

**AGROMETEOROLOGICAL PARAMETERS AND HYDRO-NUTRITIONAL
MANAGEMENT PRACTICES ON RICE CULTIVARS**

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ABSTRACT

AGROMETEOROLOGICAL PARAMETERS AND HYDRO-NUTRITIONAL
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Field experiments in low land rice were conducted during South West Monsoon 1985, North East Monsoon 1985 and Summer 1986 seasons to study the influence of meteorological parameters and water management on growth and yield of rice as well as to identify the factors responsible for differential response between seasons.

The first experiment treatments consisted of fortnightly transplantings (six, five and five during SWM 85, NEM 85 and Summer 86, respectively) and four irrigation levels (continuous 5 cm submergence, recouping 5 cm submergence one, two and three days after disappearance of ponded water). In the second experiment a combination of varieties (two) and irrigation levels (two) in one strip and levels of N (0, 75, 150 and 225 kg ha⁻¹) in the other

strip were tried. The variety used was IR 50 in SWM 85 and Summer 86 and IR 20 in NEM 85 season in the first experiment. They were IR 50 (V_1) and CO 37 (V_2) in SWM 85 and Summer 86 and IR 20 (V_1) and CO 44 (V_2) in NEM 85 for the second experiment. Both the experiments were laid out in a strip plot design with three replications.

Plant height at harvest was positively correlated to minimum temperature at vegetative phase and mean relative humidity (RH) during the whole growth period. LAI at flowering was positively correlated with integrated mean temperature during the vegetative phase. Both these characters were negatively correlated to solar energy sources at later phases.

In NEM the duration upto 50 per cent flowering was negatively correlated with minimum temperature. The maximum : minimum temperature ratio had a positive association with flowering duration in SWM and Summer seasons. The ripening period duration was negatively correlated to minimum temperature of the same period. Yield attributes like filled grain percentage, panicle weight and degree of ripening were also negatively correlated with minimum temperature during reproductive and ripening phases.

Panicles per m^2 , grains per m^2 , degree of ripening and grain yield were positively correlated with solar energy sources during the later phases. Panicle weight and filled grain percentage were also correlated with solar energy sources at one stage or other. Influence of RH was masked either by solar energy or temperature. Transplanting rice during mid July (SWM), late November (NEM) and late February (Summer) was ideal for the respective seasons in achieving higher yield.

Plant growth and development as well as yield were similar under continuous 5 cm submergence or recouping 5 cm submergence one day after disappearance of ponded water in SWM and NEM seasons. In Summer, however, all these characters decreased with moisture stress.

Scheduling irrigation one day after disappearance of water reduces the water use by $1/3$ resulting in greater water use efficiency. Moisture stress in Summer reduced response to applied N and percentage recovery of N. Return per rupee on water and N were high with irrigation given one day after disappearance of water.

Though panicle weight, 1000 grain weight and number of filled grain increased upto 225 kg ha^{-1} in

SWM and NEM, the increase in panicles per m^2 and grain yield with N application was only upto 150 kg ha^{-1} . Grain yield was lower during NEM than the other two seasons. Response to applied N and return per rupee on N was high with 75 kg ha^{-1} . Water use efficiency, gross and net income, benefit cost ratio as well as return per rupee on water was high with 150 kg ha^{-1} .

IR 50 as an early maturing and CO 44 as a medium duration variety are preferable.

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INTRODUCTION

I. INTRODUCTION

Today rice is the staple food for half to two-thirds of world's population and accounts for one-third to half of the daily caloric intake in many Asian countries. Rice contributed almost one-third of the total food production of India (Ramachandran, 1984) from an area of 35.8 million ha (Agricultural Situation in India, 1986). Rice is, therefore, India's principal food crop and any improvement in increasing rice productivity would go a long way in meeting country's food problems.

Although rice is considered to be a tropical and subtropical crop, best rice yields are obtained in temperate areas such as Po Valley, Italy (45°N), northern Honshu, Japan (38°N) and New South Wales, Australia (Moomaw and Vergara, 1964). According to 1984 statistics, the yield per hectare of rice was only 2103 kg in India whereas in some of the temperate countries like Japan and Korea it was more than 6 tonnes/ha (FAO, 1985). The difference may be mainly due to the effect of climatic conditions prevailing in the respective regions because particularly in South East Asia about 60 to 70 per cent of rice is grown during monsoon season when the light

intensity is only 40 to 60 per cent than that of dry season.

Best (1962) reported that the average solar radiation available during wet season in the tropics is only two-thirds of that available in a temperate rice growing area. Since solar energy cannot be increased artificially it imposes a ceiling on grain yield in monsoon season. High temperature in this season, especially during night, is another factor responsible for low productivity in wet season.

In tropical areas only a few major studies on climatology have been carried out. However, from the available data it can be assumed that production level of a crop that is fertilized and supplied with sufficient water would be mainly determined by climate. This study becomes all the more important in the present day emphasis on multiple cropping because it has to be grown on a rotational basis in any period of the year.

Apart from climatic factors, yield of rice is largely governed by the interplay of hydro-nutritional and genetic factors. In India about 60 per cent of the total available irrigation water is utilized by rice and

more than 86 per cent of the total irrigation water in Tamil Nadu is diverted for rice cultivation. The prospects of further increase in the irrigation potential in Tamil Nadu is remote as a saturation point has been achieved in this regard.

Considerable amount of water delivered to the rice crop is lost in the traditional continuous land submergence system through deep percolation. Because of flooding about 50 to 60 per cent of water applied is lost by deep percolation (Reddi, 1976). Rice production could be made more economical if water, one of the major inputs, is used most judiciously. Suitable water management measures of minimising water loss through deep percolation is one as it is not related to productivity (IRRI, 1984). Reduction in deep percolation could be achieved by reducing the depth of flooding and frequency of irrigation.

In command areas, consequent to low storage of water in the dams during the crop season and intermittent water supply, instead of continuous submergence of fields, farmers resort to widening the gap between irrigations. In this context the knowledge of optimum water requirement of rice to produce optimum yield is very useful to engineers who regulate water supply and to the farmers for successful raising of the rice crop. The effect of

such cyclic supply of water has not been studied on the various aspects of crop production exclusively so far.

Though the yield potential of high yielding dwarf indica rice cultivars is much higher than that of indigenous tall indica, the key factor for exploration of this high yield potential is lying in nitrogenous fertilizers, which is gradually getting short in supply due to severe energy crisis in the country. This warrants economisation of this costly input.

Evidence exists from various countries including India to the effect that response to nitrogen is much more under dry and sunny weather than under rainy or cloudy season. This difference in N response can to a certain extent be also attributed to lower pests and disease incidence, better water management practices during dry season cultivation, and, in the absence of these factors to the weather conditions themselves. Results of experiments from IRRI (1982) suggest that an optimum N application rate should be based not only on the inherent soil fertility level and variety used but also on the solar radiation level.

Taking all these in view to make sound agronomical manipulations to increase the yield of rice separate investigations were carried out with the following objectives.

1. To identify the weather parameter responsible for the individual growth or yield parameter of rice.
2. To evaluate the climatic influence on the stage of crop growth which contributes to grain yield during different periods of the year and closeness of their relationship.
3. To optimise the use of water and fertilizer N and identify the efficient rice genotype for different seasons of cropping.

II. REVIEW OF LITERATURE

The present studies were carried out to evaluate the effect of weather parameters on growth and yield of rice and to arrive at a suitable planting time based on environmental factors and water management. A study was also carried out to assess seasonal influence on water and nitrogen requirement of rice for its maximum productivity. The review pertaining to these aspects are presented below.

2.1. Influence of weather parameters on rice

2.1.1. Solar energy

Several reports on the relationship between rice yield with environmental factors, particularly light energy are available (Matsushima, 1970; Murata and Togari, 1973; Yoshida, 1972).

Studying the solar radiation at 26 sites in 15 rice-growing countries Yoshida (1978) reports to range from $50 \text{ cal cm}^{-2} \text{ d}^{-1}$ in December at Milan, and Italy, to $700 \text{ cal cm}^{-2} \text{ d}^{-1}$ or higher in June or July at Lisboa, Portugal and Davis, California, U.S.A.

2.1.1.1. Influence on growth characters

Solar energy is the major governing factor for photosynthesis and hence dry matter production (DMP) and yield are dependent on solar radiation to a considerable extent. The low light intensity upto flowering in Kharif (monsoon season) imposes a ceiling on tillering and reduces DMP as compared to Rabi (Venkateswarlu, 1977; Venkateswarlu et al., 1977). From shading experiments, Sreedharan and Vamadevan (1981) report that LAI is 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.

2.1.1.2. Influence on yield attributes and yield

Murata (1975) and Yoshida (1983) stress the importance of considering the physiological stage of rice plant development when relating plant responses and final yield to weather factors. Influence of light intensity on panicle production (Osada et al., 1973), and grain filling are reported (Yoshida, 1972 and Venkateswarlu et al., 1977). Field studies at IRRI, Los Baños, reveal a high positive correlation of grain number per m^2 with solar radiation and a negative correlation with mean temperature during 25 days before flowering (IRRI, 1974).

Under low light intensity photosynthetic rate and translocation of photosynthates to panicles are reduced (Nayak et al., 1979; Fagi and De Datta, 1981 and Sreedharan and Vamadevan, 1981).

The solar radiation requirements of a rice crop differ from one stage to another. Low light intensity during the vegetative phase only, slightly affect the yield and yield components whereas, during reproductive phase a pronounced effect on spikelet number and, hence, on yield. Low solar radiation during the ripening phase also reduces the grain yield considerably, because of a decrease in the percentage of filled grain (Yoshida, 1972; Yoshida and Faeo, 1976). From his studies in Texas Stansel (1975) finds the most critical sunlight requiring period to be the 42 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.

Many reports are available about the correlation between grain yield and solar radiation received during reproductive or ripening periods. However, the critical period of high solar radiation requirement vary.

Solar radiation received during three weeks before and after flowering (Stansel, 1966; Murata and Tegari, 1973) or one week before harvest (Childyal and Jena, 1967

and De Datta and Zarate, 1970) or 15 days before and 25 days after flowering (Matsushima, 1970) are reported to have positive influence on grain yield.

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 conducive for better yield (Sreenivasan and Benerjee, 1978).

From the data on monthly plantings over a 10 year period, Evans and De Datta (1979) suggest that irradiance during reproductive stage (30 days before flowering) appears to be as significant to grain yield as irradiance during the ripening stage (30 days after flowering). Seku et al. (1983) and Nishiyama (1985) find that solar radiation during ripening stage to have high correlation with grain yield.

2.1.1.3. Solar energy utilisation

Loomis and Williams (1963) estimate a possible growth rate of $71 \text{ g m}^{-2} \text{ d}^{-1}$ which indicates a net solar energy utilisation of 5.6 per cent. According to Bolton (1976) the efficiency of solar radiation for net photosynthesis is about 5.8 per cent. However, the solar

energy utilisation in rice is very low and reported to be about 1.25 per cent for total DMP and about 0.4 per cent for grain yield under temperate climates of Japan (Kanda, 1975). Hayashi (1969) observes average efficiency of DMP on absorbed solar energy basis (E_a) to be 2.81 - 3.53 per cent and that on incident energy basis (E_c) to be 1.42 - 1.71 per cent.

Fagi and De Datta (1981) notice that IR 26 is more efficient than IR 28 in utilising solar radiation, particularly under high solar radiation of the dry season plantings. As solar radiation decreases, IR 26 is less efficient than IR 28 in utilising sunshine. The efficiency of conversion of photosynthetic light energy is noticed to be 4.6 to 7.7 per cent for the early season culture and 5.3 to 7.0 per cent for the normal season culture (Suzuki, 1983).

Variation to the extent of three and five times in E_a per cent for DMP (0.58 - 1.64) and grain yield (0.13 - 0.67), respectively, are reported by Narasings Rao and Murty (1984).

From the literature it appears that a lot of work on solar radiation are done in temperate countries. However, under tropical countries studies to a limited

extent are available from IRRI, Philippines and CRRI, Cuttack and TNAU, Coimbatore. All the studies show the influence of solar radiation in increasing the grain yield. Detailed investigations with newly evolved photo-insensitive varieties of rice under field conditions when planted during different periods of the year are necessary.

2.1.2. Air temperature

Among the climatic factors that affect the growth of rice plant, air temperature plays an important part. The response of the rice plant to temperature is much more complex and less understood than its response to day length.

Yoshida (1977) defines the environment under which the life cycle of the rice plant can be completed and within the critical temperature range, it influences the rate of development of leaves and panicles and the rate of ripening, thereby determining the duration of a variety under a given environment.

2.1.2.1. Influence of temperature at vegetative stage

De Datta (1970) attributes low average yield in the tropics to warm climate during early growth periods. Chang and Vergara (1972) attribute it to more vegetative growth.

Sato (1972) finds that DMF is favourably influenced by day-night temperature regime of 25°-20°C for IR 8 rice

and the leaf area per plant is high at 30°-25°C. Kim et al. (1973) report increase in height and dry weight of plants at 20°C.

Increase in tiller production and number of panicles are also reported at 25° -20°C day-night temperature (San, 1979).

Suzuki (1983) reports a significant positive correlation between the mean temperature and CGR at the initial growth stage. However, with the advancement of growth, the correlation is lowered and it turns to be significantly negative for the period from 3 to 6 weeks after heading.

2.1.2.2. Influence of temperature on duration of vegetative phase

Growth duration is considered 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 a rice cultivar determines its specific adaptability to the regular crop season in a given location (Chang and Vergara, 1974).

A duration of 167 to 168 days in rabi and 125 days in kharif for the same variety is reported by Chatterjee et al. (1969). They also observe 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 shows that minimum air temperature has the best negative correlation with growth duration. This correlation is higher than with that of temperature summation (Vergara et al., 1970). Kang and Heu (1976) and Chaudhury and Sodhi (1979) report extended vegetative growth due to low temperature.

2.1.2.3. Influence of temperature at ripening stage

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 during the grain filling period.

A significant negative correlation between yield and the minimum temperature 30 DAT and a significant correlation between yield and maximum temperature over the 45 days before maturity are reported by De Datta and Barate (1970). Osada et al. (1973) notice that low temperatures during maximum tillering stage produce more panicles. During the reproductive stage, within a temperature range of 22° to 31°C, the spikelet number per plant increases as the temperature drops (Yoshida, 1973). He also suggests that the optimal temperature

tends to shift from high to low as growth advances from the vegetative to the reproductive stage.

Temperature appears to influence the ripening of rice in two ways. First, low temperature favours an increase in weight per grain (Murata, 1964) and second, the length of period is inversely correlated with daily mean temperature (Yamakawa, 1962). Thus, persistent cloudy weather conditions will be more detrimental to grain filling under high temperatures because of a shorter ripening period. From experimental results of 12 years, at Pantnagar in Uttar Pradesh Huda et al. (1975) indicate that higher maximum and minimum temperature during tillering, ear initiation and maturity depress the yield of rice.

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). In a low temperature situation, both day and night temperature appear to affect spikelet sterility. A daily mean temperature of less than 20°C may induce sterility and a day time temperature higher than 35°C at flowering time may also increase spikelet sterility.

From the studies conducted under the All India Co-ordinated Crop-Weather Scheme, Sreenivasan (1979) finds the favourable maximum temperature period for Aduthurai in Tamil Nadu is from 10th to 16th week from sowing and for Coimbatore in Tamil Nadu, the significant periods are the minimum temperature for five weeks commencing with flowering and the maximum temperature during tillering phase.

Influence of temperature on sterility is reported by Chaudhary and Sedhi (1979). The sterility is minimum (12-18 per cent) when the mean temperature is 27-28°C during flowering whereas it is maximum (36 per cent) when the mean temperature average about 36°C. Sesha and Gady (1984) try to predict yield based on solar radiation and minimum temperature during the ripening stage of 30 days after flowering. The predicted yield decreases by 0.075 (0.0068) t ha⁻¹ for each degree increase in minimum temperature.

2.1.2.4. Influence of temperature on duration of ripening phase

It is generally seen that duration of ripening phase is longer as the temperature during this period is lower. Vergara et al. (1970) report that minimum

rather than the mean temperature has the best negative correlation with flowering duration of a variety. With lower temperature the translocation of photosynthates to the grain take place at a slower rate and the maturity period get delayed according to the observations of Boerma (1974). Biswas et al. (1975) notice exposure to low temperature during active vegetative period to extend the time of flowering. In tropics where the daily mean temperature ranges from 25° to 30°C, duration of ripening becomes about 30 days after the beginning of panicle emergence (Yoshida and Hara, 1977).

Yoshida (1981) observes a 13-day delay in flowering for each degree drop in temperature between 24°C and 21°C in IR 26. Evidently high temperature (both maximum and minimum) and lower diurnal variation in temperature are more conducive for early flowering in rice. The average flowering duration of the varieties ranged from 58 to 91 days in August and December plantings, respectively, at CRAI, Cuttack (Sahu et al., 1983). They find that the ratio of maximum : minimum temperature has a positive relation with duration of flowering. It means that the crop flowers earlier when the difference between day and night temperature is minimum.

2.1.2.5. Temperature summation

Heat requirement is generally calculated as degree days over a specific period. A particular variety will have a fixed range of temperature summation depending on its duration. The temperature summation indices of 14 Japanese rice varieties for the period from sowing to flowering range from 1000 to 3000 degree days, depending on varieties, latitudes and planting seasons (Toriyama et al., 1969). In contrast to many temperate region trials, Chang and Vergara (1972) report that IR 8 does not appear to have a fixed temperature summation to complete its life cycle. Mahapatra et al. (1973) report that temperature summation for short and medium duration varieties varied from 3000 to 3300°C and it is 3500°C for long duration varieties. Biswas et al. (1975) estimate an amount of 2211.8° heat unit as the minimum requirement for flowering among the varieties studied.

2.1.3. Light x temperature interaction

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.

Wada et al. (1973) and Yoshida and Parao (1976) report 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/m². A combination of low daily mean temperatures and high solar radiation gives a high yield. Venkateswarlu et al. (1977) explain that the expression of tillering and panicle number are a function of the environment mainly dominated by light within the range of 20 to 39°C mean maximum temperatures.

In general it is seen that low temperature accompanied by bright sunshine hours and high solar radiation during the ripening period are highly desirable for the proper ripening of grains.

2.1.4. Interaction between temperature and nutrient supply

From studies on the effect of air temperature on the organic and mineral composition of rice seedlings under various day-night temperature regimes, Sato (1972) reports that the concentration of mineral elements increase with rising temperature regime, except at the highest regime (35°-30°C). He notices that the inhibition of N absorption is remarkable at 35°-30°C. Hoshino et al. (1969) report that the accumulation of N and carbohydrate

in seedlings is largest at 31°C air temperature and at 16°C water temperature.

Grist (1975) finds temperature effect to be most important in retarding the uptake of N, if it is below 30°C. Reports from Taiwan (Anon, 1976) highlights the finding that N absorption is naturally different in relation to temperature variations in rice growing countries.

2.1.5. Soil and water temperature

As there is always standing water in the rice field from the seedling stage onwards and temperature of the water in the field acts more effectively on the growth of rice than temperature of the air. 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.

2.1.5.1. Influence on growth

Tillering is affected by the water temperature. The number of emerging tillers is highest when water temperature is 15-15°C at night and 31°C during the day, but the optimum temperature for tiller development is

31°C both day and night (Matsushima et al., 1964). Bhattacharya and De Datta (1971) observe that low soil temperature cause the death of lower leaves and chlorosis of upper leaves and retard the DMP. However, plant growth and grain yields are least affected by low soil and water temperatures during the period from heading to maturity. The results of extensive study by Choudhary and Ghildyal (1970) show that tiller development is greatly accelerated at 32°C/20°C. 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. Beneficial effects of this temperature regime on yield characteristics such as number of spikelets/panicle, minimum sterility, hundred grain weight and grain yield is also reported.

The temperature of the water with which rice is irrigated has a profound influence on duration. When the temperature of water is 18°C or less a delay in ripening of 7 to 10 days is noticed (Anon., 1974). Bonneau (1982) reports that daily mean temperature in flooded soil is 2°C more from the surface water to 5 cm below soil compared to aerial temperature. Singh et al. (1984) observe an increase in water temperature of 2-3°C in

continuous flow submergence which contributes to increased tillering, panicle size and grain number.

2.1.5.2. Influence on root development

Growth and development of root system is also considerably affected by soil and water temperature. Chaudhary and Ghildyal (1970) notice maximum dry weight of roots at harvest when the temperature is 32°/20°C. Higher temperature than this cause greater root decay in submerged soil. Lummoore et al. (1970) suggest that under submerged conditions, since the oxygen need of the rice root system is essentially met through the aerial parts of the plant, 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).

2.1.5.3. Influence on nutrient uptake

The effect of water temperature on nutrient absorption by rice seedlings differ among different ions. Fujiwara and Ishida (1963) report that the inhibition of absorption is equally severe at 17°C for phosphorus, potassium, nitrogen, iron, calcium and

magnesium for the first two weeks after transplanting, whereas at tillering stage, severe inhibition occur for phosphorus, potassium and calcium at 17°C. Studies made by Chaudhary and Gildyal (1970) indicate the influence of soil temperature on nutrient uptake by rice plants; nitrogen, phosphorus and potassium are all most actively absorbed at an average soil temperature of 26°C, and the uptake decrease at 31°, 21° and 36°C, in that order.

Thus it can be seen from the review that the temperature of soil and water used for irrigating the crop has an influence on its growth characters and nutrient uptake.

2.2. Effect of sowing/planting time on rice

Farmers have found out certain optimum time for sowing or transplanting of the crop in a location to get the increased production. Often a delay of planting causes considerable reduction in yield.

The studies by Sinha et al. (1971) and Misra and Khan (1973) reveal that the late sown rice crop generally shows reduced growth, development and vigour.

