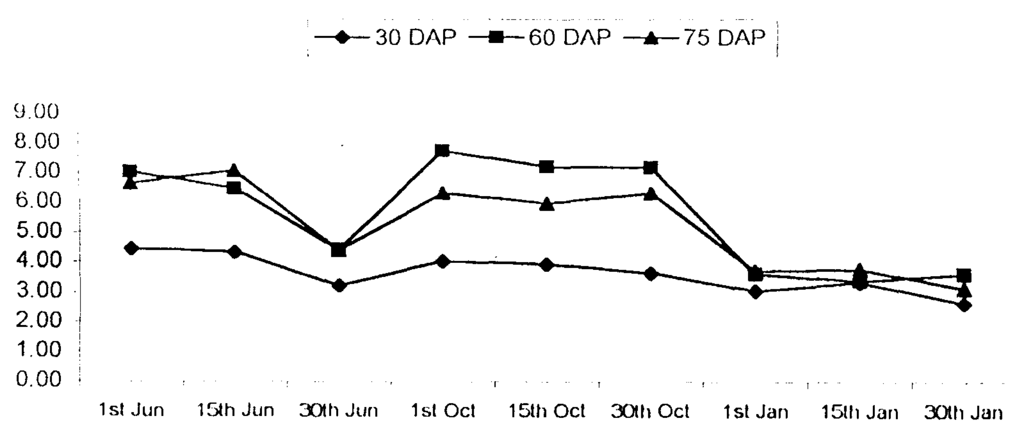


Fig.6. Effect of times of planting on leaf Area Index at 30, 60 and 75 DAS

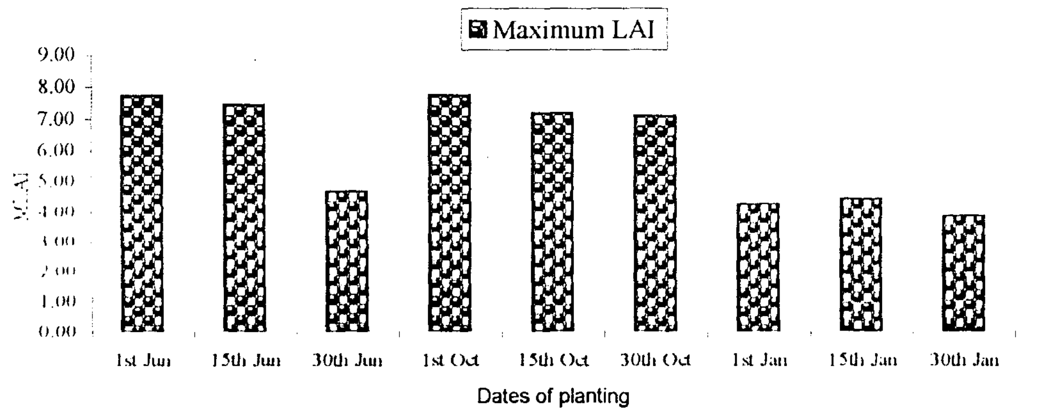


Fig. 7. Effect of times of planting on maximum leaf area index

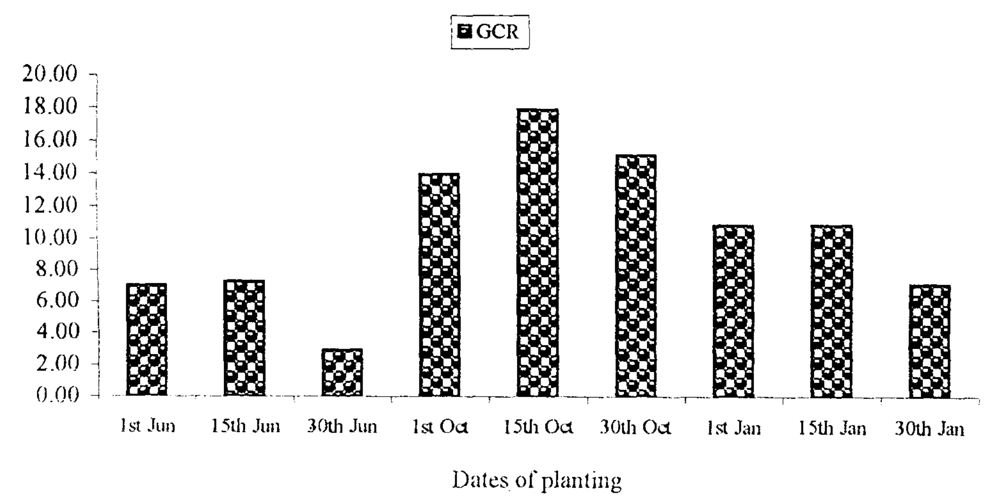


Fig. 8. Effect of times of planting on number of panicle per plant

5.2.2 Number of filled grains per panicle

The crop planted on October 1st produced maximum number of filled grains per panicle (108). The lowest number was recorded by January 30th (Fig.9). High maximum temperature during the reproductive period might be the reason for lesser number of filled grains in January 30th planted crop. This is in agreement with the findings of Hayase *et al.* (1969) and Satake and Yoshida (1978). Another reason may be due to high wind speed (8-9 km h^{-1}) and temperature (>34.5^{0}C) during the period from heading to ripening phase as they increased spikelet sterility due to high evaporation rate and dessication of spikelets. Similar results were reported by Krishnakumar (1986).

5.2.3 Thousand grain weight

Variations in 1000-grain weight were not very wide. It ranged from 25.2 to 28.5 g. Mandal and Chatterjee (1973) also observed the same trend. Maximum weight (28.47g) was recorded in crop planted on October 15th. This may be due to low temperature during ripening phase (Nagato and Ebata, 1966).

5.2.4 Grain chaff ratio

Grain chaff ratio was the highest (17.87) for crops planted on October 15th. The lowest was recorded by June 1st (7.03) and January 30th (7.07) planted crops (Fig.10). This may be due to high minimum temperature of more than 23.5^{0}C during ripening period.

Increase in the daily maximum temperature during active tillering stage may decrease number of panicles/ hill. Similarly maximum temperature above 33°C during reproductive period reduced number of filled grains/panicle. A high minimum temperature above 23°C during ripening reduces grain chaff ratio.

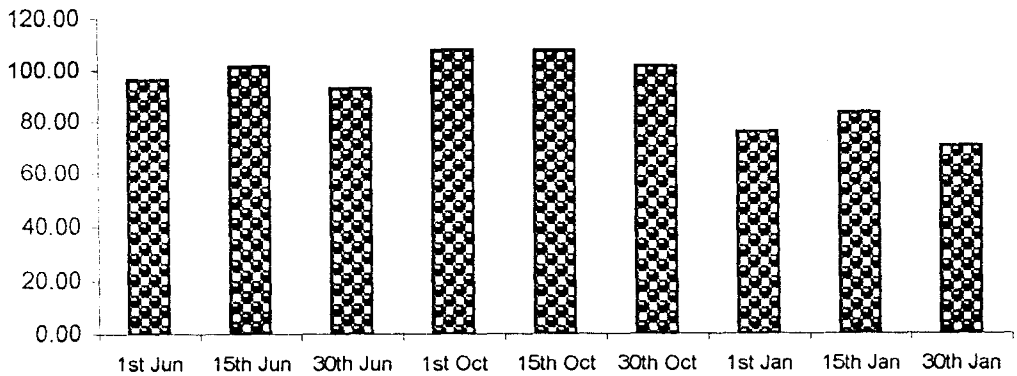


Fig. 9. Effect of times of planting on number of filled grains per panicle

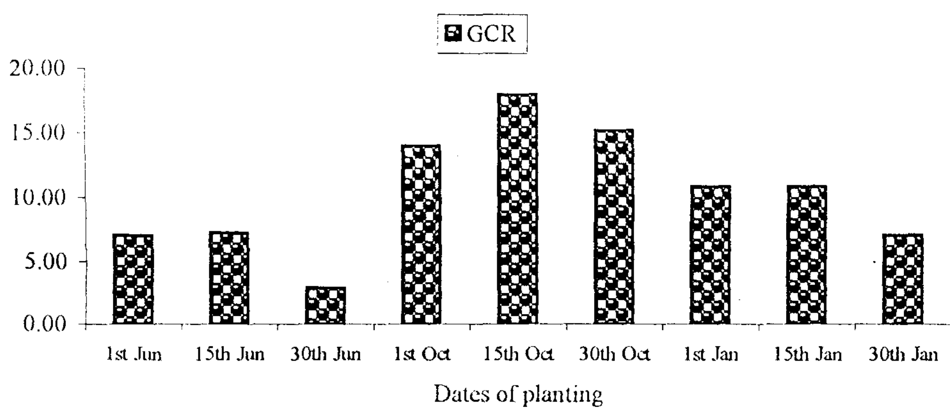


Fig. 10. Effect of times of planting on grain chaff ratio per plant

5.2.5 *Grain yield*

Among all the treatments, crop planted on October 15th recorded the highest grain yield of 6.2 t ha^{-1}, followed by October 30th (5.8 t ha^{-1}) (Fig.11). 1000 grain weight and grain chaff ratio were also superior in the above treatments. The increase in yield may be due to low minimum temperature during ripening stage. Similar observations were made by Nagato and Ebata (1966). January 30th planted crop showed much reduced yield (2.06t ha^{-1}). This may be due to high temperature during grain development (Tashiro and Wardlaw, 1991b).