Rajagopalan et al. (1973) report the yield performance of some IRRI varieties under different

dates of planting at Coimbatore, Tamil Nadu. 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.

Seeding on June 15 produces 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 Palival (1980) from sowing time experiment report that the cultivars Chambal and IR 8 give the highest yield when sown on May 26. The yield reduction for the four subsequent sowings are 1.2, 7.7, 21.8 and 44.6 per cent in Chambal and in IR 8 sown on three dates after June 7 are 16.8, 31.6 and 51.7 per cent, respectively.

Results of experiments conducted at Thanjavur, Tamil Nadu, shows that sowing on June 6 gives a yield of 4036 kg ha⁻¹ with the yield reduction of 9 per cent and 14 per cent in the subsequent sowings (Anon., 1980). During 1980-81 significantly higher yield is obtained with sowing on June 16 (Anon., 1981).

The best time for direct seeding in Punjab is between May to first week of June (Singh and Garg, 1983). Urkurkar (1983) reports optimum yield for the rice variety, Asha when transplanted between 11 and 21 July. The water use efficiency for grain yield is highest for rice transplanted between 11 and 31 July. Machhi et al. (1984) from Narsari in Gujarat report the highest yield of 6.89 t ha⁻¹ when transplanted on June 20. Narayanasamy (1985) notices 22 per cent reduction in yield at Thanjavur when transplanting is delayed by a fortnight from June 14.

2.3. Seasonal influence on growth and yield of rice

Rice is being cultivated in different seasons in different parts of the country.

Chandler (1963) holds the opinion that many rice varieties respond to nitrogen better in dry season than in wet season. Chatterjee (1970) has made observations on tillering in a number of varieties of rice and finds that in rainy season tillering is continued for 42-45 days, whereas in dry season the duration is 50-55 days. Venkateswarlu et al. (1976) report high panicle number in rabi season, thus being responsible for high yields in this season. The number of panicles goes upto 500 in rabi while it is only 400 in kharif.

Sabu and Murty (1976) report that DMP and grain yield are invariably lower by about 50 and 54 per cent, respectively, in wet (July-Oct) than in dry (Jan-May) season. Sikder and Gupta (1979) report an overall reduction of 44.5 per cent in grain yield during kharif compared to rabi season from Chinsurah in West Bengal.

2.4. Influence of water management practices on rice

The practice of land submergence in rice cultivation is widely adopted although attempts are made to economise water usage and maximise yield by alternate wetting and drying and such other water management practices in some places.

2.4.1. Continuous submergence

Many reports are available on the superiority of continuous submergence over other methods of irrigation.

Sharma and De (1976) report that for sandy clay loam soils the water level of 4 cm throughout the growing period is the best especially when the evaporative demand of the atmosphere is high during the grain filling stage. Ehan (1979) while discussing the water management practices for rice in Uttar Pradesh reports that 5 ± 3 cm submergence

throughout the growth period gave average yields of 4.69 t ha⁻¹ compared to 4.13 t ha⁻¹ when submergence alternated with soil saturation at 25 day intervals.

Iruthayaraj and Morahan (1980) confirm that yield is lower when soil is saturated or alternately submerged and dried for 4 or 8 days and conclude that submergence with 5 cm is necessary for higher yields.

When rice variety Jaya is grown either on sandy loam or sandy clay loam soil it is noticed that a continuous shallow submergence of the soil is the best to record higher yield components and yield (Krishnamurthy et al., 1980; Pillai and De, 1980a). Soil drying done at 2 and 5 weeks after transplanting yield lower than that of continuously irrigated (Khind and Ponnasperuma, 1981). Irrigating rice crop to 5 cm submergence at saturation gives higher yield than irrigation at field capacity (Roychaudhury et al., 1983).

2.4.2. Intermittent irrigation or saturation

Subramanian et al. (1978) and Katare and Upadhyay (1981) report that scheduling intermittent irrigation of 5 cm submergence to hair line crack (0.3 atm) is as good as continuous submergence. Sandhu et al. (1980) are of the opinion that continuous submergence is not essential to get good yield of rice. After establishment irrigation could be delayed for some period for the infiltration of ponded water without any yield loss.

Panda et al. (1981) report that rice yield are comparable when it is irrigated 5 ± 2 cm submergence throughout the growth or with submergence during tillering period and soil saturation during the other growth periods. A reduction of 12-20 per cent in the water requirement is noticed with the latter treatment. When rice is grown under unfertilized conditions, any soil drying during the growing season does not reduce rice yields. However, when fertilized with 100 or 200 kg N ha⁻¹ alternate flooding and drying result in significant depression in grain yield (Sahrawat, 1981). Subramanian and Thengamithu (1984) suggest alternate wetting and drying to get good rice yield.

Dongale and Chavan (1982) suggest that for rice variety Jaya cultivated in alfisols, the optimum moisture regime is soil saturation. The growth, development and yield of rice do not vary between continuous submergence and submergence to saturation (Reddy, 1985).

2.4.3. Influence of frequency (interval) of irrigation

Sahu and Rath (1972) report that continuous submergence is not necessary in sandy loam soils of Orissa and 10 cm submergence at an interval of four days is found to be the best for control of weeds, higher yield and net

profit. The reduction in yield is 11.6 and 21 per cent as the frequency is raised to 6 and 8 days, respectively. Continuous submergence and irrigations a day after infiltration of ponded water gives comparable grain yields of rice (Sandhu et al., 1980). As the interval between infiltration and irrigation increase from 1 to 3 days or more, the yield declines by 8.7 to 11.6 q ha⁻¹.

Jha et al. (1981) conclude from CRRI, Cuttack that scheduling 7 cm irrigation 2 to 3 days after disappearance of water result in equal yield to those of continuous or partial flooding. Irrigation upto a depth of 5 ± 2 cm once in a week in rotational system does not significantly affect grain yield (Pham Sy Tan and Pillai, 1981 and Anon., 1983).

Experimental results from sandy loam soils at Chalakudy, Kerala, suggest that irrigation can be withheld from 2 to 5 days after complete infiltration of ponded water (Anon., 1983). However, Ajula et al. (1984) from Ludhiana, Punjab observe a 11.6 per cent reduction in mean yield if the drainage period is increased from one to three or more days either throughout or a part of the growth season.

Thus, it is seen that many reports are available on the frequency or interval of irrigations. A general tendency noticed is that as the interval increases, yield declines.

2.4.4. Influence on root growth

Root system is compact and horizontally developed under submergence while under continuous saturation or saturation upto maximum tillering or from maximum tillering phase, the roots develop more vertically having deep brown colouration (Raju and Varma, 1979a).

Katara and Upadhyay (1981) report that longest roots are noticed in irrigating at field capacity. The continuous submergence result into formation of shortest roots with less weight per plant. Drought tolerance in rice is characterised by slow rate of stem elongation, low to moderate tillering, a predominantly large and thick crown and fairly deep roots (Raychaudhuri and Gupta, 1981).

2.4.5. Influence on nutrient uptake

Inorganic nitrogen transformation in the soil is greatly influenced by alternate aerobic and anaerobic conditions brought about by different systems of water management. Ponnasaperuma (1965) and Patrick and

Mahapatra (1968) furnish excellent reviews on the availability of plant nutrients due to flooding.

Patrick and Wyatt (1964) from their investigations on losses of nitrogen from rice soils as a result of alternate cycles of submergence and drying observe that the losses account for about 15-20 per cent of the soil nitrogen. Peterson and Patrick (1968) recommend flooding of the rice fields immediately after fertilizer application and maintaining shallow submergence for achieving stability of added nitrogen and its effective utilisation.

The nutrient content of plants growing in submerged and cyclic submergence conditions is generally higher than in cyclic wetting and drying situations (Pande and Singh, 1970). Yoshida and Padre (1975) notice the uptake of fertilizer nitrogen to be the highest in plants grown under submerged soil conditions. Similar increased uptake of nitrogen and phosphorus due to submergence are reported by Pathak et al. (1980) and Kakade and Senar (1983). However, Moturi (1977) reports that the rate and total uptake of nutrients are higher in plants under soil saturation between initial tillering and maximum tillering and submergence upto flowering. Pillai and De (1979 and 1980b) observe that the total N, P_2O_5 and K_2O

uptake are more by 14, 23-30 and 10 per cent, respectively, under continuous shallow 4 cm submergence compared to cyclic submergence. The former is also beneficial in terms of N use efficiency and N response by the rice crop.

Patel et al. (1984) indicate that mean inflow values of N and P are highest in continuous drainage followed by no drainage and flooding followed by 2-and 4-day drainage. Inflow values of K are lowest in no drainage. However, Pande and Adak (1971) notice that during the rice growth period more nitrogen is lost under continuous submergence than under saturation. Results of experiments by Sahrawat (1980) show that mineralization of soil N is enhanced by the flooding and drying treatments both under aerobic and flooded conditions. The nitrification - denitrification processes due to alternate flooding and drying cause heavy losses of applied NH_4^+ - N.

2.4.6. Influence of water management on weed growth

Whenever there is no standing water in rice fields weeds germinate, establish and compete with rice more aggressively.

The effect of submergence depth (0 to 15 cm) on weed occurrence in transplanted rice is studied by Park et al. (1973). Echinochloa crus-galli population and dry

weight decrease sharply as the depth of water increase from 0 to 5 cm. Yamamoto and Ohba (1976) report that optimum soil moisture for emergence of 12 weed species range from 70 to 85 per cent of maximum water holding capacity. Chauhan (1978) finds that maximum weed dry matter is recorded with the water regime of field capacity to 5 cm submergence and weed dry matter decrease as the water regime increased from saturation to 5 cm submergence and from 5 to 10 cm submergence. Moturi (1977) and Raju and Varma (1979b) also report increase in number of weeds and their dry weight in saturated condition than in submerged condition.

2.4.7. Water requirement of rice

In Tamil Nadu it is reported that 1673 mm water is required for a main crop in the heavy clay soils of Coimbatore, while 2000 mm for kuruwai (June-Sep) crop and 2500 mm for samba (Aug-Jan) are found to be optimum in the light soils of Pattukottai (Chandraseohan, 1970). Continuous submergence with 5 cm depth at IRRI, Philippines result in the highest consumption of 1701 mm of water. Cyclic submergence of impounding water to 7 cm depth and irrigations given 2, 4 and 6 days after depletion result in a progressive decrease in water requirement (IRRI, 1981).

Mantajabuddin and Borulkar (1983) report that the mean consumptive use of water by rice is 609 mm in the first and 646 mm in the second crop seasons at Parbhani, in Maharashtra. At Bhavanisagar, Rangasamy et al. (1984) observe that water requirement for rice crop on sandy clay loam soil varied with depth of irrigation. It was 749, 1100 and 1332 mm of water, respectively, for the depths of 1.5, 2.5 and 3.0 cm.

2.4.5. Influence of moisture stress on rice

Entire growth of rice is not equally sensitive to moisture stress. Rice shows differential tolerance both to the intensity and duration of stress applied at different growth stages.

De Datta (1981) reports that rice is sensitive to moisture stress at reproductive stage as it consumes large amount of water during the major part of reproductive phase. He suggests that when moisture stress is allowed to develop only between tillering and heading stage, the grain yield remain fairly high.

Rew and Venkateswarlu (1983) report similar findings. However, moisture stress during the period from 20 days before flowering to 10 days after flowering

is reported to have less effect on the percentage of filled grains (Jones, 1981). Draining the field during tillering enhances tillering due to faster mineralisation and uptake of N under the constant aerobic condition at the base of the stem (Kanakaraju, 1983). Kobata and Takami (1985) notice that stressed plants have accelerated leaf senescence and 40 per cent reduction in dry matter production.

Cruz and O'Toole (1984) find that the actual cause of spikelet sterility is due to water stress given during the flowering stage and this is associated with poor panicle exertion. They suggest that the degree of exertion of panicle is a viable response to water stress which can be taken as a useful indicator in assessing the yield.

There is, thus, wide variations in the method of irrigation adopted for rice. The best method and its frequency etc., are to be decided based on the soil and climatic conditions prevailing in a locality.

2.5. Influence of nitrogen on rice

The N responsiveness of modern short-statured rices has been well documented and is a key parameter in their adoption and use in increasing food production in Asia over the past decade.

2.5.1. Effect on growth characters

The beneficial influence of N on plant growth is well established; plant height increases by N application is reported by a number of researchers (Pillai and De, 1980a; De Datta, 1981; Yoshida, 1981). Increase in tiller number, DMF, leaf area index with N application is shown by Balasubramanian (1980), Sadayappan (1982), Ramasamy (1982) and Salam (1984).

2.5.2. Effect on yield attributes and yield

Effect of N on yield attributes and yield of rice has been reported by many workers.

Kulandaivelu and Kaliappa (1971) observe positive response upto 135 kg N ha^{-1} with the variety ADT 27 and a reduction in yield thereafter. Sadayappan (1972) finds no response in IR 20 beyond 100 kg N ha^{-1} of applied N. IR 8 responds economically upto 225 kg N ha^{-1} at Coimbatore (Purushothaman and Morachan, 1974), whereas it gives the highest yield when applied with 120 kg N ha^{-1} at Karaiyiruppu (Anon., 1977).

From IARI, New Delhi, Sharma and De (1979) report increase in grain yield upto 100 kg N ha^{-1} during 1969 and upto 150 kg N ha^{-1} during 1970. Panicle number m^{-2} ,

panicle length, number of filled grains panicle⁻¹ and 1000 grain weight increase due to N application in rice varieties upto 100 kg N ha⁻¹ (Mani, 1979). Pillai and De (1980a) report favourable influence of N on these characters upto 150 kg N ha⁻¹. Subbiah et al. (1983) find linear response to N upto 90 kg ha⁻¹ under low land conditions.

2.5.3. Effect of N on straw yield

Straw production in response to N is closely parallel to grain production (Shastri and Freeman, 1971). A linear increase in straw yield with N application is reported by many workers (Salam, 1984; Raddy, 1985; Sheik Dawood, 1986). However, Santhi (1985) reports decrease in straw yield beyond an application of 75 kg N ha⁻¹.

2.5.4. Effect of N on nutrient uptake

Uptake of N increase linearly with increasing levels of N application (Pillai and De, 1980b and Salam, 1984). Uptake of P (Kalyanikutty, 1970) and K (Pillai and De, 1980b and Salam, 1984) also increase with increasing levels of N application.

2.5.5. Seasonal influence on N use of rice

Increase in N response by 87.8 per cent during rabi (dry season) over kharif (wet monsoon) is reported (Murty and Murty, 1978). Sikder and Gupta (1979) observe higher values for yield attributes and yield in boro (Jan-April) than in kharif (July-Nov). According to Iruthayaraj and Morachan (1980) higher grain yields are obtained in summer. Under high solar radiation grain yield increases linearly with increasing N levels upto 120 kg N ha^{-1} during dry season, whereas it increases only upto 60 kg N ha^{-1} during wet season (Fagi and De Datta, 1981).

Sreedharan and Vamadevan (1981) observe a positive increase in yield in the dry season upto the level of 160 kg N ha^{-1} while in the wet season the increase is only upto 80 kg N ha^{-1} beyond which a decline is noticed.

2.6. Influence of water management and N on rice

Effect of water management on N loss and uptake are reported elsewhere.

Highest grain yields are obtained when 150 kg N ha^{-1} is applied to rice under continuous 5 cm submergence or when it is kept under submergence for the 25 DAT

alternated by saturation (Singh and Pal, 1973). Singh and Singh (1973) notice response only upto 100 kg N ha⁻¹ under continuous submergence beyond which lodging of the crop is noticed. According to Khind and Ponnamparuna (1981) crops grown in partially irrigated or rainfed conditions show lower N uptake and consequently lower yields than crops in continuously submerged soil conditions. Such results are reported by Ramenathan (1985).

The above review on N reveals universal influence of N on growth and yield of rice. When water management is also considered along with N application it could be seen that continuous submergence is necessary to get a better response of applied N.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The present investigations were carried out to find the influence of weather parameters on growth and yield of rice and to evolve a suitable water management practice for rice. Identification of factors responsible for the yield difference between seasons is also aimed at. The materials used and the methods adopted are presented hereunder.

3.1. MATERIALS

3.1.1. Location: The field experiments were conducted in C block of the wetlands, Tamil Nadu Agricultural University, Coimbatore. The farm is situated at 11°N latitude and 77°E longitude, at an altitude of 427 m above MSL.

3.1.2. Meteorological parameters: The minimum number of agro-meteorological variables recommended for fundamental research in rice by the World Meteorological Organisation and International Rice Research Institute (1980) were considered for the present studies. The data on maximum and minimum temperature and solar radiation were taken from paddy breeding station which is situated about 500 m from the experimental field and the other data from the Agromet observatory of Tamil Nadu Agricultural University.

The weather parameters recorded during the cropping periods are reported in Table 1. The abstracts of the observations on weather parameters are given in Table 2.

3.1.3. Soil: The fields of the experimental site come under the classification as aquepts. They were deep, moderately drained and clayey. The experimental soils were medium to low in N and P and high in K. The physical and chemical characteristics of the soil are presented in Table 3.

3.1.4. Irrigation source: The experimental fields were irrigated by a deep bore well situated on the northern end of the E block. The analysis of the irrigation water is given in Table 4.

TABLE 4. CHEMICAL ANALYSIS OF IRRIGATION WATER
(Richards, 1954)

Particulars	Value
pH	7.8
EC	0.89 mmhos/cm
Carbonates	Nil
Bicarbonates	41.48 parts per lakh
Sulphates	Traces
Chlorides	17.04 parts per lakh
Calcium	6.56 "
Magnesium	4.32 "
Sodium	10.95 "

TABLE 1. WEATHER DATA DURING THE CROPPING PERIOD

Month and standard week	Mean solar radiation (cal cm ⁻² d ⁻¹)	Mean sunshine hours d ⁻¹	Mean temp. (°C)		Mean RH (%)		Total rain-fall (mm)	Total rainy days	Evaporation mm d ⁻¹	Wind velocity (kmph)
			Max.	Min.	0722 h	1422 h				
<u>1985</u>										
25 18-24 June	471	5.9	30.6	22.2	75	57	1.5	-	9.2	19.3
26 25-1 July	294	1.1	27.5	21.9	87	76	33.7	5	1.0	14.7
27 2-8	429	5.3	28.8	22.3	78	54	-	-	7.6	13.9
28 9-15	390	3.3	29.6	21.9	96	53	-	-	6.5	6.4
29 16-22	403	2.8	29.4	21.2	95	57	5.0	1	4.9	6.2
30 23-29	408	5.3	28.8	20.6	95	61	15.0	2	4.4	7.4
31 30-5 Aug	418	4.8	28.9	21.7	82	57	2.0	-	7.0	13.4
32 6-12	463	6.5	29.6	21.2	87	53	-	-	8.1	13.1
33 13-19	479	4.2	28.9	22.4	82	54	-	-	8.5	18.2
34 20-26	460	4.0	30.1	21.2	95	67	34.0	2	3.8	5.3
35 27-2 Sept	517	6.8	30.6	21.2	93	62	14.2	1	5.4	6.4
36 3-9	506	5.6	30.6	21.3	96	51	5.0	1	5.3	6.9
37 10-16	442	8.0	29.9	21.4	88	54	-	-	6.8	11.8
38 17-23	419	7.4	30.9	21.2	91	52	14.0	1	7.0	4.0
39 24-30	458	5.8	30.5	21.8	95	61	79.9	6	3.7	1.5
40 1-7 Oct	462	6.1	30.8	21.7	95	78	58.0	1	4.1	5.4
41 8-14	496	8.4	30.8	21.1	95	52	-	-	6.3	4.2
42 15-21	509	7.5	31.6	20.0	95	58	8.1	1	4.9	3.4
43 22-28	435	8.4	30.7	20.6	87	50	18.0	1	4.9	2.6
44 29-4 Nov	472	4.4	29.9	21.1	83	57	-	-	4.3	5.1
45 5-11	322	1.3	28.3	21.5	96	85	115.2	5	1.0	2.3
46 12-18	370	6.0	29.4	19.9	93	64	1.2	-	3.1	0.7
47 19-25	433	7.1	30.6	18.3	92	36	12.0	1	3.3	0.8
48 26-2 Dec	492	6.8	26.5	15.9	86	53	-	-	4.4	3.7
49 3-9	441	5.5	28.6	20.4	86	54	8.0	1	3.5	3.8
50 10-16	428	7.0	29.0	18.9	86	54	-	-	3.8	2.3
51 17-23	446	8.6	29.4	17.4	92	45	-	-	4.5	3.3
52 24-31	475	8.0	30.0	17.1	86	40	-	-	4.9	3.7
<u>1986</u>										
1 1-7 Jan	468	9.9	29.2	16.4	82	36	-	-	5.1	3.9
2 8-14	374	1.7	28.5	18.8	85	56	-	-	3.7	3.3
3 15-21	397	7.4	29.7	20.2	88	46	38.0	1	3.1	1.9
4 22-28	464	9.5	29.8	18.4	86	40	-	-	5.4	4.2
5 29-4 Feb	521	9.6	31.1	17.5	81	39	-	-	4.8	2.6
6 5-11	464	7.9	31.0	16.5	78	34	-	-	5.5	3.9
7 12-18	464	7.6	31.4	19.2	85	44	1.0	-	4.9	3.2
8 19-25	506	8.7	31.2	20.3	83	43	2.2	-	5.5	3.2
9 26-4 Mar	468	9.0	30.9	18.5	81	32	1.0	-	6.1	4.5
10 5-11	518	7.9	32.6	17.6	80	43	-	-	6.4	5.5
11 12-18	509	9.0	33.1	21.3	83	36	-	-	6.4	4.6
12 19-25	494	9.8	34.1	21.1	79	26	-	-	7.5	3.7
13 26-1 Apr	535	9.9	36.0	19.7	78	28	-	-	9.2	5.1
14 2-8	534	9.9	35.7	21.8	79	29	-	-	7.9	3.7
15 9-15	516	10.4	37.0	22.9	73	25	-	-	8.1	4.0
16 16-22	527	9.6	37.3	22.2	79	31	-	-	7.9	4.6
17 23-29	481	7.5	36.5	24.5	76	37	3.0	1	7.2	4.1
18 30-6 May	486	5.4	34.0	23.2	89	46	14.8	3	4.6	2.7
19 7-13	519	9.9	35.9	22.9	77	34	3.0	1	7.1	4.6
20 14-20	503	10.0	36.9	18.8	77	36	11.6	2	8.9	6.9
21 21-27	515	8.8	36.1	20.5	73	35	15.0	1	8.0	5.2
22 28-3 June	475	7.1	33.5	21.9	79	46	3.0	1	5.2	3.4
23 4-10	519	7.3	34.2	23.0	75	43	-	-	8.4	6.8
24 11-17	451	5.4	33.1	22.4	78	53	5.4	1	6.8	10.7
25 18-24	385	4.5	30.4	23.6	68	57	8.0	1	7.3	25.3
26 25-1 July	311	2.3	29.4	23.1	79	58	20.6	2	5.8	24.3
27 2-8	418	7.7	32.4	22.8	82	42	-	-	6.7	18.0