5.2.6 *Straw yield*

The straw yield was the highest (10.36 t ha^{-1}) for the crop planted during June 15th, followed by June 30th (9.72 t ha^{-1}) crop. The lowest straw yield was recorded by crop planted on January 30th (Fig.11). Crops taken during June (first season crops) experienced high relative humidity (95%) and low temperature range (5-6^{0}C) compared to third crop season. This is in confirmity with findings of Sreelatha (1989).

5.2.7 *Harvest Index*

The highest harvest index was noticed in crops transplanted on October 1st and October 15th. The least value was recorded by crop planted on June 30th (Fig.11).

Low solar radiation (3.5 h day^{-1}) and high temperature (35^{0}C) may be detrimental to high harvest index. Only the second crop season experienced moderate solar radiation and low temperature during reproductive and ripening periods. This may be the reason for high harvest index in the case second crop season. This is in agreement with findings of Krishnakumar (1986).

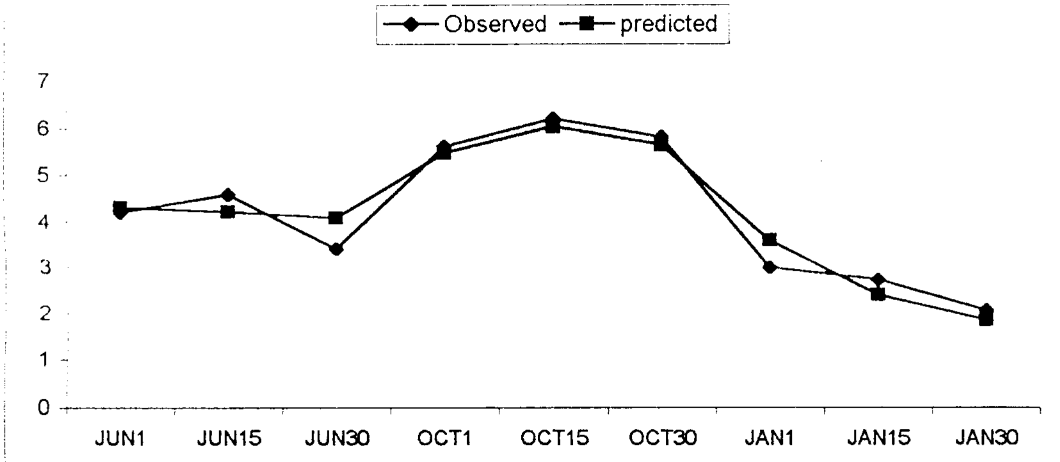


Fig. 12. Observed and predicted grain yield (t/ha)

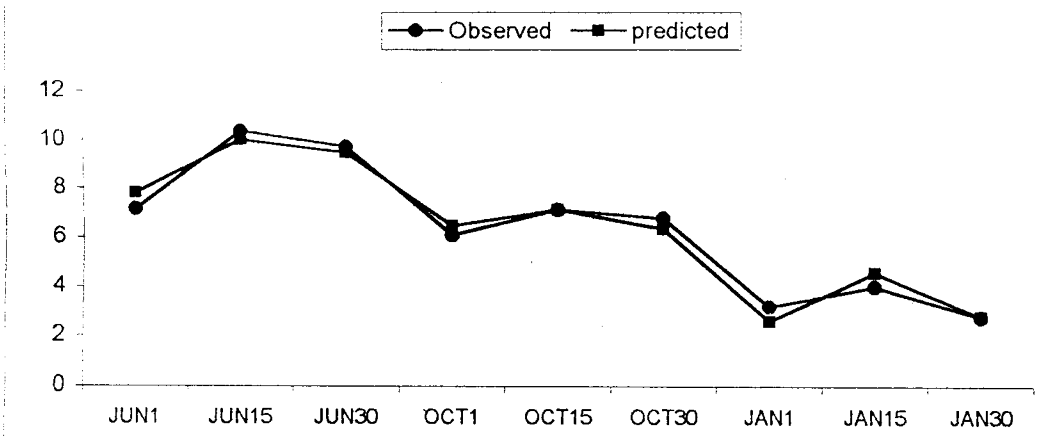


Fig. 13. Observed and predicted straw yield (t/ha)