TABLE 2. ABSTRACT OF THE OBSERVATIONS ON WEATHER PARAMETERS - SEASONWISE
EXPERIMENT-1

Weather parameters	S.W. Monsoon 1985	N.E. Monsoon 1985	Summer 1986
	June 16 th to Nov. 11 th	Oct. 1 st to April 4 th	Jan. 15 th to June 9 th
1. Rainfall total for the season (mm)	403.6	257.7	110.4
Rainy days	27	11	10
2. Maximum temperature (°C) range	27.5 to 31.6	26.4 to 36.0	29.8 to 37.3
3. Minimum temperature (°C) range	20.0 to 22.4	15.9 to 21.7	16.5 to 24.5
4. Mean incident solar radiation range (cal cm ⁻¹ d ⁻¹)	294 to 517	322 to 535	464 to 535
5. Sunshine hours range	1.1 to 8.4	1.3 to 9.9	5.4 to 10.4
6. RH (%) range 0722 hrs	75 to 96	78 to 96	73 to 86
1422 hrs	50 to 85	26 to 56	25 to 33
7. Evaporation (mm d ⁻¹) range	1.0 to 9.2	1.0 to 9.2	4.6 to 8.9
8. Wind velocity (kmph) range	1.5 to 18.3	1.9 to 5.5	2.6 to 10.7

EXPERIMENT-2

Weather parameters	S.W. Monsoon 1985	N.E. Monsoon 1985	Summer, 1986
	June 25 th to Sept. 23 rd	Nov. 26 th to Mar. 13 th	April 11 th to July 8 th
1. Rainfall total for the season (mm)	122.9	50.2	84.4
Rainy days	13	2	13
2. Maximum temperature (°C) range	27.5 to 30.9	26.5 to 32.6	29.4 to 37.3
3. Minimum temperature (°C) range	20.6 to 22.4	15.9 to 20.4	18.8 to 24.5
4. Mean solar radiation range (cal cm ⁻² d ⁻¹)	294 to 517	374 to 521	311 to 534
5. Sunshine hours range	1.1 to 8.0	1.7 to 9.9	2.3 to 10.4
6. R.H. (%) range 0722 hrs	78 to 96	78 to 92	68 to 89
1422 hrs	53 to 76	32 to 56	25 to 58
7. Evaporation (mm d ⁻¹) range	1.0 to 8.5	3.1 to 6.4	4.6 to 8.9
8. Wind velocity (kmph) range	4.0 to 18.2	1.9 to 5.5	2.7 to 25.3

SOIL TEMPERATURE AS INFLUENCED BY WATER MANAGEMENT
SUMMER, 1986

Treatment	Soil temperature (°C)	
	07.30 hrs	14.30 hrs
I ₁ Continuous 5 cm submergence	23.9	31.2
I ₂ Submerging one day after disappearance of water	23.2	30.5
I ₃ Submerging three days after disappearance of water	22.6	30.0

TABLE 3. CHARACTERISTICS OF THE EXPERIMENTAL SOILS

Particulars	Experiment 1	Experiment 2
Location	C-9 block	C-2 block
A. Mechanical analysis (on moisture free basis) (Piper, 1950)		
Coarse sand %	13.6	17.8
Fine sand %	39.5	22.0
Silt %	14.3	17.3
Clay %	32.5	43.0
Texture	Clay loam	Clay loam
B. Chemical analysis		
Available N (kg ha ⁻¹) (Subbiah and Asija, 1956)	257	257
Available P ₂ O ₅ (kg ha ⁻¹) (Olsen et al., 1954)	10.9	12.4
Available K ₂ O (kg ha ⁻¹) (Stanford and English, 1959)	548.0	523.0
pH (1:2 soil water suspension) (Jackson, 1973)	8.2	8.0
EC (1:2 soil water suspension) (mhos/cm)	0.3	0.6
CEC (me/100 g soil)	38.2	37.9
C. Physical characters		
Bulk density (g/cm ³) (Dakshinamurthy and Gupta, 1968)	1.45	1.65
Field capacity (%) (Dastane, 1972)	45.0	42.8
Permanent wilting point (%) (Richards, 1947)	20.0	17.7
Total porosity (%) (Dakshinamurthy and Gupta, 1968)	56.3	58.3
Infiltration rate (cm/day) (Dakshinamurthy and Gupta, 1968)	1.4	1.6

3.1.5. Varieties used: IR 50 was the test variety used for the first experiment during SWM 1985 and Summer 1986, whereas IR 20 was used during NEM 1985. IR 50 and CO 37 (Vaigai) comprised the test varieties used during SWM 1985 and Summer 1986 for the second experiment and IR 20 and CO 44 during the NEM 1985.

3.1.6. Fertilizers used: Nitrogen, phosphorus and potassium were supplied through urea (46 per cent N), super phosphate (16 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

3.2. METHODS

3.2.1. Treatment details: The experiments were carried out in a strip plot design for both the experiments. For the first experiment irrigation levels and planting times constituted the two different strips. In the second experiment, combination of irrigation levels and varieties were tried in first strip and nitrogen levels in the second strip. The experiments were replicated thrice in all the seasons.

3.2.2. Treatments (Experiment 1): The treatments adopted for the first experiment are given below.

A. Irrigation levels

- I_1 - 5 cm submergence throughout
- I_2 - Recouping 5 cm submergence one day after disappearance of ponded water
- I_3 - Recouping 5 cm submergence two days after disappearance of ponded water
- I_4 - Recouping 5 cm submergence three days after disappearance of ponded water

B. Date of planting

	SWM 1985	NEM 1985	Summer 1986
P_1	18-6-1985	1-10-1985	15-1-1986
P_2	2-7-1985	15-10-1985	29-1-1986
P_3	16-7-1985	12-11-1985	12-2-1986
P_4	30-7-1985	26-11-1985	26-2-1986
P_5	13-8-1985	10-12-1985	12-3-1986
P_6	27-8-1985	-	-

Experiment 2

A combination of varieties (two) and irrigation levels (two) in one strip and levels of N (0, 75, 150 and 225 kg ha⁻¹) in the other strip were tried during SWM and NEM seasons 1985. The levels of irrigation was increased to three and that of N reduced to three for the Summer season 1986. The details are given below.

A. Irrigation x varieties

I_1 - 5 cm submergence throughout

I_2 - Recouping 5 cm submergence one day after
disappearance of ponded water

V_1 - IR 50	} (SWM 1985 and Summer 1986)	V_1 - IR 20	} (NEM 1985)
V_2 - CO 37		V_2 - CO 44	

B. Nitrogen levels

N_0 - 0 kg N ha⁻¹

N_1 - 75 kg N ha⁻¹

N_2 - 150 kg N ha⁻¹

N_3 - 225 kg N ha⁻¹

For Summer season 1986, I_3 - Recouping 5 cm submergence three days after disappearance of ponded water was also included.

3.2.3. Preparation of main field: The selected main fields were first worked with tractor mounted with cage wheel after applying 50 mm of water. Another puddling was done four days later by applying another 50 mm of water. Later last puddling and levelling was done. For the subsequent seasons, the individual plots were prepared by digging with mamoty. The summary of experimental particulars are presented in Tables 5, 6 and 7.

TABLE 5. SUMMARY OF EXPERIMENTAL PARTICULARS - SEASONWISE

Particulars	Field Experiment-1		
	S. W. Monsoon 1985	N. E. Monsoon 1985	Summer 1985
Previous crop grown	Rice	Rice	Rice
Site of experiment	C9	C9	C9
Variety used	IR 50	IR 20	IR 50
Gross plot size (m ²)	4.5 x 3.0	4.5 x 3.0	4.5 x 3.0
Border rows including destructive rows	2 rows each on three sides and 4 rows on one side		
Spacing (cm ²)	15 x 10	20 x 10	15 x 10
Net plot size (m ²)	4.1 x 2.1	4.1 x 1.8	4.1 x 2.1
Design	Strip plot	Strip plot	Strip plot
No. of treatments	24	20	20
Replications	3	3	3
Amount of N, P ₂ O ₅ and K ₂ O added (kg ha ⁻¹)	100:50:50	100:50:50	100:50:50

TABLE 6. PARTICULARS OF SOWING, TRANSPLANTING AND HARVESTING IN DIFFERENT SEASONS - EXPERIMENT 1

	S. W. Monsoon 1985			N. E. Monsoon 1985			Summer 1985		
	Sowing date	Transplanting date	Harvesting date	Sowing date	Transplanting date	Harvesting date	Sowing date	Transplanting date	Harvesting date
P ₁	26-5-85	18-6-85	16-9-85	6-9-85	1-10-85	17-1-86	23-12-85	15-1-86	8-4-86
P ₂	9-6-85	2-7-85	28-9-85	20-9-85	15-10-85	3-2-86	6-1-86	29-1-86	25-4-86
P ₃	23-6-85	16-7-85	11-10-85	18-10-85	12-11-85	4-3-86	20-1-86	12-2-86	9-5-86
P ₄	7-7-85	30-7-85	4-11-85	1-11-85	26-11-85	15-3-86	10-2-86	26-2-86	29-5-86
P ₅	21-7-85	13-8-85	14-11-85	15-11-85	10-12-85	4-4-86	24-2-86	12-3-86	9-6-86
P ₆	4-8-85	27-8-85	27-11-85	-	-	-	-	-	-

TABLE 7. SUMMARY OF EXPERIMENTAL PARTICULARS - SEASONWISE

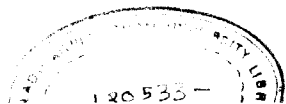
Particulars	Field experiment-2		
	S.W. Monsoon 1985	N.E. Monsoon 1985	Summer 1986
Previous crop grown	Rice	Rice	Rice
Period	June-September	November-March	April-July
Site of experiment	C2 block	C2 block	C2 block
Varieties used	V ₁ - IR 50 V ₂ - CO 37 (Vaigai)	V ₁ - IR 20 V ₂ - CO 44	V ₁ - IR 50 V ₂ - CO 37 (Vaigai)
Gross plot size (m ²)	5x3	5x3	5x3
Border rows including destructive rows	2 rows each on three sides and 4 rows on one side	2 rows each on three sides and 4 rows on one side	2 rows each on three sides and 4 rows on one side
Spacing (cm ²)	15 x 10	20 x 10	10 x 10
Net plot size (m ²)	4.6 x 2.1	4.6 x 1.8	4.6 x 2.1
Design	Strip plot	Strip plot	Strip plot
No. of treatments	16	16	18
Replications	3	3	3
Amount of P ₂ O ₅ and K ₂ O applied (kg ha ⁻¹)	50:50	50:50	50:50
Date of sowing	3-6-1985	2-11-1985	20-3-1986
Date of planting	25-6-1985	26-11-1985	11-4-1986
Date of harvest	23-9-1985	13-3-1986	8-7-1986
Field duration - Planting to harvest (days)	91	108	89

3.2.4. Layout of the plots: After the final puddling and levelling plots were laid out with bunds of 25 cm breadth and 15 cm in height all around the plot. All around the experimental field drainage channels were provided for effective drainage and control of irrigation water. The layout plan of the two field experiments are given in Fig. 1a, 1b and 1c.

3.2.5. Fertilizer application: Before transplanting, the field was drained and a uniform dose of 50 kg each of P_2O_5 and K_2O ha^{-1} was given basally to all plots. Nitrogen at 100 kg ha^{-1} for the first experiment and as per treatment for the second experiment were applied in three equal splits at transplanting, tillering (25 DAT) and panicle initiation (45 DAT) stages.

3.2.6. Transplanting: Twenty three day old seedlings were transplanted @ 3 seedlings $hill^{-1}$ at a spacing of 15 x 10 cm during SWM 1985 and Summer 1986. Twenty five day old seedlings were planted at a spacing of 20 x 10 cm during NEM 1985. Gap filling was taken up wherever necessary.

3.2.7. Weed and pest management: Butachlor @ 1 kg a.i ha^{-1} was applied by mixing with sand 4 DAT with two cm of standing water as a pre-emergence herbicide. Light



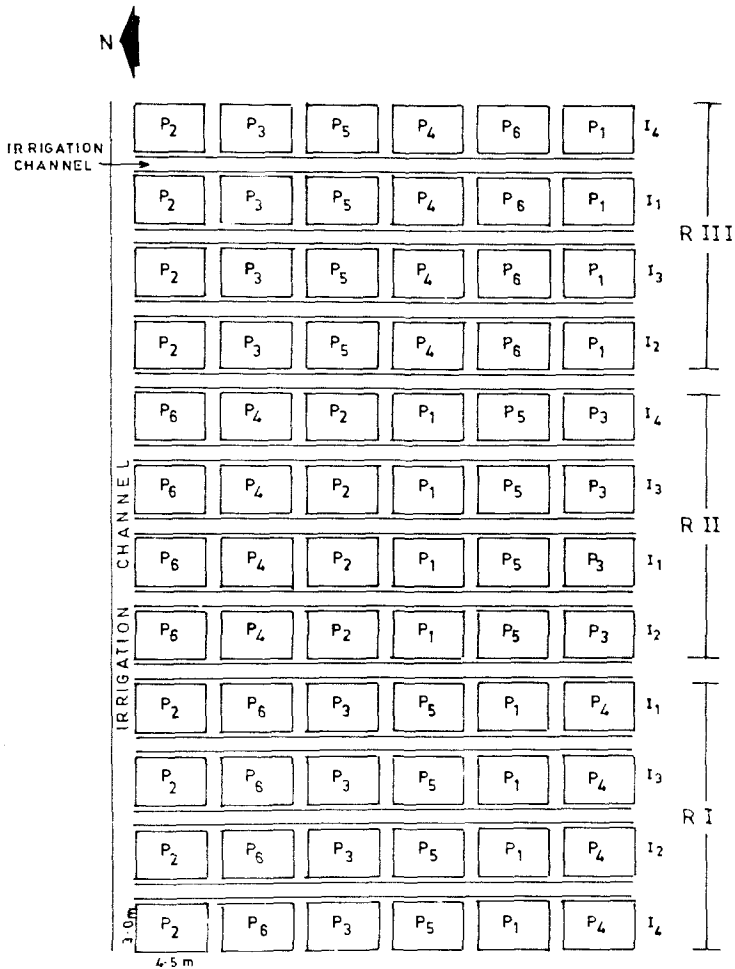


FIG. 1a. FIELD LAY OUT OF THE EXPERIMENTAL PLOT (EXPERIMENT - I SWM 1985)

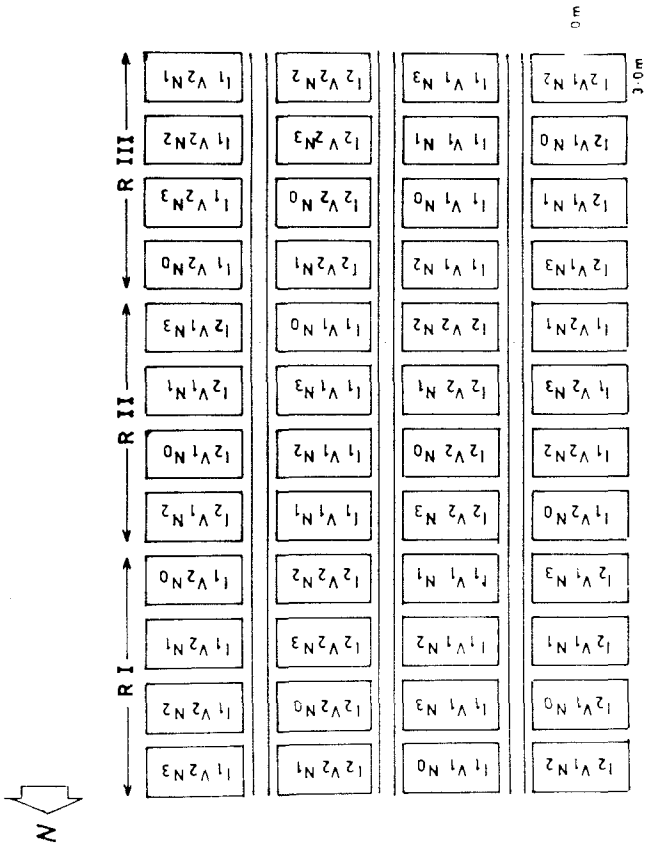


FIG. 1 b. FIELD LAY OUT PLAN OF EXPERIMENTAL PLOT
(EXPERIMENT-2 SWM AND NEM 1985)

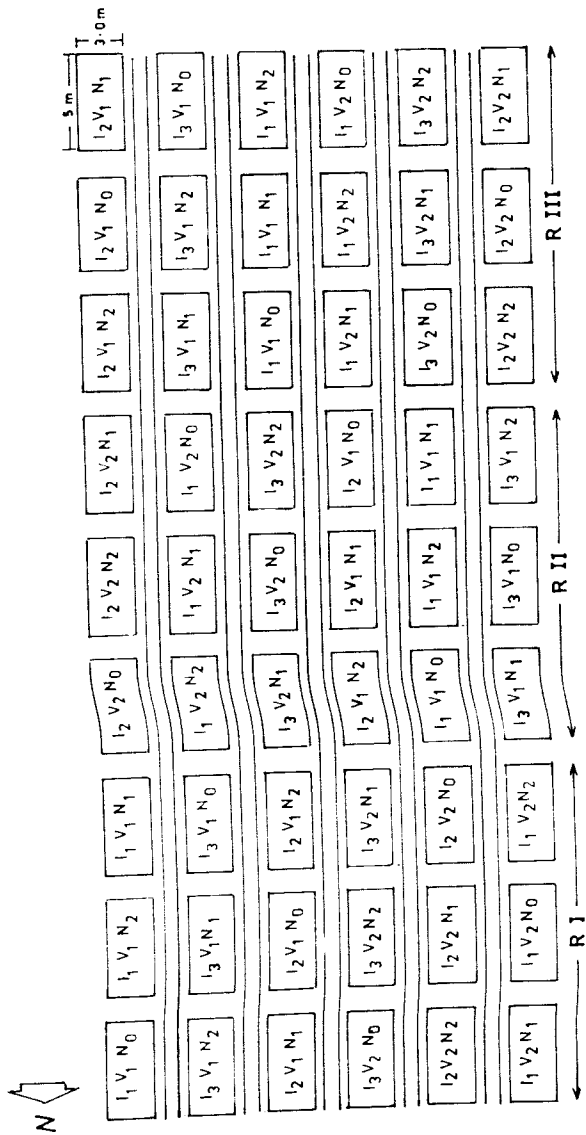


FIG. 1c. FIELD LAY OUT PLAN OF EXPERIMENTAL PLOT (EXPERIMENT -2)
SUMMER 1986

hand weeding were given 40 DAT. Plant protection measures were adopted wherever necessary.

3.2.8. Irrigation: Irrigation treatments were imposed 7 DAT onwards. The quantity of water applied was measured by using a 7.5 cm portable Parshall flume. Irrigation was stopped 15 days before harvest of the crop.

3.2.9. Harvest: Border plants on all sides of the plots were harvested first and the net plots were then harvested and threshed. The individual plot yield of grain was recorded at 14 per cent moisture. The straw weight was taken after sundrying.

3.3. OBSERVATIONS RECORDED

3.3.1. Growth characters: The following growth characters were recorded at 40 days after transplanting (DAT) flowering and harvest stages by adopting standard procedure (Gomez, 1972).

1. Height of plants: Height of plants was recorded from 10 plants tagged randomly from the net plot.

2. Number of tillers per hill: Total number of tillers per hill was counted from 10 hills in the net plot and average worked out.

3. Maximum root length: Four plants were carefully uprooted from the destructive row from each plot with minimum root damage. They were washed carefully, and the maximum root length expressed in cm.

4. Root dry weight

5. Shoot dry weight (dry matter production)

3.3.2. Growth analysis

1. Leaf Area Index (LAI): Plants collected for recording maximum root length were used to record LAI as suggested by Palaniswamy and Gomez (1974).

$$\text{LAI} = \frac{\text{L.W.K. number of leaves per hill}}{\text{Spacing adopted (cm}^2\text{)}}, \text{ where,}$$

L = Length of 3rd leaf blade from the top (cm)

W = Maximum width of the same leaf blade (cm)

K = a constant factor of 0.73 for dry and 0.75 for wet seasons

LAI was recorded at tillering, panicle initiation and flowering stages.

3.3.3. Yield components and yield: The following observations were recorded using standard procedures.

1. Number of panicles and grains m^{-2}
2. Length of panicle
3. Weight of panicle
4. Number of filled grains panicle $^{-1}$
5. Percentage of filled grains
6. 1000 grain weight
7. Grain yield
8. Straw yield
9. Water use efficiency for grain production at harvest

3.3.4. Chemical analysis: Phosphorus and potash content of plants were estimated at flowering and harvest stages (Jackson, 1973) and the total uptake was calculated by multiplying the nutrient content by dry matter and expressed as $kg\ ha^{-1}$. N content of plant was estimated at flowering and harvest stages using the microkjeldahl method as described by Jackson (1973) and the uptake worked out and expressed as $kg\ ha^{-1}$.

3.3.4.1. N response and per cent recovery of applied N

$$N\ response = (Y_t - Y_0) / A_t = Y/A_t$$

Y_t = Yield of treatment

Y_0 = Yield of control

A_t = N applied in treatment

This was worked out as suggested by Patnaik et al. (1971).

Per cent N recovery was calculated as suggested by Bartholomew and Clark (1965) as follows.

$$\% \text{ N recovery} = \frac{\text{N uptake from fertilizer treatment} - \text{N uptake from control}}{\text{N applied}} \times 100$$

3.3.5. Weed dry weight: Weeds collected from four places at random using a 50 x 50 cm quadrat at 40 DAT. They were washed, sundried for few days and oven dried at 60°C for 72 hrs. Then dry weight was recorded and expressed as kg ha⁻¹.

3.3.6. Economics: Gross and net income per ha, net return per rupee invested on water and N and benefit cost ratio were calculated based on the cost of cultivation details and input purchase and produce sale records available at the Central farm of TNAU.

- | | |
|--|-------------|
| a. Cost of cultivation (excluding N and water) | = Rs.2750/- |
| b. Cost of 1 kg urea (N = 4.5/-) | = Rs.2.10 |
| c. Cost of 1 ha cm of water | = Rs.10/- |
| d. Price of 1 kg of rice | = Rs.1.50 |
| e. Price of 1 kg of straw | = Rs.0.15 |

Total cost of 1 ha cm of water was calculated as suggested by Sivanappan and Aiyasamy (1978) by substituting present day costs.

3.3.7. Statistical analysis: The data was analysed as per the method suggested by Panse and Sukhatme (1978) for strip plot design using the computer available at the Tamil Nadu Agricultural University. Critical differences were worked out wherever necessary at five per cent probability level. Correlation coefficients between plant growth and yield attributes as well as yield and meteorological parameters were worked out and presented.

RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

Two separate field experiments were conducted during 1985-86 with the objectives to evaluate the effect of seasonal fluctuations on growth and yield of rice and to find out an appropriate planting time as well as its influence on water and N requirement for increasing productivity. The experiments were carried out during South West Monsoon 1985 (SWM 85), North East Monsoon 1985 (NEM 85) and Summer 1986 (Summer 86) seasons. Results of SWM 85 and Summer 86 are taken together for correlation and regression analysis between growth, yield components and yield and are discussed together. Results of NEM 85 and second experiment are presented and discussed separately.

Experiment 1 (SOUTH WEST MONSOON 1985 and SUMMER 1986)

4.1.1. Growth characters

4.1.1.1. Height of plant

Data relating to the effect of planting dates and water management on plant height at 40 DAT, flowering and harvest stages are presented in Table 8. In general plant height was not much affected by planting time during SWM 85. At flowering delayed plantings produced taller

TABLE 8. HEIGHT OF PLANT. (CM), STAGEWISE AND SEASONWISE

	S.W. MONSOON, 1985							SUMMER, 1986					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	44.53	47.44	45.02	45.17	49.54	55.21	47.82	45.33	45.11	47.47	47.96	46.01	45.37
I ₂	45.19	46.76	43.52	44.23	48.47	52.39	46.76	44.37	43.55	38.55	43.37	44.99	42.96
I ₃	42.52	42.69	40.38	41.49	45.94	47.61	43.44	43.19	42.61	36.33	37.49	43.05	40.96
I ₄	42.22	40.35	38.34	38.69	41.09	45.17	40.98	42.29	40.40	33.18	35.15	43.15	38.83
Mean	43.62	44.32	41.82	42.40	46.26	50.09		43.82	42.92	37.63	40.97	44.50	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	3.01	0.33	1.28	3.22				0.26	0.13	0.31	0.37		
CD(P=0.05)	N.S	0.82	N.S	N.S				0.59	0.32	0.66	0.82		

	S.W. MONSOON, 1985							SUMMER, 1986					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	55.54	54.73	56.93	69.31	62.84	60.24	59.93	54.38	58.98	58.89	66.61	63.24	60.42
I ₂	54.66	53.16	54.65	66.04	60.49	62.89	58.65	52.03	57.84	57.15	63.65	62.12	58.56
I ₃	53.81	51.92	52.92	64.72	59.38	57.93	56.78	51.21	56.03	52.82	62.75	61.09	56.79
I ₄	52.17	51.06	51.42	57.37	53.81	51.76	52.93	50.21	43.84	51.56	61.28	59.75	53.33
Mean	54.04	52.72	53.98	64.36	59.13	58.21		51.96	54.18	55.10	63.57	61.55	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	3.30	1.01	1.87	3.62				0.26	0.16	0.40	0.44		
CD(P=0.05)	7.34	2.47	4.04	7.95				0.59	0.38	0.85	0.94		

	S.W. MONSOON, 1985							SUMMER, 1986					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	68.62	67.36	69.06	69.99	67.94	65.61	68.08	61.53	72.75	67.97	71.16	64.69	67.62
I ₂	70.99	70.93	66.68	67.23	63.41	63.90	67.17	60.42	71.45	66.05	69.74	62.06	65.94
I ₃	71.27	68.74	64.97	66.50	62.26	62.64	66.05	57.84	66.45	59.60	67.98	60.27	62.23
I ₄	69.54	67.24	63.52	59.58	57.09	58.95	61.65	55.50	62.05	59.55	66.31	58.82	60.53
Mean	70.10	68.57	66.06	65.93	62.65	62.75		58.82	67.93	63.39	68.80	61.46	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	3.16	0.40	1.61	3.49				0.22	0.17	0.39	0.40		
CD(P=0.05)	7.04	0.98	3.33	7.66				0.50	0.42	0.83	0.86		

N.S - Not significant

plants whereas early plantings were taller during harvest.

During Summer 86 planting period influenced plant height in all stages of observation. At 40 DAT plants were shorter as plantings were delayed from 15th January to 12th February but the trend was reversed with the subsequent plantings. During flowering, however, a progressive increase in plant height with delay in planting was noticed. Plants behaved more or less similar during harvest stage also. Plants transplanted on 26th February were tallest during these two stages.

A significant difference in plant height due to irrigation was present at all stages in both the seasons. Plant height with continuous submergence or irrigating one day after disappearance of water were comparable at flowering and harvest stages during SWM 85 whereas the tallest plants were seen in continuously submerged treatment in Summer 86. A progressive decline in plant height with increase in interval between irrigation was also noticed. Interaction between planting and irrigation on plant height was present during flowering and harvest stages in SWM 85 and at all stages in Summer 86. Tallest plants with continuous submergence were observed with planting done on 30th July in SWM 85 and 26th February in

Summer 86. The influence of deep standing water in increasing the plant height has been reported by many workers (Iruthayaras and Morahan, 1980; Pillai and De, 1980a). The increase in height has been attributed to the elongation of internode when the water level is more.

Effect of meteorological parameters

The correlation coefficients between plant height at harvest and meteorological parameters at different phases are presented in Table 9.

1) Temperature: The height (Fig.2) in relation to minimum temperature at vegetative phase (Fig.6) shows that increase in height at preflowering and flowering is greater when the night temperature during vegetative phase is higher. The correlation coefficients presented in Table 9 show that height of the plant is influenced by minimum air temperature or night temperature ($r = 0.6137^*$) at vegetative phase. The night temperature exerts greater influence on plant height than day (maximum) temperature. A progressive decrease in plant height at harvest as planting was delayed from 18th June during SWM 85 was observed. The reduction in plant height was due to the prevalence of lower night temperature with longer hours of sunshine per day. This is evident from the positive

TABLE 9. CORRELATION COEFFICIENTS OF PLANT HEIGHT AT HARVEST WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Maximum air temperature	P I	0.3835
2. Minimum air temperature	P I	0.6137*
3. Mean relative humidity	P I + P II + P III	0.6273*
4. Total sunshine hours	P I	-0.3142
5. Total sunshine hours	P II	-0.5470
6. Total sunshine hours	P III	-0.4680
7. Total sunshine hours	P I + P II + P III	-0.6427*
8. Total solar radiation	P I	-0.4271
9. Total solar radiation	P II	-0.4884
10. Total solar radiation	P III	-0.6375*

TABLE 10. PARTIAL CORRELATION COEFFICIENT OF HEIGHT AT HARVEST (1) WITH SUNSHINE HOURS (2) AND THE MEAN RELATIVE HUMIDITY (3) DURING P I + P II + P III

Factor	r value
12	-0.6427
13	0.6273*
23	-0.6485*
12.3	-0.3979
13.2	0.3609

P I - Vegetative phase * - Significant at 5% level
 P II - Reproductive phase
 P III - Ripening phase

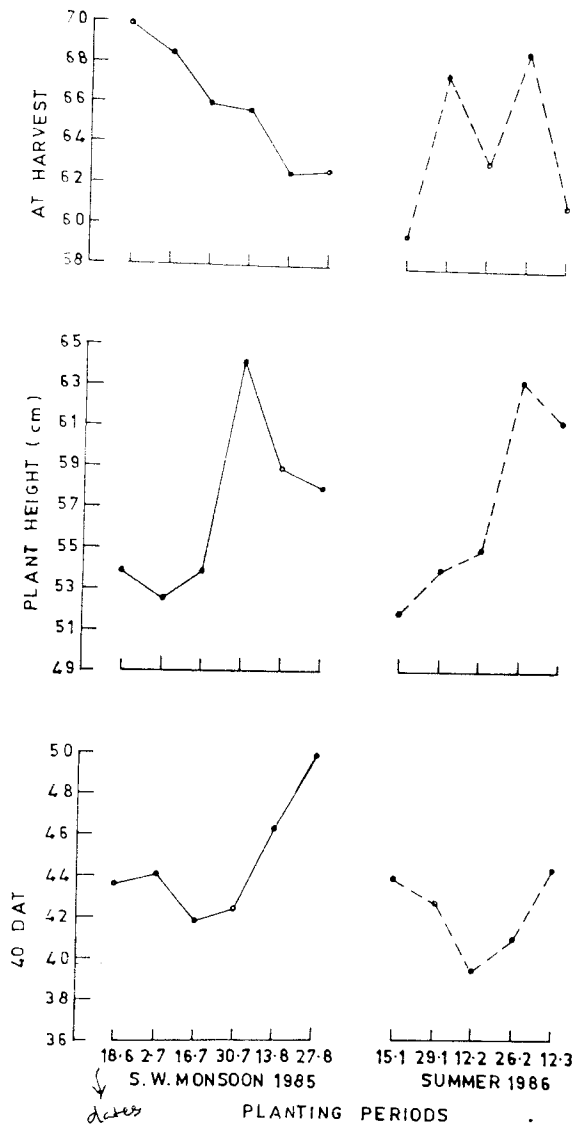


FIG. 2 PLANT HEIGHT (cm) AS INFLUENCED BY DIFFERENT PLANTING PERIODS

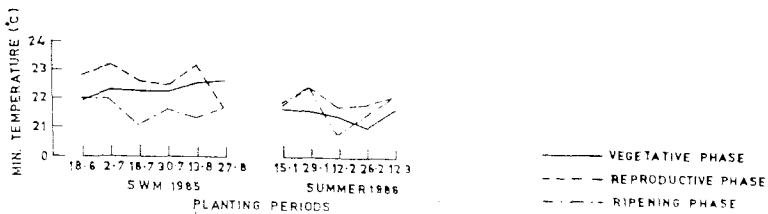


FIG. 5 MINIMUM TEMPERATURE ($^{\circ}\text{C}$) EXPERIENCED BY THE CROP DURING DIFFERENT GROWTH PHASES

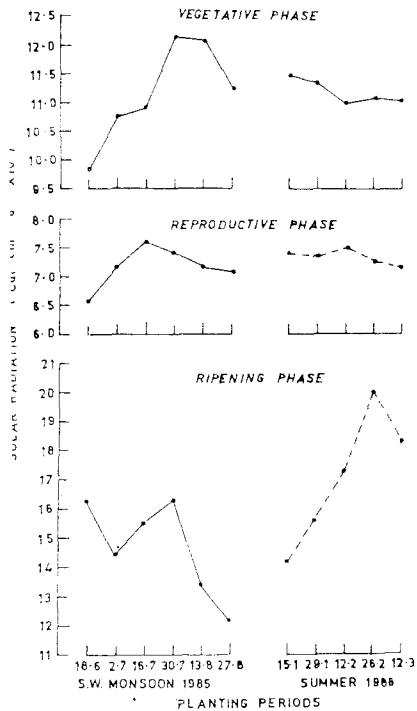


FIG. 7 SOLAR RADIATION ($\text{Cal cm}^{-2} \text{d}^{-1} \times 10^3$) EXPERIENCED BY THE CROP DURING DIFFERENT GROWTH PHASES

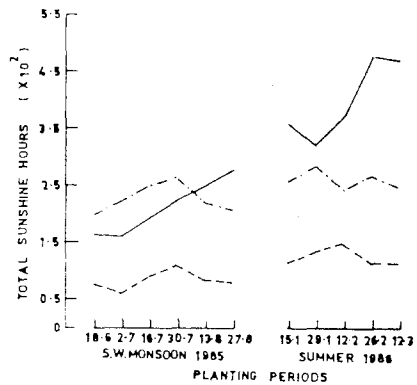


FIG. 8 SUNSHINE HOURS ($\times 10^2$) EXPERIENCED BY THE CROP DURING DIFFERENT GROWTH PHASES

influence of night temperature and negative effect of sunshine hours as revealed in the Table 9. Sato (1972), Sanchez et al. (1973) and Gopalaswamy (1975) report similar effects of temperature on plant height.

ii) Solar energy: The correlation Table 9 also brings out the influence of sunshine hours and solar radiation during the three phases of crop growth. It is clear that both these factors influence the height especially at later stages of crop growth. This amply indicates that light level becomes progressively more critical and limited availability of light to the base of the plant at later stages caused by mutual shading might have resulted in the elongation of lower internodes (Tanaka et al., 1966). This becomes an adaptation of the plants under low light situations especially during the periods of monsoon. Ghosh (1961) report that there is rapid elongation of shoot in the kharif by the influence of rainfall and temperature.

iii) Relative humidity: It is seen that plant height is positively correlated to mean relative humidity ($r = 0.6273^*$). Similar results are reported by Ghosh (1961) who observed that one of the reasons for increased plant height is humidity.

To study the effect of relative humidity with eliminating the effect of sunshine hours or vice-versa, partial correlation coefficients were worked out between plant height, sunshine hours and relative humidity (Table 10). When the effect of relative humidity is eliminated, the correlation between plant height and sunshine hours becomes lesser in magnitude but negative. However, when the effect of sunshine hours is eliminated, the correlation between plant height and relative humidity gets further reduced and becomes non-significant. This amply proves that relative humidity per se has no role in deciding plant height.

4.1.1.2. Number of tillers per hill

The data in Table 11 reveal that during SWM 85, P₃ (16th July) and P₅ (13th August) produced highest and comparable tiller numbers per hill at 40 DAT. At flowering P₃ (16th July) recorded the highest number of tillers compared to all other plantings. A decrease in tiller number as planting was delayed beyond this date was evident. During Summer 86, 29th January planting produced the highest number and 26th February planting the least. But during flowering 12th February planting had the highest tiller number and was comparable with

TABLE 11. NUMBER OF TILLERS, STAGEWISE AND SEASONWISE

40 DAT

S.W. MONSOON, 1965

SUMMER, 1966

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	10.01	10.28	12.50	11.53	13.07	9.28	11.71	10.34	10.52	10.63	10.51	10.69	10.54
I ₂	9.92	9.90	12.29	11.25	12.75	9.39	10.92	9.96	10.04	10.42	9.71	9.83	10.02
I ₃	9.50	9.34	11.92	10.63	10.71	8.59	10.08	9.77	9.56	9.20	8.79	9.30	9.30
I ₄	9.33	8.92	10.38	10.04	10.13	7.75	9.43	9.06	9.35	8.70	8.09	8.20	8.68
Mean	9.69	9.61	11.77	10.86	11.67	8.71		9.76	9.87	9.74	9.20	9.34	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	0.63	0.09	0.36	0.72				0.15	0.10	0.20	0.22		
CD(P=0.05)	1.41	0.24	0.75	1.56				0.34	0.24	0.42	0.48		

FLOWERING													
S.W. MONSOON, 1965							SUMMER, 1966						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	12.32	11.67	12.46	12.13	12.56	10.75	11.98	12.23	10.18	12.10	12.33	11.12	11.59
I ₂	11.97	11.36	12.48	11.91	11.38	10.55	11.61	10.67	9.69	11.46	11.51	10.27	10.72
I ₃	10.96	10.17	12.25	10.80	10.38	9.00	10.59	9.78	9.49	10.33	10.50	8.86	9.79
I ₄	10.50	9.58	11.25	10.17	9.34	7.88	9.79	9.11	9.35	10.00	9.65	8.64	9.36
Mean	11.44	10.70	12.11	11.25	10.92	9.54		10.45	9.68	10.98	10.97	9.73	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	0.48	0.16	0.52	0.67				0.31	0.09	0.21	0.37		
CD(P=0.05)	1.06	0.39	N.S	N.S				0.72	0.23	0.46	0.65		

N.S - Not significant

26th February and 15th January plantings. Plantings done on 29th January and 12th March had considerably lower tiller numbers.

Influence of irrigation levels on tiller number was also present. At flowering tiller number with continuous submergence and submerging one day after disappearance of water were the highest and comparable during SW# 85, whereas tiller production was the highest with continuous submergence for all plantings during Summer 86. A progressive decrease in number of tillers at flowering in SW# 85 and at both the stages in Summer 86 due to decrease in irrigation levels could be noticed. Irrigation x planting interaction was significant at 40 DAT in SW# 85 and at both the stages in Summer 86. In SW# 85 plantings done on 13th August or 16th July with continuous submergence or irrigating one day after disappearance of water produced more number of tillers at 40 DAT than other combinations. In Summer 86 with all planting dates continuous submergence had more tillers at 40 DAT. At flowering the same irrigation level with plantings done on 26th February or 15th January produced more tillers.

It is seen from Fig.3 that more tillers per hill are produced at 40 DAT and at flowering stages during mid

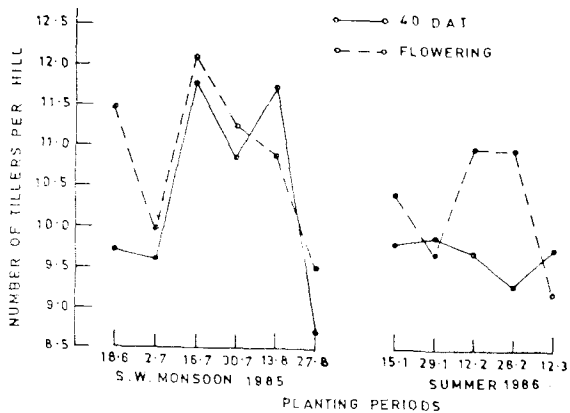


FIG. 3 TILLER PRODUCTION AS INFLUENCED BY DIFFERENT PLANTING PERIODS

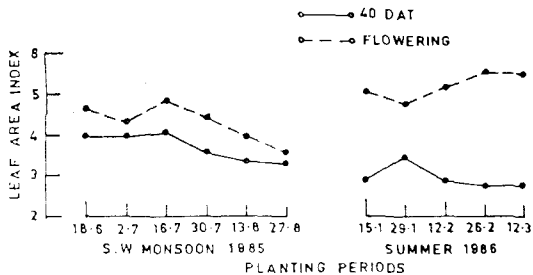


FIG. 4 a. LEAF AREA INDEX AS INFLUENCED BY DIFFERENT PLANTING PERIODS

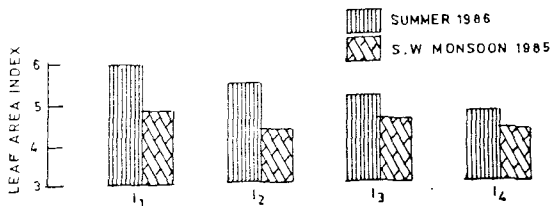


FIG. 4 b LEAF AREA INDEX AS INFLUENCED BY WATER MANAGEMENT

July or August plantings during SWM 85 which are similar. Planting done at the end of August produced the lowest number of tillers. In Summer 86 not much difference was seen between plantings at 40 DAT but at flowering February plantings produced the highest tiller number similar to 15th January planting.

During late July and mid February plantings the minimum temperature is low (Fig.6) during vegetative and reproductive phases and hence the rate of tiller production is also comparatively less. Another factor that is obvious from the Fig.3 is that decrease in tiller number during flowering starts from mid July plantings in SWM 85. The decrease is maximum in August plantings than in July plantings. In other words mortality of tiller takes place at a much higher rate in former than in the latter. Low light conditions at vegetative and reproductive phases accompanied by a comparatively high night temperature leads to less net photosynthesis due to greater respiration losses (Tanaka et al., 1966). Number of tillers per plant may be determined in two ways: number of tiller buds per plant and percentage of tiller bud development (ratio of the number of tillers developed to the number of tiller buds initiated). Higher temperature increases leaf age. Higher leaf age and greater tiller number in turn

increase the number of tiller buds per plant. On the other hand, Hoshino et al. (1969) have shown that the percentage of tiller bud development is high when the temperature is low (20-21°C). Tanaka and Garcia (1965) report that carbohydrate is necessary as an energy source for tiller development. High temperature and low light intensity decrease the carbohydrate in plant (Sato, 1972) leading to reduction in tiller number. It is not clear, however, whether low temperature per se is necessary for tiller bud development or whether low temperature favours carbohydrate accumulation which promotes tiller development. Thus tillering of rice plant should be studied in terms of interaction between light intensity, temperature and carbohydrate metabolism (Yoshida, 1973). A decrease in tiller number with increase in minimum temperature is noticed by Owen (1972) and Gopalaswamy (1975).