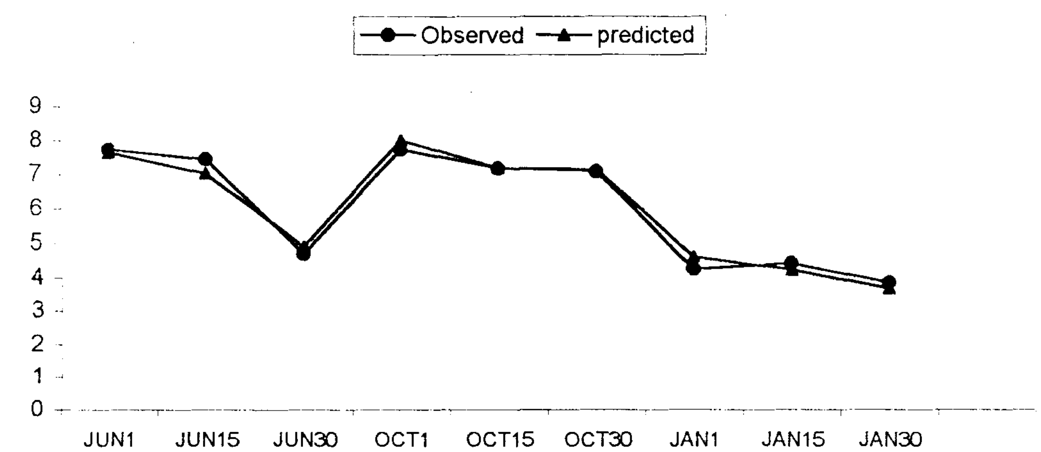


Fig.14. Observed and predicted maximum LAI

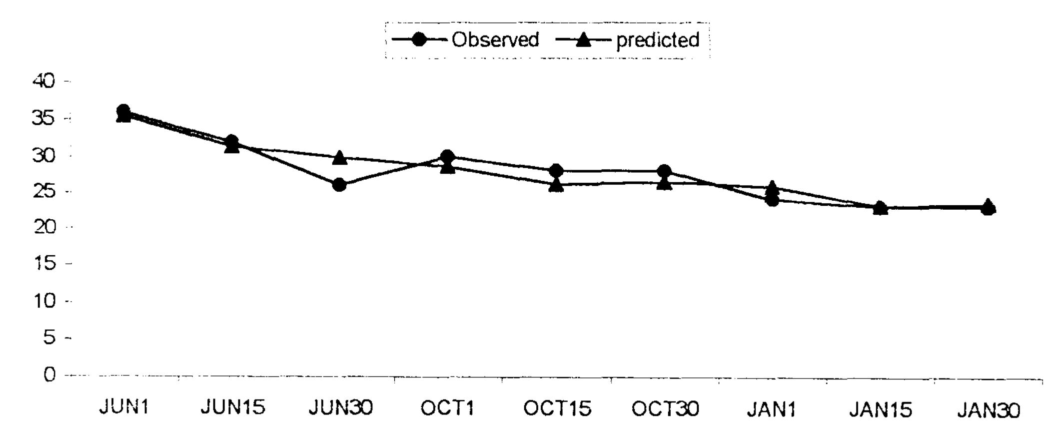


Fig. 15. Observed and predicted duration of vegetative phase

The increase in maximum LAI was due to high relative humidity, low (RH_1 - RH_2) wind speed and temperature range. These are characteristic to wet season. This was supported by Janardhan and Murthy (1980).

The multiple regression equations worked out for predicting the grain (Fig.12) and straw yields (Fig.13), Maximum LAI (Fig.14) and duration of vegetative phase (Fig.15) had a good fit between observed and predicted values, accounting more than more than 90%.

Generally, delay in planting had a negative effect on grain yield. Among the three plantings, crop planted on October 15th recorded the highest grain yield of 6.2 t ha^{-1}. For this treatment, the grain-chaff ratio and thousand grain weight were superior to others, thus responsible for the highest grain yield.

The variations in different weather parameters at vegetative and reproductive stages of October 15th crop were comparatively less. This crop experienced fairly good weather conditions during the vegetative and reproductive periods. It experienced moderate temperature range (8-8.4^{0}C) and relative humidity (80-93%). This crop also experienced low wind speed which may decrease the pollen dehydration and sterility. These favourable weather conditions might be the reason for better grain yield.

Summary

SUMMARY

An experiment was conducted at Agricultural Research Station, Mannuthy to study the crop-weather relationship in rice, variety 'Kanchana' during 1998-99.

The observations on morphological and yield attributes were recorded at different stages of development of the crop. The observations on weather factors were recorded daily to workout the phenology and crop-weather relationship in rice.