Singh and Garg (1976) have opined that short day and low temperature circumstances lead to high N accumulation in leaves. As N concentration increases in leaves more tillers are produced (Ishizuka and Tanaka, 1963).

4.1.1.3. Leaf area index (LAI)

From the data on LAI presented in Table 12 and Fig.4a it is seen that in SWM 85, higher LAI value was recorded at 40 DAT and flowering in crops planted on 16th

TABLE 12. LEAF AREA INDEX, SEASONWISE AND STAGEWISE

40 DAT

S. V. MORISON, 1965

SUMMER, 1966

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	4.06	4.61	4.49	3.76	3.57	3.91	4.07	3.21	3.96	3.43	3.40	3.13	3.35
I ₂	4.16	4.29	4.38	3.76	3.55	3.54	3.95	3.09	3.66	3.05	2.90	2.97	3.09
I ₃	3.95	3.84	4.02	3.61	3.33	3.34	3.68	2.93	3.50	2.77	2.72	2.71	2.93
I ₄	3.81	3.31	3.53	3.12	3.07	2.88	3.29	2.35	3.30	2.40	2.43	2.44	2.62
Mean	4.00	4.01	4.11	3.57	3.38	3.42		2.88	3.61	2.91	2.75	2.64	
	P	I	Pat	I	Pat	I		P	I	Pat	I	Pat	Mean
SED	0.13	0.05	0.14	0.18				0.03	0.01	0.04	0.05		
CD(P=0.05)	0.28	0.13	0.29	0.37				0.08	0.03	0.08	0.10		

FLOWERING

S. V. MORISON, 1965

SUMMER, 1966

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	5.02	4.83	5.57	4.86	4.42	4.16	4.81	5.64	5.39	5.98	6.62	5.74	5.87
I ₂	4.90	4.65	5.15	5.73	4.36	4.05	4.64	5.46	4.83	5.37	5.72	5.60	5.40
I ₃	4.40	4.22	4.70	4.38	3.64	3.52	4.14	4.82	4.60	5.18	5.22	5.40	5.06
I ₄	4.23	3.72	4.24	4.10	3.49	3.13	3.82	4.31	4.35	4.80	4.82	5.34	4.72
Mean	4.64	4.35	4.92	4.52	3.98	3.72		5.06	4.79	5.33	5.59	5.54	
	P	I	Pat	I	Pat	I		P	I	Pat	I	Pat	Mean
SED	0.12	0.05	0.14	0.17				0.04	0.01	0.03	0.05		
CD(P=0.05)	0.27	0.13	0.29	0.37				0.10	0.03	0.07	0.12		

July but did not differ with 2nd July and 16th June plantings at 40 DAT and flowering, respectively. The LAI values were lowest in August plantings. A progressive decrease in LAI values were observed as the planting was delayed beyond 16th July. Similar reduction in LAI due to delayed plantings is reported by Gopalaswamy (1975). During Summer 86 LAI at 40 DAT was the highest when planted during late January and decreased thereafter. At flowering an increase in LAI as planting was delayed could be noticed during Summer 86. The increase in LAI from 40th day to flowering was considerably greater in Summer 86 than in SWM 85.

The Fig.4a showing LAI at different stages reveals that at 40 DAT LAI is high during early plantings which decreases gradually reaching the lowest in August plantings. LAI at flowering stage shows a phenomenal increase in mid July planting (P_3) in SWM 85 and late February (P_4) and early March (P_5) plantings in Summer 86 compared to that of the previous plantings. This may be because of enhanced tiller production (Fig.3) and increased plant height (Fig.2) during these plantings of the respective seasons.

The Table 12 also shows that LAI was reduced with increase in interval of irrigations during both the seasons. LAI produced was higher and comparable with

continuous submergence and submerging one day after disappearance of water during SWM 85 whereas the former treatment registered significantly the highest LAI during Summer 86. This is clearly brought out from the Fig.4b on the effect of water management on tiller production at flowering stage. LAI is the integral of number of tillers, number of leaves per tiller and the size of the leaves. Since the number of leaves on a tiller is almost constant, LAI mostly is determined by tiller number (Tanaka et al., 1964).

At flowering during SWM 85 with optimum planting time when highest LAI are observed the irrigation regimes have greater influence than the other planting periods when the LAI is lower. For P_3 (16th July) planting each irrigation level influences the LAI whereas in the later periods I_1 and I_2 are comparable and greater than I_3 and I_4 which are again similar. However, during Summer 86 with decrease in supply of water there is progressive reduction in LAI values for all the planting dates.

Correlation coefficients worked out between LAI at flowering and various meteorological parameters at different phases are presented in Table 13.

TABLE 13. CORRELATION COEFFICIENTS OF LAI AT FLOWERING WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum temperature	P I	-0.3798
2. Minimum temperature	P II	-0.4011
3. Mean temperature summation	P I	0.6949*
4. Total sunshine hours	P I	0.5829
5. Total sunshine hours	P II	0.6646*
6. Total solar radiation	P I	0.4581
7. Total solar radiation	P II	0.6593*

P I - Vegetative phase

P II - Reproductive phase

* - Significant at 5% level

A perusal of the data shows that unlike height or tillers, LAI at flowering gives no relationship between minimum air temperature or sunshine hours or solar radiation during phase I but is significantly correlated with sunshine hours and solar radiation in phase II.

It could also be pointed out that in case of solar radiation, the r value at phase II is higher than that of the phase I. This shows that light energy has more influence on LAI at reproductive phase than at vegetative phase. The Table 13 also brings out that the correlation coefficient between LAI and integrated mean daily temperature during vegetative phase is more than sunshine hours or

solar radiation. Thus it may be concluded that LAI at flowering is almost determined by the integrated mean daily temperature during the growth period when leaf growth takes place. Similar observations are reported by Murata and Togari (1973).

4.1.1.4. Dry matter production (DMP)

The data presented in Table 14 show that DMP at flowering and harvest stages are influenced by planting periods in both the seasons. Highest DMP at flowering in SWM 85 was observed in 30th July (P_4) and the least in 2nd July (P_2) plantings, with other plantings producing the similar dry matter. At harvest stage 13th August (P_5) planting recorded the highest which was similar to planting done on 30th July. Plantings done on other dates produced comparable dry matter. In Summer 86, plantings done on 26th February (P_4) or 29th January (P_2) or 12th March (P_5) produced the highest dry matter at flowering whereas at harvest highest DMP was observed with planting done on 26th February.

The superiority of late July in SWM 85 and late February in Summer 86 plantings in producing highest dry matter at flowering and harvest stages may be attributed to the following.

TABLE 14. DRY MATTER PRODUCTION (KG HA⁻¹) STAGEWISE AND SEASONWISE

FLOWERING													
S.W. MONSOON, 1965						SUMMER, 1966							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	7526	6317	6862	8076	7034	7028	7191	6550	6755	6675	6777	6640	6677
I ₂	6590	6161	6626	7868	6793	6589	6770	6324	6602	6568	6555	6571	6524
I ₃	6080	5694	6315	7561	6098	6194	6324	5720	6513	6444	6501	6514	6539
I ₄	5669	5405	5920	7298	5705	5985	5997	5507	6414	6398	6450	6467	6263
Mean	6417	6019	6431	7701	6408	6447		6045	6566	6521	6571	6550	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	179.54	72.57	186.12	153.01				12.44	8.26	18.69	18.01		
CD(P=0.05)	397.99	177.59	401.87	324.98				28.69	20.22	40.22	30.48		

HARVEST													
S.W. MONSOON, 1965						SUMMER, 1966							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	13067	13006	12661	13689	14067	13812	13450	13686	13154	13428	14316	13964	13689
I ₂	11495	12578	12248	13565	13661	12763	12718	13227	12905	13135	13528	13239	13227
I ₃	11117	12028	11601	12000	12945	11499	11865	12955	11791	12881	13265	12924	12741
I ₄	10650	10275	10373	11331	12050	10445	10854	11754	10939	11532	12652	12657	11903
Mean	11562	11972	11771	12696	13181	12130		12905	12195	12744	13465	13141	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	429.44	125.61	385.80	266.24				35.78	6.75	40.27	32.70		
CD(P=0.05)	956.80	307.36	842.87	565.26				82.50	16.51	88.26	68.02		

An examination of Fig.5 on DMP and tiller production at flowering (Fig.3) shows that DMP follows more or less a similar trend of tiller production except in 30th July planting in SWM 85 and 29th January in Summer 86. A comparison of minimum temperature given in the Fig.6 reveals that the minimum temperature is low at the reproductive phase during 30th July and 26th February in SWM 85 and Summer 86 seasons, respectively. Thus tiller production at maximum tillering and flowering stage are exposed to a congenial condition for further dry matter accumulation during the reproductive phase. Since the night temperature is lower, the respiration loss will be lower and photosynthetic accumulation more thus resulting in an increased DMP. The reduction in height of plants noticed for 15th January in Summer 86 might have resulted in lesser DMP at this stage.

The Fig.5 on DMP at harvest shows that 13th August planting in SWM 85 and 26th February planting in Summer 86 produced the highest DMP at this stage. Subsequent to flowering the plants are exposed to maximum solar energy during the ripening phase and this could have helped to further enhance the dry matter according to Yoshida (1971). This assumption is also supported by the comparatively high LAI at flowering in 26th February

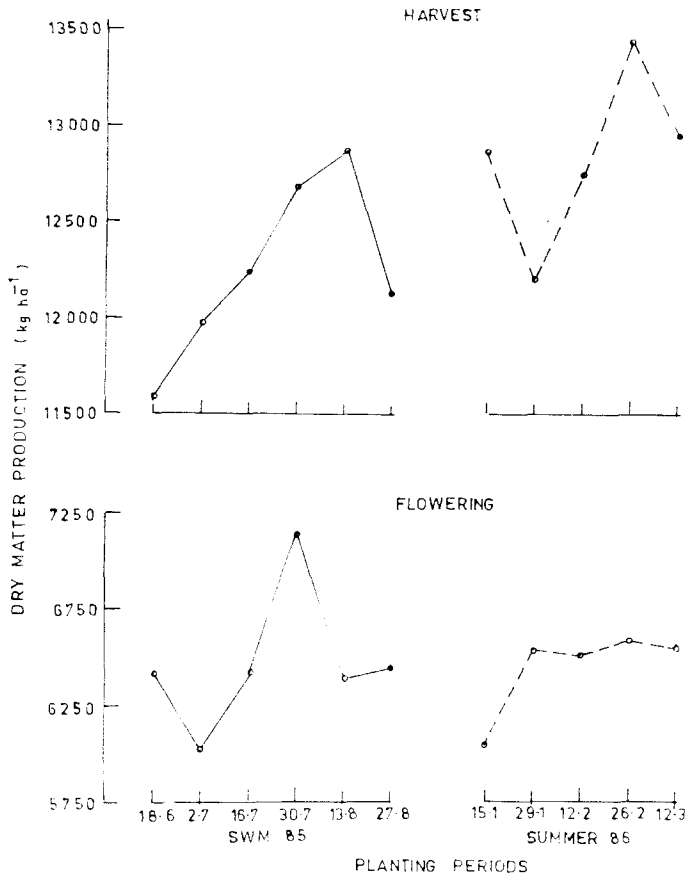


FIG. 5 DRY MATTER PRODUCTION (kg ha⁻¹) AS INFLUENCED BY DIFFERENT PLANTING PERIODS

planting indicating that dry matter accumulation continued upto harvest. In SWM 85 planting done on 2nd July produced lower DMP. This may be because plants are shorter with less tiller production. Whereas, the lower DMP noticed with planting done on 29th January in Summer 86 could be attributed to lower tiller production. Apart from this the quantum of solar energy received by these plantings are also poor.

Table 14 shows that continuous submergence resulted in highest DMP than other irrigation levels. The irrigation x planting interaction was also significant. Transplanting at the end of July in SWM 85 or at the end of February in Summer 86 together with continuous submergence resulted in the highest DMP than other plantings and water management.

4.1.1.5. Duration

The growth duration is considered important especially when associated with planting time under the context of multiple cropping systems. Since the variety used in this experiment is photoinsensitive, the difference in growth duration observed may chiefly be attributed to temperature effect.

4.1.1.5.1. Duration upto 50 per cent flowering

The duration upto 50 per cent flowering during SWM 85 and Summer 86 is presented in Table 15. The duration upto flowering is influenced by planting time. It is longest in 27th August planting in SWM 85 and during January plantings in Summer 86. As the plantings are advanced in SWM 85 or delayed in Summer 86 the duration gradually gets reduced since the temperature at this stage for these plantings is high. The correlation coefficients worked out with duration of different phases and temperature components (Table 16) have shown that minimum air temperature is negatively correlated with duration upto flowering. Vergara et al. (1970) report that minimum rather than mean temperature of the atmosphere had the best negative correlation with flowering duration of a variety. It is also seen that air temperature range at this period is also correlated with duration. The temperature range reflects mainly the variation in minimum temperature at vegetative phase wherein when the minimum temperature is low the range is more and the duration is longer. Yoshida (1981) observes considerable delay in flowering for reduction of temperature between 24° and 21°C in IR 26. Evidently higher temperature (both maximum and minimum) and lower diurnal variation are more conducive for early flowering in rice varieties (Sahu et al., 1983).

TABLE 15. DURATION UPTO 50 PER CENT FLOWERING AND RIPENING PHASES UNDER DIFFERENT PLANTING PERIODS

Date of planting	Duration (days)	
	Upto 50 per cent flowering	Ripening phase
P ₁ 18-6-1985	58	31
P ₂ 2-7-1985	59	30
P ₃ 16-7-1985	56	32
P ₄ 30-7-1985	59	32
P ₅ 13-8-1985	61	32
P ₆ 27-8-1985	62	30
P ₁ 15-1-1986	59	31
P ₂ 29-1-1986	59	30
P ₃ 12-2-1986	56	32
P ₄ 26-2-1986	55	31
P ₅ 12-3-1986	57	30

TABLE 16. CORRELATION COEFFICIENTS SHOWING RELATIONSHIP BETWEEN DURATION OF DIFFERENT PHASES AND METEOROLOGICAL PARAMETERS

Factor	Phase	Duration from	
		Planting to flowering	Flowering to harvest
----- r value -----			
1. Maximum air temperature	P I	-0.0957	-0.1516
2. Minimum air temperature	P I	-0.5875	-0.3831
3. Maximum air temperature	P III	-	-0.5086
4. Minimum air temperature	P III	-	-0.8657**
5. Maximum : minimum temperature ratio	P I	0.6694*	-
6. Maximum : minimum temperature ratio	P III	0.6944*	-
7. Air temperature range	P I	0.6158*	-
P I - Vegetative phase		* - Significant at 5% level	

The ratio of maximum : minimum temperature also had a positive relationship with duration upto flowering. This also suggests that the crop flowers earlier when the difference between day and night temperature is minimum.

4.1.1.5.2. Duration of the ripening phase

The data presented in Table 15 on the duration of ripening phase under different planting periods go to show that the durations were shorter in 2nd July and 27th August plantings in SWM 85 and 29th January or 12th March in Summer 86 when the minimum temperature at the ripening phase of these plantings are higher. The duration is slightly more in other plantings when the temperature registers a decrease as in Fig.6. It may be further seen from the Table 16 that the duration of ripening phase is very strongly and negatively correlated with minimum air temperature at this stage. Vergara et al. (1969) opine that the ripening phase duration of rice ranges from 30-35 days in tropics. As the temperature is lower, the translocation of photosynthates to grain takes place at a slower rate and therefore the maturity period is delayed proportionately (Best, 1962). Similar increase in ripening phase duration due to low temperature is reported by Owen (1971) and Gopalaswamy (1975).

4.1.1.5.3. Temperature summation and duration

The temperature summation or heat requirements of a crop is usually calculated as degree days over a specific period such as planting to harvest (Owen, 1972). The total duration of the crop in the main field and the temperature summation during respective planting periods are presented in Table 17 for the two seasons studied.

TABLE 17. TEMPERATURE SUMMATION (°C) AND DURATION FROM PLANTING TO HARVEST UNDER DIFFERENT PLANTING PERIODS

Date of planting	Temp. summation (°C)	Duration
18-6-1985	2431	89
2-7-1985	2426	89
16-7-1985	2402	88
30-7-1985	2443	91
13-8-1985	2487	93
27-8-1985	2454	92
15-1-1986	2382	90
29-1-1986	2260	89
12-2-1986	2229	88
26-2-1986	2185	86
12-3-1986	2204	87

A perusal on temperature summation and duration reveals that the former behaves independently of the latter in different planting periods. With respect to the

relationship between duration of the variety and the temperature summation, it is seen that with increase in duration of the variety the temperature summation also increases. Thus the temperature summation for the shortest duration of planting in 26th February is 2185°C while the longest duration of crop planted in 13th August has 2477°C.

4.1.1.6. Nutrient uptake

The data on nutrient uptake at flowering and harvest stages are presented in Tables 18a, b and c. Uptake of nutrients varied with planting period. At flowering uptake of N and P was more with 30th July planting in SWM 85 and 26th February planting in Summer 86. July plantings had higher K uptake, early or late plantings in SWM 85 having lower uptake values. In Summer 86 plantings done on 29th January recorded the highest uptake of K which was similar to the two February plantings. During harvest stage early August plantings resulted in highest uptake of N and P which declined with early plantings in SWM 85 whereas February plantings recorded more uptake in Summer 86. Plantings done on January resulted in lowest uptake. In case of K, the uptake during harvest was more with July plantings in SWM 85 and with February plantings in Summer 86. The

TABLE 18a. NUTRIENT UPTAKE (KG HA⁻¹) STAGEWISE AND SEASONWISE

NITROGEN													
FLOWERING													
S.W. MONSOON, 1985							SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	
I ₁	53.21	56.89	67.78	70.33	70.53	64.62	66.33	72.20	69.59	83.09	83.71	80.63	77.86
I ₂	50.61	52.32	64.92	72.38	64.55	57.27	60.34	69.35	66.34	81.05	81.10	77.27	75.18
I ₃	47.80	49.00	61.56	66.35	58.71	52.03	58.91	66.32	64.08	80.46	80.15	75.15	73.23
I ₄	45.05	47.95	60.91	63.90	55.83	47.54	53.53	61.03	64.89	76.02	77.14	74.23	70.66
Mean	49.32	51.54	63.79	70.24	62.41	55.36	67.25	66.22	80.36	80.52	76.82		
	P	I	P at I	I at P			P	I	P at I	I at P			
SED	0.99	0.66	1.54	1.51			0.21	0.22	0.52	0.54			
CD(P=0.05)	2.21	1.60	3.24	3.20			0.49	0.53	1.09	1.14			

HARVEST													
S.W. MONSOON, 1985							SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	67.00	73.28	55.04	65.35	81.04	74.53	69.52	89.00	85.80	104.96	107.96	97.86	97.01
I ₂	54.71	63.65	54.20	62.35	76.50	69.58	63.50	86.01	84.04	102.16	103.32	93.41	93.79
I ₃	45.53	58.32	46.81	58.65	69.25	61.93	56.75	84.24	76.85	100.18	100.66	91.50	90.69
I ₄	38.27	51.90	42.01	54.47	63.87	56.34	51.15	76.74	71.08	95.02	96.48	90.21	85.91
Mean	51.38	61.80	49.74	60.20	72.67	65.60		84.00	79.44	100.45	102.11	93.24	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	1.89	0.89	2.77	2.64				0.56	0.24	0.63	0.54		
CD(P=0.05)	4.20	2.19	N.S	N.S				1.29	0.59	1.39	1.14		

N.S - Not significant

TABLE 19b. PHOSPHORUS

FLOWERING

	S.W. MONSOON, 1985						SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	21.82	21.46	21.52	24.56	21.62	21.23	21.04	22.92	26.22	27.97	26.39	23.26	26.15
I ₂	13.89	20.07	21.09	23.86	20.76	20.00	20.93	19.35	27.56	27.29	27.59	21.11	24.60
I ₃	16.82	18.55	19.07	22.08	19.18	18.52	19.05	18.50	26.42	26.30	26.44	19.05	23.50
I ₄	15.65	18.06	18.42	21.08	18.40	17.42	18.17	17.42	25.41	25.16	25.1	13.01	22.42
Mean	18.53	19.56	20.03	22.89	19.99	19.29		19.55	26.93	26.68	26.88	20.81	
P	I	P at I	I at P	P	I	P at I	I at P	P	I	P at I	I at P	P	I
SEM	0.39	0.38	0.50	0.51				0.17	0.14	0.27	0.27		
CD(P=0.05)	0.88	0.92	1.07	1.14				0.39	0.35	0.57	0.58		

HARVEST

	S.W. MONSOON, 1985						SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	37.34	36.90	34.12	37.78	40.28	34.58	36.83	54.35	46.04	55.96	48.93	45.22	53.36
I ₂	33.75	35.64	32.68	35.90	39.01	32.84	35.00	52.32	44.18	54.30	53.91	53.77	51.70
I ₃	30.83	34.56	30.59	34.67	37.48	29.92	33.01	47.67	43.59	53.61	52.37	52.96	50.93
I ₄	28.86	33.38	29.35	33.22	36.06	28.05	31.49	46.08	42.97	52.33	51.40	52.01	48.78
Mean	32.70	35.12	31.73	35.39	38.21	31.35		50.11	43.97	54.02	53.31	53.44	
P	I	P at I	I at P	P	I	P at I	I at P	P	I	P at I	I at P	P	I
SED	0.78	0.11	0.75	0.54				0.32	0.21	0.34	0.30		
CD(P=0.05)	1.73	0.28	1.62	1.11				0.74	0.52	0.75	0.67		

TABLE 18c. POTASSIUM

FLOWERING

S. W. MONSOON, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	94.62	105.59	115.00	114.60	108.07	107.72	107.63	89.32	87.21	94.59	95.70	91.70	91.71
I ₂	89.38	105.72	111.95	113.08	107.25	106.68	105.78	88.84	86.31	94.10	95.25	90.96	91.09
I ₃	89.34	104.02	111.60	111.35	106.71	105.40	104.74	88.12	85.78	93.67	94.68	90.34	90.52
I ₄	88.17	103.68	110.64	109.36	105.40	104.79	103.67	87.68	85.12	93.04	93.78	89.11	89.75
Mean	90.53	104.75	112.30	112.15	106.86	106.15		88.49	86.10	93.05	94.85	90.53	
P	I	P	I	P	I	P		P	I	P	I	P	
	0.52	0.17	0.70	0.64			-	0.49	0.11	0.37	0.15		
SD(P=0.05)	1.16	0.42	1.49	1.32				1.14	0.27	0.85	0.34		

HARVEST

S. W. MONSOON, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	148.83	157.11	163.62	154.36	149.64	146.37	153.32	139.05	136.08	144.41	149.28	143.30	142.42
I ₂	147.78	156.37	162.55	153.54	148.42	145.45	152.35	138.23	135.05	143.88	148.22	141.25	141.33
I ₃	147.37	155.34	161.84	152.71	147.68	144.45	151.57	137.63	134.32	141.01	147.39	139.54	140.14
I ₄	146.09	154.19	160.96	151.77	146.42	143.74	150.53	136.92	133.12	141.90	145.47	139.10	139.30
Mean	147.52	155.75	162.24	153.10	148.04	145.00		137.96	134.64	143.00	147.59	140.80	
P	I	P	I	P	I	P		P	I	P	I	P	
	0.59	0.11	0.49	0.27				0.21	0.35	0.50	0.55		
SD(P=0.05)	1.32	0.26	N.S.	N.S.				0.49	0.06	N.S.	N.S.		

N.S. - Not significant

uptake decreased with early or late plantings than the above plantings in both the seasons.

The effect of water management was also pronounced on nutrient uptake in both the seasons. The highest nutrient uptake was noticed with continuous submergence followed by irrigating one and two days after disappearance of water. The lowest uptake was seen with irrigating three days after disappearance of water. The planting x irrigation interaction was also significant. Continuous submergence with those plantings that resulted in increased uptake have given the highest values.

Continuous submergence of water in the field increases soil temperature and this in turn also might have enhanced nutrient uptake (Chaudhury and Ghildyal, 1970). It could also be pointed out that the uptake of N remained more or less the same between flowering and harvest stages whereas uptake of P was doubled and that of K increased by 1.5 times between these two stages.

The correlation coefficients worked out on the relationship between nutrient uptake and meteorological parameters at reproductive and ripening phases are presented in Table 19.

TABLE 19. CORRELATION COEFFICIENTS SHOWING RELATIONSHIP OF NUTRIENT UPTAKE AT FLOWERING (P II) AND HARVEST (P III) WITH METEOROLOGICAL PARAMETERS

Factor	Phase	r value		
		N	P	K
1. Maximum air temperature	P II	0.8794**	0.7604*	-0.2886
2. Maximum air temperature	P III	0.8312**	0.8533**	-0.6876*
3. Minimum air temperature	P II	0.1716	0.1103	-0.0711
4. Minimum air temperature	P III	0.5156	0.5175	-0.1476
5. Total sunshine hours	P II	0.6504*	0.8012**	-0.4507
6. Total sunshine hours	P III	0.6285*	0.8093**	-0.5790
7. Total solar radiation	P II	0.5271	0.5644	-0.3526
8. Total solar radiation	P III	0.7485**	0.7366**	-0.7675**

There is a strong positive correlation between N and P uptake and the various meteorological parameters considered. De Datta and Zarate (1970) report that the solar energy received during the ripening period was the most important factor affecting the N response and grain yields of four rice varieties.

4.1.2. Yield and yield attributes

4.1.2.1. Panicles per m²

The data presented in Table 20 and Fig.9 show that panicle production was affected by planting periods and

TABLE 20. PANICLES M^2 SEASONWISE

S.W. MONSOON, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	409	406	421	404	379	352	395	468	465	480	502	479	479
I ₂	405	400	417	403	384	346	393	459	452	463	483	462	464
I ₃	400	399	410	395	375	332	385	446	430	454	472	452	451
I ₄	393	386	392	387	358	325	374	440	419	443	462	443	441
Mean	402	398	410	397	374	339		453	442	460	480	459	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	3.55	1.54	3.69	4.76				0.82	0.76	1.65	1.64		
CD(P=0.05)	7.90	3.78	7.80	10.21				1.90	1.85	3.54	3.49		

TABLE 21. CORRELATION COEFFICIENTS OF PANICLES M^2 WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Maximum air temperature	P I	-0.7017*
2. Minimum air temperature	P I	-0.8717**
3. Mean relative humidity	P I + P II + P III	-0.7687**
4. Total sunshine hours	P I	0.6613*
5. Total sunshine hours	P II	0.7110*
6. Total sunshine hours	P III	0.7250*
7. Total sunshine hours	P I + P II + P III	0.7372**
8. Total solar radiation	P I	0.4191
9. Total solar radiation	P II	0.7458**
10. Total solar radiation	P III	0.9708**

TABLE 22. PARTIAL CORRELATION COEFFICIENTS BETWEEN PANICLES M^2 (1), SUNSHINE HOURS (2) AND MEAN RELATIVE HUMIDITY (3) DURING P I + P II + P III

Factor	r value
12	0.7372**
13	-0.7687**
23	-0.6485*
123	0.4903
132	-0.5054

P I - Vegetative phase
P II - Reproductive phase
P III - Ripening phase

* Significant at 5% level
** Significant at 1% level

irrigation levels both in SWM 85 and Summer 86 seasons. Panicle production was highest with 16th July planting in SWM 85 which was almost similar with 18th June planting. It decreased considerably when planting was delayed after 16th July. In Summer 86 an increase is seen from 29th January planting onwards upto 26th February, the highest being produced with 26th February planting. However, it decreased considerably with last planting done on 12th March. A progressive decrease was noticed as irrigation interval was increased. In SWM 85, continuous submergence (I_1) and one day after disappearance of water (I_2) produced similar number of panicles (395 and 393, respectively) whereas in Summer 86, I_1 resulted in production of the highest number of panicles per m^2 (479). Irrigation x planting interaction was also present in both the seasons. A similar trend as that of planting with continuous submergence i.e., I_1P_3 (16th July) in SWM 85 and I_1P_4 (26th February) in Summer 86 producing higher panicle could be observed.

It was also observed that in both the seasons plantings done either earlier or later than the optimum period with more quantity of water (I_1 or I_2) could not produce comparable number of panicles as those recorded

under lower levels of irrigation in the optimum planting period.

To study the pattern of panicle production as influenced by meteorological parameters at different phases, correlation coefficients are worked out and presented in Table 21.

Effect of meteorological parameters

1) Temperature

It is seen that panicle number bears negative association with minimum or maximum air temperature at vegetative phase. This is also supported by Fig.6 where it is seen that tiller number is more in mid July (SWM 85) and mid February (Summer 86) plantings when night temperature is lower and less in end of August (SWM 85) and mid March (Summer 86) plantings when the night temperature is higher at vegetative phase. This increase in tiller and panicle number may be attributed to the comparatively cool temperature at the base of the plant (Matsushima, 1970). The higher night temperature experienced during late August and mid March plantings must have increased the respiratory loss leading to death of many tillers (Tanaka et al., 1964).

ii) Solar energy

The importance of light energy for panicle production is clearly brought out by the correlations of sunshine hours and solar radiation during the different phases of crop growth. A significant positive correlation is obtained with sunshine hours in all the three phases and with solar radiation at later two phases. This is another probable reason for the higher number of panicles in mid July and mid February plantings. Hayashi (1972) observes that any increase in solar energy at any stage increases photosynthesis of rice plant which ultimately leads to an increase in size and function of sink. The significance of light energy in increasing the percentage of productive tillers after the maximum tillering stage has been stressed by previous workers like Rao and Deb (1975) who attribute this phenomenon to a reduction in death of late formed tillers.

iii) Relative humidity

The correlation Table 24 also brings out that panicle production is negatively correlated with mean relative humidity during the whole growth period of the crop ($r = -0.7687^{**}$) showing that low relative humidity is essential for increased panicle production. To study the effect of either sunshine hours or relative humidity

by eliminating the other factor, partial correlation coefficients were worked out and presented in Table 22. It is observed that when the effect of sunshine hours is eliminated, the correlation remains negative whereas when the effect of relative humidity is eliminated, the correlation becomes reduced and non-significant. Thus it could be suggested that panicles per m^2 may be decided combinedly by the influence of relative humidity and sunshine hours.

Thus it is seen that a combination of low night temperature at vegetative phase and a high solar radiation at reproductive and ripening phases are essential for higher number of panicles per m^2 . This view is supported by the findings of Venkateswarlu et al. (1977).

4.1.2.2. Grains per m^2

The Table 23 shows that highest number of grains per m^2 was recorded in 16th July (SWM 85) and 26th February (Summer 86) plantings. They were followed by 2nd July and 29th January plantings in the respective seasons. The lowest numbers were recorded by late August (SWM 85) and mid January (Summer 86) plantings. With regard to water management, a similar pattern of influence as of panicles per m^2 was observed.

TABLE 23. NUMBER OF GRAINS M^2 (10^4) SEASONWISE

	S.W. MONSOON, 1965							SUMMER, 1966						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	
I ₁	2.47	2.65	2.79	2.59	2.32	1.94	2.45	3.03	3.43	3.16	3.50	3.26	3.29	
I ₂	2.30	2.50	2.55	2.53	2.14	1.83	2.32	2.89	3.33	3.02	3.29	3.06	3.12	
I ₃	2.29	2.37	2.41	2.36	2.05	1.62	2.17	2.52	2.83	2.83	3.16	2.96	2.86	
I ₄	2.10	2.20	2.20	2.11	1.90	1.51	2.00	2.33	2.65	2.53	2.99	2.85	2.67	
Mean	2.31	2.43	2.48	2.40	2.10	1.73		2.69	3.06	2.89	3.23	3.03		
	P	I	P at I	I at P				P	I	P at I	I at P			
SED	0.06	0.03	0.06	0.08				0.01	0.01	0.01	0.01			
CD(P=0.05)	0.15	0.08	0.27	0.17				0.01	0.01	0.02	0.02			

TABLE 24. CORRELATION COEFFICIENTS OF GRAINS M^2 (10^4) WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Maximum air temperature	P I	0.7223*
2. Minimum temperature	P I	-0.4974
3. Minimum temperature	P II	-0.3055
4. Summation of minimum temperature	P II	-0.4873
5. Mean relative humidity	P II + P III	-0.7874**
6. Total sunshine hours	P I	0.5022
7. Total sunshine hours	P II	0.7017*
8. Total sunshine hours	P III	0.8098**
9. Total sunshine hours	P II + P III	0.8730**
10. Total solar radiation	P I	0.3848
11. Total solar radiation	P II	0.4728
12. Total solar radiation	P III	0.8072**
13. Total solar radiation	P II + P III	0.9048**

TABLE 25. PARTIAL CORRELATION COEFFICIENTS BETWEEN GRAINS M^2 (1), SUNSHINE HOURS (2) and MEAN RELATIVE HUMIDITY (3) AT P II + P III

Factor	r value
12	0.8730**
13	-0.7874**
23	-0.8051**
12.3	0.6558*
13.2	-0.2911

P I - Vegetative phase

P II - Reproductive phase

P III - Ripening phase

* - Significant at 5% level

** - Significant at 1% level

Effect of meteorological parameters

1) Temperature

The correlation coefficients worked out between grains per m^2 and different meteorological parameters at different growth phases are presented in Table 24. Maximum and minimum air temperature at vegetative phase is negatively correlated with grain number. This could be attributed to the indirect effect of low minimum temperature on the panicle number as already indicated in the correlation Table 21. This is probably one of the reasons for the higher number of grains per m^2 in 16th July (SWM 85) and 26th February (Summer 86) plantings when the minimum temperature at vegetative phase is considerably lower. Yoshida (1973) finds grain number per unit area to increase with decrease in temperature. The Table 24 also brings out that grains per m^2 is negatively correlated with minimum temperature at reproductive phase and summation of minimum temperature during the whole growth period. The low respiration loss consequent on the low night temperature during the two phases might have helped in conserving higher net photosynthesis (Anon., 1974) ultimately leading to higher grain production.

ii) Solar energy

Both sunshine hours and solar radiation during vegetative phase do not influence grain number. But solar energy received during the reproductive and ripening phases have a considerable significant bearing on grain formation (Yoshida and Parao, 1976). This could be suggested as the reason for high grain number observed in 16th and 2nd July (SWM 85) and 26th February and 29th January (Summer 86) plantings when the solar energy receipt during these phases are fairly high.

iii) Relative humidity

The relative humidity at later stages exerts a negative influence on grain number. This shows that a high relative humidity may cause reduction in grain production. The partial correlation coefficients worked out (Table 25), however, shows that when the effect of sunshine hours is eliminated the correlation becomes reduced and non-significant. Whereas, when the influence of relative humidity is eliminated, sunshine hours retains significant correlation thus indicating that relative humidity has not much influence on grain production.

4.1.2.3. Weight of panicle

The panicle weight presented in Table 26 indicate that highest panicle weight was recorded in 16th July

TABLE 26. HEIGHT OF PANICLE (C), SEASONWISE.
S.V. MONSOON, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	1.49	1.57	1.56	1.24	1.17	1.20	1.37	1.61	1.48	1.62	1.66	1.61	1.60
I ₂	1.43	1.55	1.60	1.26	1.12	1.12	1.35	1.60	1.47	1.58	1.64	1.58	1.56
I ₃	1.44	1.49	1.54	1.24	1.10	1.09	1.32	1.54	1.37	1.57	1.58	1.53	1.52
I ₃	1.27	1.45	1.50	1.14	1.08	1.08	1.29	1.52	1.29	1.50	1.57	1.50	1.48
Mean	1.41	1.52	1.55	1.22	1.12	1.12	1.36	1.57	1.39	1.57	1.61	1.56	
	P I P at I at P P I P at I at P												
SED	0.04	0.02	0.40	0.05				0.003	0.003	0.007	0.007		
CD(P=0.05)	0.09	0.05	N.S	N.S				0.006	0.007	0.016	0.015		

N.S - Not significant

TABLE 27. CORRELATION COEFFICIENTS BETWEEN HEIGHT PER PANICLE AND METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factors	Phase	r value
1. Minimum air temperature	P II	-0.6749*
2. Minimum air temperature	P III	-0.6570*
3. Total sunshine hours	P I	0.4630
4. Total sunshine hours	P II	0.6150*
5. Total sunshine hours	P III	0.6981*
6. Total solar radiation	P I	0.4759
7. Total solar radiation	P II	0.5740
8. Total solar radiation	P III	0.6078**

P I - Vegetative phase
P II - Reproductive phase
P III - Ripening phase

* - Significant at 5% level
** - Significant at 1% level

(SWM 85) and 26th February (Summer 86) plantings. Panicle weight increased from 18th June planting upto 16th July in SWM 85 which declined thereafter. Similarly in Summer 86 an increase could be seen from 29th January upto 26th February which declined with 12th March planting.

Water management practice also influence the panicle weight. The highest values are obtained with continuous submergence (I_4) or submerging one (I_2) or two (I_3) days after disappearance of water in SWM 85 whereas I_1 produced significantly heavier panicles than other irrigation treatments in Summer 85.

The correlation coefficients worked out between panicle weight and meteorological parameters at different phases are presented in Table 27. It is found that the minimum air temperature at reproductive and ripening phase is negatively correlated with panicle weight. In July (SWM 85) and February (Summer 86) plantings minimum air temperature in this phase is lowest than other plantings (Fig.6) and this is probably responsible for high panicle weight. This is supported by the data on filled grain percentage (Table 30) which is also higher in these plantings. According to Yoshida (1973) the optimum temperature shifts from high to low as growth phase advances from vegetative to ripening. With respect to

sunshine hours and solar radiation it is manifested that panicle weight is not at all related to these energy sources in vegetative and reproductive phase. But they do exert an influence on panicle weight during ripening phase. This is probably the reason for more panicle weight in the early plantings in SWM 85 and mid season plantings done during Summer 86. According to Yoshida and Ahn (1968) the accumulation of starch after flowering depends on the extent of photosynthesis. Since grain filling process starts only after flowering the photosynthesis after flowering mainly contributes to panicle weight (Tanaka and Yamaguchi, 1968) and hence the significance of these correlations.

4.1.2.4. Length of panicle

From Table 28 on length of panicle it is seen that panicles produced were longer when planted on 16th July (SWM 85) and 26th February (Summer 86). In SWM 85 all the plantings produced panicles of similar length whereas during Summer 86 each of the planting differed significantly. The shortest panicles were seen with planting done on 12th February (Summer 86).

Panicle length decreased with increase in interval between irrigations in both the seasons. However, continuous submergence (I_1) and submerging one day after

TABLE 28. PANICLE LENGTH (CM), SEASONWISE

	S.W. MONSOON, 1985						SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	18.23	17.95	18.90	18.56	18.24	18.27	18.36	18.69	20.27	18.11	20.87	19.86	19.56
I ₂	18.15	17.82	18.96	18.30	17.86	18.15	18.21	18.40	20.07	17.73	20.14	19.72	19.22
I ₃	17.86	17.09	18.42	17.89	17.63	17.60	17.75	18.17	19.87	16.26	19.86	19.53	18.74
I ₄	17.18	16.95	18.07	17.38	17.04	17.23	17.31	18.00	19.55	15.88	19.57	19.46	18.49
Mean	17.86	17.45	18.59	18.03	17.69	17.81		18.32	19.94	16.99	20.11	19.64	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	0.51	0.40	0.23	0.51				0.06	0.03	0.08	0.09		
CD (P=0.05)	N.S	N.S	N.S	N.S	N.S			0.13	0.73	0.17	0.19		

N.S - Not significant

disappearance of water (I_2) produced panicles of similar length in SWM 85. The panicles were lengthy with I_1 in Summer 86. Interaction between irrigation and planting period was present in Summer 86 wherein I_1P_4 (26th February) produced longest panicles.

4.1.2.5. Number of filled grain per panicle

The data presented in Table 29 on number of filled grains show that there was not much variation with respect to planting period during SWM 85. Plantings done during July produced more number of filled grains compared to June or August plantings. The filled grain decreased considerably with the last plantings. Whereas, in Summer 86 the filled grain number was affected by different planting periods. The highest number was seen with 29th January followed by 26th February planting. A decrease in filled grain number was noticed with very early or late plantings.

A significant difference in number of filled grains with water management could be observed in both the seasons. During SWM 85 I_1 or I_2 produced more and comparable number of panicles than the other two irrigation levels. Whereas, in Summer 86 all the irrigation levels differed and I_1 resulted in production of highest number of filled grains per panicle. A reduction of about 2, 8 and 12 per cent

TABLE 29. NUMBER OF FILLED RAINS FOR PAPULA, SEASONWISE

S. W. HUNTER, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	60.33	65.18	66.21	64.05	61.20	55.24	62.04	64.83	73.80	65.77	69.70	68.07	68.63
I ₂	58.87	62.51	61.08	62.84	55.67	53.03	59.00	63.07	73.57	65.30	68.20	66.27	67.28
I ₃	57.31	59.40	58.78	59.78	54.77	48.74	56.46	56.40	65.87	62.30	66.93	65.40	65.38
I ₄	53.40	56.94	56.08	54.59	53.07	46.34	53.40	52.97	63.23	57.07	64.70	64.30	60.45
Mean	57.48	61.01	60.54	60.32	56.18	50.84		59.32	62.12	62.66	67.38	66.01	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	3.21	1.33	1.91	3.58				0.27	0.18	0.40	0.44		
LD (P=0.05)	7.15	3.26	4.08	7.84				0.61	0.43	0.85	0.94		

in the number of filled grains panicle⁻¹ was observed when irrigation was scheduled one, two or three days after disappearance of water as compared to continuous submergence. The interaction between irrigation and planting period were present during both the seasons. Continuous submergence with plantings done on 16th and 2nd July (SWM 85) produced the highest number of filled grains. Planting done on 26th February (Summer 86) resulted in production of more number of filled grains than other plantings with any one of the irrigation levels.