The salient finding are summarised as follows:

1. June 15th planted crop was the tallest at 30, 45, 60, and 75 DAP and superior to other dates of transplanting.
2. The number of tillers produced per hill was high when the crop was transplanted on second crop irrespective of times of planting. How ever the crop taken up on June 1st was also on par.
3. Plant biomass and number of leaves per hill were high during the first and second crop seasons except on June 30th.
4. Crops planted on June 1st and 15th recorded the highest leaf area index in all the growth stages except during beginning of grain filling stage. First and third crop seasons recorded their maximum leaf area index during heading stage, whereas second crop season recorded maximum LAI at beginning of grain filling stage.
5. The number of panicles was high when crop was taken up on October 1st and was on par with June 1st, 15th, October 15th and 30th planted crops.
6. In the case of number of filled grains/panicle the maximum and minimum were recorded by October 1st and January 30th plantings respectively.
7. Compared to second and third crop seasons, 1000 grain weight was inferior during the first crop season.
8. The highest grain-chaff ratio was recorded by October 15th and 30th planted crops and lowest in the case of June 30th planted crop.

9. The grain yield was maximum when the crop was planted on October 15th and was on par with October 1st and 30th planted crops. The lowest grain yield was recorded by January 30th planting.
10. Highest straw yield was recorded by June 15th and 30th plantings and the lowest was observed in January 30th planting.
11. In the case of harvest index, October 1st and 15th planted crops recorded the maximum and the minimum was found in January 30th planted crop.
12. An increase in the daily maximum and minimum temperature during the entire cropping season may decrease plant height and number of tillers. Maximum temperature (28-32°C) and higher relative humidity (80-90%) may increase plant biomass which can be linked to the fact that low solar radiation and higher relative humidity increase leaf production and leaf area index in rice.
13. Increase in the daily maximum temperature during active tillering stage may decrease number of panicles/hill. Similarly maximum temperature above 33°C during reproductive period reduced number of filled grains/panicle. A high minimum temperature above 23°C during ripening reduces grain chaff ratio.
14. Some of the important weather parameters, which are closely linked to the grain yield, straw yield and harvest index were temperature, wind speed, relative humidity and solar radiation. Of this, daily minimum temperature and wind speed during reproductive phase had a profound effect on grain yield. However low temperature and high humidity during the entire growth period increased the straw yield. Low solar radiation and high temperature were detrimental to harvest index.
15. The multiple regression equations predicted the grain and straw yields, duration of vegetative phase and maximum LAI well and a close relation existed between observed and predicted values. In all the equations coefficient of determination (R^2) was more than 90%.
16. The minimum data set developed under the project can be used for testing the IBSNAT – CERES- Rice model.

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CROP WEATHER RELATIONSHIP IN RICE

By

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ABSTRACT OF THE THESIS

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2000

ABSTRACT

An experiment was conducted in the Agricultural research Station, Mannuthy during first, second and third crop seasons of 1998-99 to study the crop weather relationship in rice variety 'Kanchana'. The experiment was laid out in randomised block design with three replications. The treatment consisted of three dates of planting in each season i.e., 1st, 15th and 30th of June, 1st 15th and 30th of October and 1st, 15th and 30th of January.

Observations on morphological and yield attributes were recorded during the course of investigation. The daily values of weather elements viz., maximum and minimum surface air temperature, bright sunshine, morning and afternoon relative humidity and wind speed were collected from the Principle Agro Meteorological Station, College of Horticulture, Vellanikkara, to work out the crop weather relationships in rice.

Crops transplanted on 1st 15th and 30th of October and 1st 15th of June were significantly superior in terms of grain yield, panicle number, number of filled grains/panicle, number of leaves, plant biomass, number of tillers and leaf area index.

The crop weather relationship studies showed that the wind speed, minimum temperature and mean temperature during flowering to maturity had a significant negative correlation with grain yield. But morning relative humidity and mean relative humidity during transplanting to panicle initiation stage had a significant positive influence on ultimate grain yield.

The wind speed, mean temperature, temperature range, RH1-RH2 and solar radiation during vegetative stage were negatively correlated with the straw yield. Maximum temperature during beginning of grain filling to maturity stage also

had a negative correlation. But increase in minimum temperature, mean relative humidity, morning and afternoon relative humidities during transplanting to flowering stage was significantly increase the straw yield as there was a positive correlation.

The regression equations developed in the study predicted the grain yield, straw yield, duration of vegetative phase and maximum leaf area index well and a close relation existed between observed and estimated yield.

Based on the experimental data, minimum data set for the validation of rice model of the IBSNAT has been generated.