4.1.2.6. Percentage of filled grains

From Table 30 it is evident that percentage of filled grains during SWM 85 was highest with 2nd July and was similar upto the mid August plantings. A general picture available is that the percentage decreased when plantings were advanced or delayed from 2nd July, the more the delay higher was the decline in percentage. The prevalence of high day temperature and cloudy weather with shorter hours of sunshine during the November-December (ripening period) contributed to increased sterility in the crops planted during August. In Summer 86, 26th February planted crop produced significantly the highest percentage followed by 29th January planting. Crop planted on mid January gave the lowest

TABLE 30. PERCENTAGE OF FILLED GRAINS - SEASONWISE

	S.W. MONSOON, 1905							SUMMER, 1986					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	83.07	84.14	84.01	82.33	83.14	81.20	82.98	86.10	89.17	89.47	89.10	87.53	88.07
I ₂	82.67	83.36	83.18	81.62	82.28	77.97	81.81	85.23	89.43	87.40	88.10	86.63	87.26
I ₃	80.77	81.00	80.93	79.56	80.21	74.82	79.55	82.87	84.57	86.57	87.00	85.73	85.35
I ₄	79.35	80.02	78.06	76.19	78.27	74.01	77.65	81.20	82.57	80.93	86.03	85.20	83.19
Mean	81.47	82.13	81.55	79.93	80.98	76.95		83.85	86.31	85.84	87.56	86.28	
	P	I	P at I I at P					P	I	P at I I at P			
SED	1.42	0.50	0.84	1.60				0.68	0.58	1.24	1.26		
CD(P=0.05)	3.16	1.21	N.S	N.S				1.56	1.41	2.66	2.69		

N.S - Not significant

TABLE 31. CORRELATION COEFFICIENTS OF PERCENTAGE OF FILLED GRAINS WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum temperature	P II	-0.6810*
2. Minimum temperature	P III	-0.7245*
3. Mean relative humidity	P II + P III	-0.7211*
4. Total sunshine hours	P I	0.4756
5. Total sunshine hours	P II + P III	0.8082**
6. Total solar radiation	P I	0.2608
7. Total solar radiation	P II	0.6629*
8. Total solar radiation	P III	0.9053**

P I - Vegetative phase
 P II - Reproductive phase
 P III - Ripening phase
 * - Significant at 5% level
 ** - Significant at 1% level

TABLE 32. PARTIAL CORRELATION COEFFICIENTS BETWEEN PERCENTAGE FILLED GRAINS (1) SUNSHINE HOURS (2) AND MEAN RELATIVE HUMIDITY (3) AT P II + P III

Factor	r value
12	0.8082**
13	-0.7211*
23	-0.6055*
12.3	0.6739*
13.2	-0.4943

P II - Reproductive phase
 P III - Ripening phase
 * - Significant at 5% level
 ** - Significant at 1% level

percentage of filled grains. Water management influenced the fertility in both the seasons. Continuous submergence (I_1) or submerging one day after disappearance of water (I_2) produced higher and comparable percentage than other two irrigation levels in both SWM 85 and Summer 86 seasons. A steady decrease could be noticed as interval of soil drying increased between two irrigations from one to three days. The interaction was present during Summer 86 wherein planting done on 26th February with any one of the irrigation produced more percentage of filled grains.

Correlation coefficients presented in Table 34 indicate that percentage of filled grains is negatively related to minimum temperature during reproductive and ripening phases. This may possibly be due to the fact that accumulation of starch in the leaves and culms begins about ten days before flowering and starch accumulates in the grain after flowering (Murata, 1966) and lower the temperature during this period, the lesser the respiration losses and higher the net photosynthesis (Tanaka et al., 1964).

The r value increases with maturity thereby showing that minimum temperature is more important at ripening phase in reducing sterility or increasing fertility. The low minimum air temperature during early

July (SWM 85) and late February (Summer 86) might have been responsible for the high filled grain percentage. Higher minimum temperature in combination with low light intensity have been reported to seriously impair ripening (Hayashi, 1972) because grain weight and percentage filled grains were greatly affected by light and temperature.

Mean temperature prevalent at the flowering stage has also influenced fertility percentage. This is in agreement with the observations of Lin and Peterson (1975).

Solar energy sources do not have any effect on filled grain percentage during vegetative phase. But at later phases they show a profound effect by solar radiation during ripening and by sunshine hours at reproductive and ripening phases. This could be the probable reason for the fairly high filled grain percentage during early July plantings in SWM 85 and 26th February and 29th January plantings in Summer 86, when sunshine hours are high. Luo et al. (1979) have demonstrated that high solar energy increases percentage of filled grains. Furthermore the rate of translocation of rice crop is about twice as high as in the presence of light as in darkness (Matsushima, 1975).

According to Togari and Kashiwakura (1958) sterility under low light is caused by inhibition of pollination and

abnormal behaviour of filaments at flowering bringing a decreased seed setting rate. Matsushima (1970) is of the opinion that cloudy weather or rainy weather occurring at the reduction division stage is the factor most closely connected with the degeneration of spikelets. As per Yoshida and Parao (1976) filled grain percentage appears to be determined by (a) source activity relative to sink (spikelet number) size, (b) ability of grains to accept carbohydrate, and (c) translocation of assimilates from leaves to grain. Climatic factors affect each of them in different ways. Solar radiation appears to affect grain filling and hence filled grain percentage mainly by controlling source activity and, within moderate range of temperature, appears to affect filled grain percentage mainly by controlling the capacity of grains to accept carbohydrate, or length of growing period. The length of ripening period is inversely correlated with daily mean temperature (Yamakawa, 1962).

It is also seen that when mean relative humidity at reproductive and ripening phases is more the fertility is low or sterility is high. The partial correlation coefficients worked out (Table 32) on filled grain percentage with sunshine hours and relative humidity show that r value for relative humidity becomes reduced and non-significant and as such is not related to fertility.

4.1.2.7. Thousand grain weight

The data presented on thousand grain weight (Table 33) show that the planting means apparently do not differ during SWM 85, whereas they affect test weight during Summer 86. The highest thousand grain weight was noticed with 16th July followed by 18th June plantings in SWM 85 and 26th February followed by the two January plantings in Summer 86. With regards to water management, a decline in test weight due to irrigation intervals could be noticed, the decrease being more in Summer 86 than in SWM 85. Continuous submergence (I₁) or submerging one day after disappearance of water (I₂) gave rise to higher and similar grain weight in SWM 85 whereas I₁ was found to be producing significantly more grain weight in Summer 86. The irrigation x planting interaction present in Summer 86 shows that I₁P₄ (26 February) produced heavier grains .

The correlation coefficients worked out between thousand grain weight and meteorological parameters presented in Table 34 do not show any significant correlations. This may be because the variation is not strictly in accordance with the change in climatic conditions during the different planting periods.

TABLE 33. THOUSAND GRAIN WEIGHT (G), SEASONWISE

	E.W. MONSOON							SUMMER, 1986					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	20.16	20.06	20.56	20.36	20.27	19.99	20.23	20.64	20.65	20.20	21.02	19.92	20.49
I ₂	20.11	20.19	20.61	19.90	19.89	19.83	20.09	20.47	20.39	20.27	20.43	19.87	20.29
I ₃	20.04	20.11	20.57	20.01	19.73	19.65	20.02	19.63	19.93	19.91	20.19	19.80	19.94
I ₄	19.62	20.03	20.36	19.92	19.60	19.42	19.97	19.73	19.82	19.72	19.87	19.75	19.83
Mean	20.13	20.10	20.53	20.05	19.87	19.72		20.20	20.20	20.09	20.36	19.84	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	0.23	0.95	0.19	0.28				0.10	0.07	0.18	0.19		
CD(P=0.05)	0.51	0.23	N.S	N.S				0.23	0.18	0.38	0.40		

N.S - Not significant

TABLE 34. CORRELATION COEFFICIENTS OF 1,000 GRAIN WEIGHT WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P I	-0.1840
2. Minimum air temperature	P II	-0.2140
3. Minimum air temperature	P III	-0.4520
4. Total sunshine hours	P I	0.1321
5. Total sunshine hours	P II	0.2135
6. Total sunshine hours	P III	0.3951
7. Total solar radiation	P I	0.1853
8. Total solar radiation	P II	0.4001
9. Total solar radiation	P III	0.4757

P I - Vegetative phase
P II - Reproductive phase
P III - Ripening phase

Thornely (1971) proposes that the substrate required for growth may be partitioned in three ways, part into the final product, part into respiration to supply the energy needed to form the final product and part into the respiration required for cell maintenance. Due to the limited availability of water under I_2 to I_4 and resultant low photosynthesis the substrate is limited and it is possible that an increase in maintenance respiration, with increasing temperature (Fig.6) might limit the amount of substrate available for growth. This could be ascribed as the reason for low thousand grain weight noticed under late August plantings in SWM 85 and mid March planting in Summer 86.

4.1.2.8. Degree of ripening

The degree of ripening is the product of percentage of ripened grains and thousand grain weight (Osada et al., 1973).

The correlation Table 35 shows that the degree of ripening is related to yield and yield attributes at a very high level.

There is a greater association of degree of ripening with most of the meteorological parameters (Table 36) than with percentage of filled grains (Table 31)

TABLE 35. CORRELATION COEFFICIENTS OF DEGREE OF RIPENING WITH YIELD AND YIELD ATTRIBUTES

Factor	r value
1. Grain yield	0.9383**
2. Panicles m^{-2}	0.9335**
3. Grains m^{-2}	0.9641**
4. Weight panicle ⁻¹	0.8589**
5. Fertility percentage	0.9673**
6. Thousand grain weight	0.3601
7. LAI	0.0236

** - Significant at 1% level

TABLE 36. CORRELATION COEFFICIENTS OF DEGREE OF RIPENING WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P II	-0.6329*
2. Minimum air temperature	P III	-0.7361*
3. Total sunshine hours	P II	0.8449**
4. Total sunshine hours	P III	0.7570**
5. Total sunshine hours	P II + P III	0.8150**
6. Total solar radiation	P II + P III	0.9021**
7. Total solar radiation	P II	0.6552*
8. Total solar radiation	P III	0.9117**
9. Mean relative humidity	P II + P III	-0.7211*

* - Significant at 5% level

** - Significant at 1% level

P II - Reproductive phase

P III - Ripening phase

or with thousand grain weight (Table 34). This explains that some of the variations in yield obtained under different meteorological conditions are attributable to variations in degree of ripening. Thus the degree of ripening may as well serve as a major yield attribute determining the yield.

The Fig.9 shows that degree of ripening is highest in 16th July (SWM 85) and 26th February (Summer 86) plantings followed by 2nd July and 29th January of 12th February plantings during these seasons, respectively. The lowest degree of ripening is recorded when planted in late August (SWM 85) or mid January (Summer 86).

The minimum air temperature at later two phases is strongly correlated with this character (Table 36). The minimum temperature at ripening phase is much more related to degree of ripening than at reproductive phase. In 16th July and 26th February plantings minimum air temperature during these two phases are lower than other plantings. Yoshida and Hara (1977) have shown that optimum daily mean temperature to achieve maximum weight of grain was 19-25°C for IR 20 rice indicating the importance of low minimum temperature in grain filling. The relatively high degree of ripening obtained in 2nd July (SWM 85) or 29th January/12th February (Summer 86)

may be attributed to the effect of high sunshine hours and solar radiation received during the reproductive and ripening phases even though the minimum temperature is high. Thus the unfavourable effect of temperature is more than compensated by the most favourable influence of sunshine hours and solar radiation during the period of ripening.

Another most striking feature that could be identified from Table 37 is the ratio between sunshine hours and minimum temperature which shows a comparatively high value for 16th July and 26th February plantings.

TABLE 37. DEGREE OF RIPENING AS INFLUENCED BY METEOROLOGICAL CONDITIONS DURING RIPENING PHASE

Planting date	Average sunshine (hrs)	Minimum temp. (°C)	SSH Min. temp. ratio	Ripened grain (%)	1000 grain wt(g)	Degree of ripening
18-6-1985	5.98	22.14	0.27	81.5	20.1	16.38
2-7-1985	7.01	22.13	0.32	82.3	20.1	16.54
16-7-1985	7.35	21.18	0.35	81.6	20.5	16.73
30-7-1985	7.41	21.73	0.34	79.9	20.0	15.98
13-8-1985	5.69	21.37	0.27	81.0	19.9	16.12
27-8-1985	5.36	22.69	0.24	71.0	19.7	15.17
15-1-1986	9.96	22.13	0.45	83.9	20.0	16.78
29-1-1986	10.09	22.51	0.45	86.3	24.0	17.26
12-2-1986	8.64	20.88	0.41	85.8	20.0	17.16
26-2-1986	9.54	20.57	0.46	87.6	20.2	17.70
12-3-1986	8.92	22.15	0.40	86.3	19.8	17.09

This is due to low minimum temperature and high sunshine hours during the period providing most congenial condition for the proper ripening of grains.

With high solar energy receipt, maximum photosynthesis takes place and under low minimum temperature less respiration losses and maximum conversion of assimilates (Sato et al., 1973) result. Even though a high night temperature is observed in mid August or early January plantings the photosynthesis taking place during day consequent on high solar energy more than compensates for the respiration losses during night (Moss et al., 1961). During late August (SNM 85) or mid March (Summer 86) lower degree of ripening is observed because under complex conditions of low light intensity and high temperature ripening is most adversely affected (Matsushima, 1957 and Hayashi, 1972).

The correlation Table 36 also brings out that degree of ripening is negatively correlated ($r = -0.7211^*$) with mean relative humidity during reproductive and ripening phases. But the partial correlation coefficients worked out (Table 36) shows that when the influence of sunshine hours during these phases is eliminated the correlation of degree of ripening with relative humidity becomes reduced and non-significant. Whereas, even after

removing the effect of relative humidity, the correlation of degree of ripening with sunshine hours still retains a significant value. This shows that relative humidity as such has no apparent influence on degree of ripening.

TABLE 38. PARTIAL CORRELATION COEFFICIENTS BETWEEN DEGREE OF RIPENING (1), SUNSHINE HOURS, (2) AND MEAN RELATIVE HUMIDITY (3) AT REPRODUCTIVE AND RIPENING PHASES

Factor	r value
12	0.8150**
13	-0.7211*
23	-0.6055*
12.3	0.6863*
13.2	-0.4935

* - Significant at 5% level
 ** - Significant at 1% level

4.1.2.9. Grain yield

4.1.2.9.1. Response to planting period

The grain yield data are presented in Table 39 and depicted in Fig.9. Transplantings done on 16th July and 26th February gave the highest yields during SWM 85 and Summer 86, respectively. This is followed by 2nd July (SWM 85) and 12th February (Summer 86) plantings. The lowest yields are recorded when planted either on 27th August in SWM 85 or on 29th January in Summer 86.

TABLE 39. GRAIN YIELD (KG HA⁻¹), SEASONWISE

S.W. MONSOON, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean		
I ₁	5666	5771	6199	5808	4974	4286	5451	6021	5961	6351	6528	6243	6219		
I ₂	5586	5726	6009	5542	4876	4291	5338	5928	5828	6173	6378	6175	6096		
I ₃	5496	5470	5827	5239	4918	4294	5208	5818	5715	6000	6206	6020	5952		
I ₄	5175	5200	5573	5132	4760	4179	4998	5733	5648	5888	5997	5662	5789		
Mean	5481	5542	5902	5430	4881	4263		5875	5788	6103	6275	6025			
	P						I						P at I at P		
SED	68.82						52.48						84.00		92.79
CD	153.34						130.41						184.81		198.97

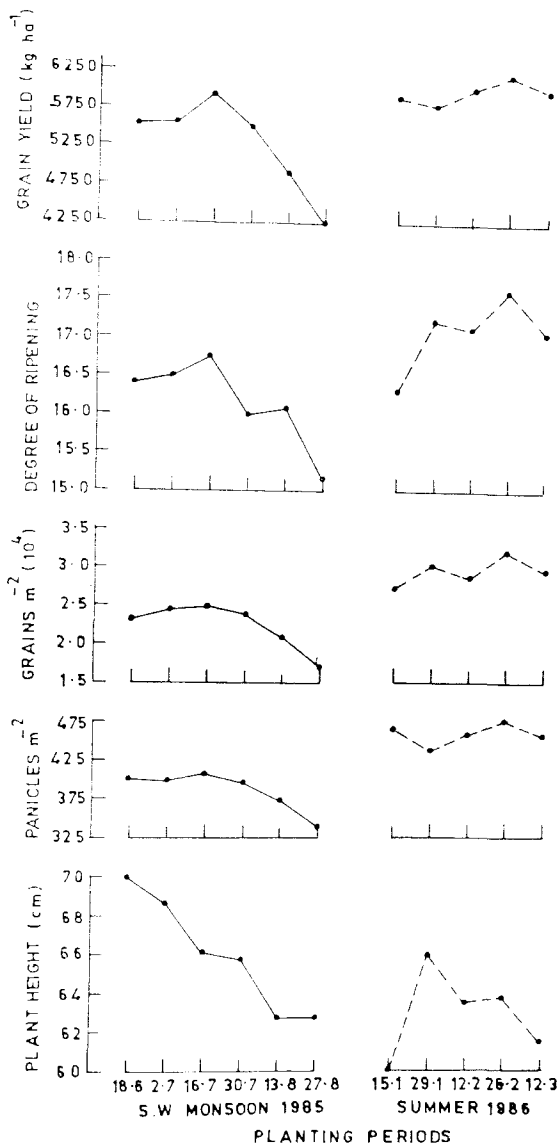


FIG. 9 GRAIN YIELD (kg ha^{-1}) IN RELATION TO GROWTH AND YIELD ATTRIBUTES UNDER DIFFERENT PLANTING PERIODS

The results obtained may be explained in view of the performances of various growth and yield attributes discussed earlier and the correlation coefficient (Table 40). Observations made on plant height (Table 8) have shown that the height was lowest in August plantings during SWM 85 and 15th January planting in Summer 86. The highest height was recorded with plantings made on 18th June and 29th January in the respective seasons. An increase in height leads to mutual shading and greater respiration loss leading to reduced net photosynthesis and grain yield. Comparatively higher LAI at flowering displayed by the planting periods of SWM 85 might have also caused more mutual shading and impaired the yield.

From Table 20 on panicles it could be seen that panicles are lowest in the two August (SWM 85) and 29th January (Summer 86) plantings and are highest when plantings were done on 16th July (SWM 85) and 26th February (Summer 86). 18th June and 12th February plantings also recorded a much higher number of panicles than plantings made on August or late January. Since panicle number (Table 40) is one of the important yield attributes having a significant positive influence on yield ($r = 0.9299^{**}$) this character must be primarily responsible for the grain

yield differences noticed in different plantings. Hence grain yield data follows more or less the same pattern as this character.

TABLE 40. CORRELATION COEFFICIENT OF GRAIN YIELD WITH GROWTH AND YIELD ATTRIBUTES

Factor	r value
1. Panicles per m ²	0.9299**
2. Grains per m ²	0.8170**
3. Weight of panicle	0.8267**
4. Fertility percentage	0.8674**
5. 1000 grain weight	0.4907
6. Degree of ripening	0.9383**
7. Dry matter production at harvest	0.6249*
8. LAI at flowering	0.8327**

Another important yield attribute i.e., grains per m² also follows the same trend as that of panicles per m² and influence the yield of different plantings in the same manner. Its positive correlation with grain yield is also quite high ($r = 0.8170^{**}$).

Based on the high correlations obtained between yield and panicles per m² and grains per m² the following explanation holds good for variations in yield obtained under different planting periods.

Theoretically, a high yield of cereal is realised only after, (i) the plant development has been carried out favourably enough to have sufficiently large potential storage capacity, (ii) the assimilates have been abundantly produced, and finally (iii) they have been smoothly translocated to the grain (Murata and Togari, 1973). In the case of rice plants, the grain is rigidly enclosed by inner and outer glumes which impose a physical restriction on grain development. Because, size of glume is decided already one week before the start of endosperm development (Matsushima, 1957) it must be considered, therefore, that the potential storage capacity of rice is determined by the two factors i.e., the total number of grains per m^2 and the size of each hull. According to Matsushima (1957), grains per m^2 is determined by the balance between the number of generated grains and that of degenerated ones. Judging from the time sequence of events, various inner and outer conditions which are effective for preventing degeneration, must also be effective for increasing the hull size. The fact that there exists a correlation, significant at 1 per cent level in cases of panicles per m^2 and grains per m^2 , indicates that the first factor responsible for determining grain yield of rice is most probably the potential storage capacity.

However, 1000 grain weight does not vary much between different plantings (Table 33). Its correlation with yield is also not significant (Table 40). From the Table 33 it could be seen that in 16th July and 26th February plantings comparatively a higher 1000 grain weight is observed due to favourable ripening conditions. The picture is more or less the same with weight per panicle (Table 26) in these plantings. All these might have contributed to higher yield in the above plantings.

Table 30 shows that fertility is high (in other words sterility is low) in 2nd July (SWN 85) and February (Summer 86) plantings followed by 16th July and 12th March plantings in these respective seasons. The degree of ripening (Table 37) is also the highest in them. The degree of ripening and fertility percentage show a strong positive association with grain yield giving r values of 0.9383** and 0.8674**, respectively. The higher yield resulted by plantings made on 16th July or 26th February might have also been influenced by these characters to a considerable extent.

The correlation Table 40 shows that there exists a higher positive correlation between grain yield and degree of ripening ($r = 0.9382^{**}$) than in case of each

of the other factor alone. As already mentioned, panicles per m^2 and grains per m^2 also showed positive correlations with yield. However, they were of lesser magnitude than in case of degree of ripening. Thus it could be suggested that the yield of crops under different plantings were governed mainly by the degree of ripening.

A perusal of data on DMP at flowering and harvest (Table 14) show that post-flowering DMP is comparatively higher in mid July in SWM 85 and highest in 26th February planting in Summer 86. Yield also records a positive correlation with DMP at harvest ($r = 0.6249^*$) as seen in Table 40. As already explained the favourable weather conditions during the reproductive and ripening phases of these plantings must have helped in enhanced post flowering DMP which in turn must have contributed to high grain yield, since according to Tanaka et al. (1966) post flowering increase in dry matter is primarily in the form of grain.

This may be due to that in these experiments plants were grown under fertilizer conditions with the three major nutrient elements at $100:50:50 \text{ kg ha}^{-1}$, respectively. That yield is limited by ripening rather than number of grains is often seen when plants produced

spikelets more than a certain extent by applying enough fertilizer or by other measures (Murata, 1969 and Osada et al., 1973).

Thus it is seen that mid July plantings in SWM 85 and February planted crops in Summer 86 have given higher yield than early or late plantings. Rajagopalan et al. (1973) report plantings done on 15th July and 15th February resulted in highest grain yield for IR 8 under Coimbatore conditions. Subbiah (1976) also observes significantly high yield with February plantings. Mandal (1970) has reported that when plantings are done in kharif season such a way that their ripening period coincides with high solar radiation, higher yields could be expected.

4.1.2.9.2. Response to water management

The data presented in Table 39 and Fig.10 show that by and large continuous submergence was necessary to get higher yields in all the plantings. A reduction of about 2.19, 4.46 and 8.31 per cent in yield due to irrigations done at one (I_2), two (I_3) or three (I_4) days after disappearance of water compared to continuous submergence (I_1) was noticed during SWM 85. In Summer 86 the differences were 1.98, 4.29 and 5.96 per cent. The reduction in grain yield may be due to moisture stress at a time during 20 days before and 10 days after heading (Matsushima, 1962)

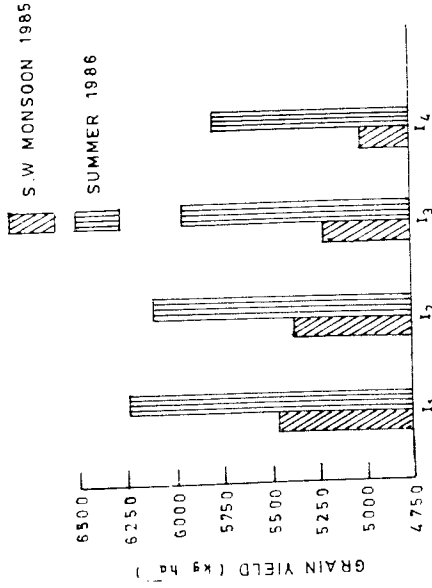


FIG. 10 GRAIN YIELD (kg ha⁻¹) IN RELATION TO WATER MANAGEMENT (MEAN OF ALL PLANTINGS)

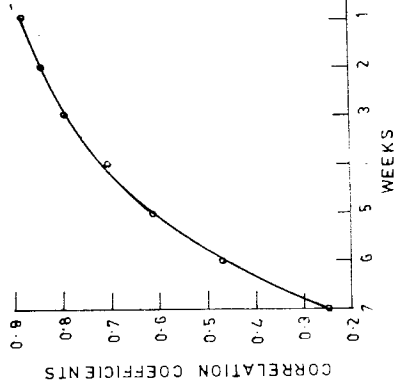


FIG. 11 CORRELATION COEFFICIENTS OF GRAIN YIELD WITH WEEKLY SOLAR RADIATION TOTALS FROM SEVEN WEEKS BEFORE HARVEST

due to the frequent soil drirage which is the peak period of water requirement and as a result of high atmospheric evaporative demand and imbalance of soil moisture stress under the lower irrigation levels. That soil moisture stress depresses the rate of photosynthesis more than of respiration (De Datta et al., 1973) and affects the crop yield (Ghildyal and Jana, 1967) is an established fact. The yield reduction with the irrigation regimes I_3 or I_4 in SWM 85 and I_2 to I_4 in Summer 86 is a reflection of the impairment in the growth components since the plant growth and yield attributes LAI, panicles per m^2 , grains per m^2 etc., which exhibited positive and significant correlation with grain yield showed reduction under these irrigation regimes. The rice crop response to water stress at vegetative phase has been reported primarily in terms of reduced plant height, tillers and leaf area (IRRI, 1975) while at a more sensitive reproductive stage like flowering due to I_4 level high sterility resulted in the greatest reduction in grain yield (Matsushima, 1968). It may also be pointed out that Tomar and Ghildyal (1975) observe that resistance to water transport in non-flooded rice plant (0.3 atm) was nearly twice as high as in flooded plants. Evidently in this study the irrigation regimes of submerging two or three days after disappearance of water (I_3 or I_4) was not able to fully meet the water

need necessitated during the critical period for primordial initiation and development especially during Summer 86 leading to reduced panicles per m^2 , shorter panicles and lesser number of grains per panicle culminating in reduced grain yield.

A perusal of Table 47 on quantity of water consumed for all plantings together and irrigation levels alone it could be seen that continuous submergence required 1524 mm followed by 976, 839 and 752 mm of water under I_2 , I_3 and I_4 irrigation levels, respectively, during SWM 85. The figures for the respective irrigation levels during Summer 86 were 1681, 1131, 959 and 829 mm.

Since the grain yields obtained under the irrigation regimes of I_4 and I_2 are similar in SWM 85 and because a reduction of 36 per cent in water could be obtained by scheduling irrigation one day after disappearance of water (I_2) and considering the economy in irrigation water, it can be suggested that irrigation can be resorted to one day after disappearance of water in SWM 85. The planting x irrigation interaction was significant in both the seasons. Planting done on 16th July either with continuous submergence (I_4) or submerging one day after disappearance of water (I_2) produced the highest grain yield during SWM 85. This was followed by planting done on 30th July together

with I_1 level of irrigation. During Summer 86, 26th February planting under continuous submergence (I_1) was found to give the highest yield than other combinations. This was followed by I_2 with the same planting.

4.1.2.9.3. Effect of meteorological parameters

Plant height, plant weight or leaf expansion were affected by temperature as already discussed in this chapter. In general influence of climatic factors during vegetative growth or preheading stage on these morphological characters, tillering or spikelet formation must exert upon grain production. However, in this experiment no appreciable relation between grain yield and climatic factors during vegetative stage could be found.

In general the influence of climatic factors on grain yield may be considered in the following two phases: (1) the influence upon the establishment of "yield production system" upto heading (flowering stage), and (2) the influence upon the "operation efficiency" of the established system during the grain filling period. It is mainly in the second phase that the climatic factors give direct effect upon grain yield.

1) Temperature

The correlation Table 41 shows that grain yield records a negative association with minimum air temperature

TABLE 41. CORRELATION COEFFICIENTS OF GRAIN YIELD WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P I	-0.6910*
2. Minimum air temperature	P III	-0.6143*
3. Minimum air temperature	P I + P II + P III	-0.6247*
4. Maximum air temperature	P III	0.6327*
5. Mean relative humidity	P II + P III	-0.7554**
6. Mean relative humidity	P I + P II + P III	-0.8246**
7. Total sunshine hours	P I	0.6008
8. Total sunshine hours	P II	0.6584*
9. Total sunshine hours	P III	0.7406**
10. Total sunshine hours	P I + P II + P III	0.6470
11. Total sunshine hours	P II + P III	0.8216**
12. Total solar radiation	P II	0.6830*
13. Total solar radiation	P III	0.9296**
14. Total solar radiation	P II + P III	0.8784**

P I - Vegetative phase

P II - Reproductive phase

P III - Ripening phase

* - Significant at 5% level

** - Significant at 1% level

at vegetative phase. The low minimum temperature during this phase influences grain yield indirectly by increasing the panicles as already explained. The low night temperature at later phases influences the panicle number and produce more spikelets by preventing the death of panicles initiated tillers (Yoshida, 1973). The high DMF at harvest is also favoured by cool nights by preventing the excessive respiration and conserving maximum photosynthates. This effect of low night temperature is manifested on other yield components such as filled grain percentage, panicle weight and degree of ripening. This is probably the reason for high yields in 16th July (SWM 85) and February (Summer 86) plantings. Moreover the low temperature during the ripening period prolongs the ripening phase (Tanaka et al., 1966) which in turn increases the amount of solar radiation received by the crop resulting in a higher yield.

In 2nd July (SWM 85) and 12th March (Summer 86) even though high night temperature is experienced at reproductive and ripening phases the grain yield is comparatively high because under conditions of high solar radiation receipts during this period, photosynthesis during day time more than compensates the respiration losses during night due to high minimum temperature. The table 41 also shows that the grain yield is negatively

correlated with minimum temperature during ripening phase. According to Matsushima and Kanaka (1957) an optimum temperature for ripening on the ripening stage seems to be approximately 22°C and higher temperature than 25°C bring about unfavourable effects on ripening of the rice grain. The rate of translocation of carbohydrate increases with temperature upto about 25°C, but it seems to keep almost constant in higher temperatures (Matsushima and Wada, 1959). It is reported that within 17-30°C, lower the temperature, the higher the grain weight (Suzuki et al., 1966). Very high temperature also brings out disturbances of starch accumulation (Ebata and Nagato, 1967) or deterioration of grain quality (Nagato and Ebata, 1965). These studies indicate that high temperature has unfavourable influence on yield of rice and the optimum temperature for grain production in indica rice seems to be around 22°C.

ii) Relative humidity

Grain yield is negatively correlated with relative humidity during the entire growth period or reproductive and ripening phases. However, the partial correlation Table 42 shows a negative association between relative humidity and sunshine hours during the reproductive and ripening phases taken together ($r = -0.6473^*$). The negative

effect of relative humidity on yield may be due to its indirect effect of sunshine hours on yield. Since relative humidity is inversely related to sunshine hours, cloudy days being more humid than bright days, sunshine hours gives better correlation with yield than relative humidity. The humidity of the atmosphere influences the rate of transpiration. The increased or decreased transpiration may influence the physiological processes affecting the yield. Chidyal and Jana (1967) observe similar negative influence on yield with relative humidity and they conclude that lower relative humidity is one of the agro-meteorological factors for maximum rice production.

However, in the present investigation the partial correlation coefficients worked out (Table 42) shows that when the effect of sunshine is eliminated, the coefficient value of relative humidity is reduced to a low, negative and non-significant level. At the same time even after removing the influence of relative humidity, the association between grain yield and sunshine hours still retains a positive significant value.

TABLE 42. PARTIAL CORRELATION COEFFICIENT OF GRAIN YIELD (1) WITH SOLAR RADIATION (2) AND MEAN RELATIVE HUMIDITY (3) AT REPRODUCTIVE AND RIPENING PHASES

Factor	r value
12	0.8669**
13	-0.7534**
23	-0.6473*
12.3	0.7562*
13.2	-0.5062

Tables 25, 32 and 38 also show same effect in the case of yield components like grains per m^2 , fertility percentage and degree of ripening. Thus it is seen that the influence of relative humidity on growth and yield components and yield are confounded by the effects of solar energy. Therefore no significance need be attributed to the negative correlation of these characters with relative humidity.

iii) Solar energy

Grain yield is related to the solar energy sources from the early phase onwards upto harvest (Table 41).

The preflowering accumulation of carbohydrates becomes very active about four weeks before heading according to the results of Soga and Zozaki (1957). As

for after heading period the production of assimilates to be translocated to the grain is generally most active during the four weeks or so after heading and its amount is most heavily dependent on solar radiation during the same period (Moomaw et al., 1967; Munakata et al., 1967 and Tanaka and Vergara, 1967). Since a major portion of grain carbohydrates comes from current photosynthesis during the ripening period (Yoshida, 1972) it is obvious that active photosynthesis during that period is important. These may be the main reasons why solar radiation during the ripening phase as a single weather factor showed highest correlation with yield ($r = 0.9296^{**}$).

It has already been shown that panicle number is significantly related to sunshine hours at vegetative phase and it is presumed that this has reflected on grain yield. During reproductive and ripening phases the correlations are much more pronounced than at vegetative phase. A perusal of correlation tables on panicles per m^2 (Table 21) and filled grain percentage (Table 31) will reveal that these characters have been influenced by these energy sources at the later phases.

Sunlight do not generally becomes a limiting factor on the growth of rice in the early stages (Yoshida and Parao, 1976). As the plants grow older and produce more

leaves the light level becomes progressively more critical. This is probably the reason for greater relationship of grain yield with sunshine hours and solar radiation at later phases. During the reproductive phase solar radiation affects grain number m^{-2} and during ripening it affects filled grain percentage.

Experiments conducted at INRI, however, show that correlations were recorded between solar energy total for the last 45 days before harvest and DMF for that period (De Datta et al., 1968). This period corresponds to panicle initiation to maturity stage. Since photosynthesis for grain production is also important for the period between panicle initiation and heading (Murata, 1966) high correlation value for grain yield response to solar energy total during the reproductive and ripening period together ($r = 0.8784^{**}$) are understandable. Evans and De Datta (1979) conclude that seasonal variation in irradiance amounts for much of variation in grain yield with time of planting, that this is expressed most clearly under high irradiance conditions and that yield of rice crop appears to be responsive to periods of high irradiance at any time after panicle initiation.

The Fig.8 on solar radiation received during reproductive and ripening phases indicates that crops

planted in July (Summer 85) and February (Summer 86) usually pass through these phases under progressively increasing irradiance whereas August (Summer 85) and January (Summer 86) planting with falling irradiance. Thus the increase in grain yield obtained in 16th July and 26th February plantings must be mainly attributed to these meteorological factors discussed above.

Another factor of importance that comes out of the Table 41 is that maximum air temperature at ripening phase is positively correlated with grain yield. Normally in periods where solar radiation is high the temperature will also be high. In order to prove whether the yield is related to maximum temperature at ripening phase or not, partial correlation coefficients are worked out and presented in Table 43.

TABLE 43. PARTIAL CORRELATION COEFFICIENTS BETWEEN GRAIN YIELD (1), SOLAR RADIATION (2) AND MAXIMUM AIR TEMPERATURE (3) DURING RIPENING PHASE

Factor	r value
12	0.9296**
13	0.6327*
23	0.5617
12.3	0.8962**
13.2	0.3552

* - Significant at 5% level
 ** - Significant at 1% level

It is seen that when effect of solar radiation is eliminated, the effect of maximum temperature is reduced to non-significant level. This shows that yield is not at all related to maximum temperature at ripening phase. De Datta (1970) obtains similar result at INRI where the effect of solar radiation has masked the influence of maximum temperature during reproductive and ripening phases. In order to determine at which stage of the reproductive and ripening phase the receipt of solar radiation is most critical, the solar radiation totals are calculated at weekly intervals for the seven week period before harvest and the correlation of the grain yield with these weekly totals of solar radiation are presented in Table 44. The r values (Y axis) and weekly intervals (X axis) are plotted in Fig.11.

TABLE 44. CORRELATION COEFFICIENTS OF GRAIN YIELD WITH SOLAR RADIATION TOTAL AT WEEKLY INTERVALS FROM HARVEST TO SEVEN WEEKS BEFORE HARVEST (WBH)

	Stage	r value
1. Solar radiation	1 WBH	0.8718**
2. "	2 WBH	0.8033**
3. "	3 WBH	0.7896**
4. "	4 WBH	0.6807*
5. "	5 WBH	0.6325*
6. "	6 WBH	0.3171
7. "	7 WBH	0.2385

It could be seen that as the period precedes from harvest the importance of solar radiation gradually gets reduced and after the fifth week stage r value comes down to non-significant level.

The grain yield is related to solar radiation during the fifth week before harvest because accumulation of starch in the leaves and culms begins at about ten days before heading (Murata, 1966) which in turn is dependent on the extent of solar radiation receipt. The solar radiation after flowering is much more strongly correlated with grain yield because the DMF at this stage is primarily in the form of grain (Tanaka et al., 1966 and Kanakata et al., 1967) and this is dependent on photosynthesis which is primarily associated with amount of solar energy received by the crop during this period.

Consequently it can be concluded that solar radiation during the reproductive and ripening phases exerted a positive effect on yield attributes, ripening and yield of rice, whereas temperature had a negative influence i.e., the lower the temperature, the better the ripening. These results indicate that high yield will be obtained if crop planting is done so that ripening period coincides with times of low temperature in the planting seasons.

4.1.3. Straw yield

The data presented in Table 45 reveal that straw yield was affected by planting time, water management and their interactions in both the seasons. The highest straw yield was recorded by the planting done on 16th July in SWM 85 and 26th February planting in Summer 86. The lowest straw yields were observed with plantings done on 27th August (SWM 85) and 15th January (Summer 86).

Continuous submergence registered the highest straw yield of 5.3 and 6.8 t ha⁻¹ in SWM 85 and Summer 86 seasons, respectively. The favourable influence of continuous submergence on nutrient uptake, plant growth and development etc., resulted in highest straw yield in this treatment. The interaction shows that during SWM 85 continuous submergence with optimum planting in July resulted in highest straw yield. With 16th July planting I₁ and I₂ produced the highest and comparable straw yield. However, in Summer 86 a reduction in straw yield in each of the planting with decrease in water supply was observed.

4.1.4. Water use efficiency (WUE)

It is seen from Table 46 that different plantings influenced WUE in SWM 85 only. 2nd July planting recorded

TABLE 45. STRAW YIELD (KG HA⁻¹), SEASONWISE

S. S. MONAGHAN, 1985

SUMMER, 1986

	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	F ₁	F ₂	F ₃	F ₄	F ₅	Mean
I ₁	7064	7196	7229	7242	6201	5344	6713	6490	6479	6958	7269	6857	6810
I ₂	6572	6749	7132	6519	5411	4968	6225	5961	5927	6472	6482	6442	6257
I ₃	5817	5784	6212	5500	5120	4688	5522	5824	5805	6103	6413	6254	6080
I ₄	5479	5512	5065	5367	4917	4313	5242	5638	5693	5871	6119	5662	5795
Mean	6233	6311	6610	6159	5412	4828		5976	5976	6351	6571	6303	
	P I P at I I at P												
SED	268.24	149.35	491.65	519.05				63.85	32.73	89.93	103.21		
CD	597.63	365.56	1022.34	1085.69				147.23	80.10	190.17	222.59		
	(P=0.05)												

TABLE 46. WATER USE EFFICIENCY (GRAINS), (KG/MM), SEASONWISE

	S.W. MONSOON, 1985						SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	4.06	4.07	3.52	3.56	3.17	3.02	3.58	3.80	3.69	3.67	3.57	3.79	3.70
I ₂	6.56	6.59	6.55	5.26	4.52	3.91	5.57	5.86	5.22	5.32	5.29	5.33	5.40
I ₃	7.60	7.52	6.73	6.25	5.15	4.52	6.33	5.95	6.35	6.41	6.07	6.27	6.21
I ₄	7.58	7.91	7.78	6.71	5.88	4.75	6.77	6.66	6.67	7.04	6.81	7.91	7.02
Mean	6.45	6.52	6.22	5.45	4.68	4.05		5.57	5.48	5.61	5.44	5.83	
	P	I	P at I	I at P				P	I	P at I	I at P		
SED	0.23	0.16	0.41	0.43				0.15	0.12	0.19	0.20		
CD(P=0.05)	0.52	0.40	0.86	0.89				N.S	0.28	0.41	0.45		

N.S - Not significant

TABLE 47. CONSUMPTIVE USE OF WATER (MM) - SEASONWISE

	S.W. MONSOON, 1985						SUMMER, 1986						
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	1396	1419	1711	1631	1568	1418	1524	1585	1615	1731	1829	1647	1681
I ₂	852	860	917	1053	1079	1097	976	1012	1116	1160	1206	1159	1131
I ₃	723	727	841	838	954	950	839	978	900	936	1023	960	959
I ₄	683	657	717	765	809	879	752	862	847	837	861	717	829
Mean	914	916	1047	1072	1103	1086		1109	1120	1166	1235	1121	

DATA NOT ANALYSED

the highest value in SWM 85 and 12th March planting in Summer 86. The lowest WUE was observed with the two transplantings done in August (SWM 85).

WUE was found to increase with decrease in quantity of water required. The highest values were obtained with I_4 in both the seasons with lowest quantity of water consumed (Table 47). However, the lowest grain yield obtained in this treatment does not permit scheduling irrigation in this water regime for higher WUE values alone. Interaction was present in both the seasons. Highest WUE was noticed with lower irrigation levels with early plantings in SWM 85 whereas in Summer 86 the highest values were obtained with delayed plantings for the same irrigation level.

North East Monsoon 1985

The planting time of experiment was repeated during this season by taking five plantings with the variety IR 20. Hence these results were not included in the correlation analysis on the influence of meteorological parameters where SWM 85 and Summer 86 were taken together and discussed already. Separate analysis was done for this season and results are presented hereunder.

4.1.5. Growth characters

4.1.5.1. Height of plant

Height of plants as influenced by planting time and water management are presented in Table 48. There was appreciable difference in plant height either due to planting period or water management. Transplantings done during first fortnight of October produced taller plants whereas planting done on 26th November resulted in reduction of plant height at all stages during this season. The height (Fig.12) in relation to the minimum temperature recorded at vegetative phase (Fig.17) go to indicate that plant height increased when the night temperature is high. This is evident with respect to plantings done during 1st and 15th October and 10th December. The correlation coefficients worked out between plant height at harvest and different meteorological parameters presented in the Table 49 indicate that the correlation between sunshine hours or solar radiation increases with age of the crop indicating that these energy sources play an important role in deciding the plant height.

Continuous submergence produced taller plants, however, was comparable with that of submerging one day after disappearance of water (I_2). The shortest plants

TABLE 48. HEIGHT OF PLANT (CM), STAGEWISE (N.E. MONSOON, 1965)

	FLOWERING										HARVEST							
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	45.87	54.70	47.20	39.49	47.03	46.58	56.42	55.55	55.30	45.46	52.51	53.05	73.57	76.03	71.20	62.67	73.30	72.67
I ₂	44.09	52.48	46.73	34.23	45.19	44.54	58.57	55.26	54.96	40.33	50.78	51.98	73.35	74.14	69.40	57.34	73.89	71.74
I ₃	43.54	52.17	45.09	34.17	39.42	42.68	57.63	54.69	51.34	38.03	40.95	50.07	72.03	71.20	67.97	68.11	73.22	70.51
I ₄	43.40	48.80	42.66	32.80	36.87	40.90	56.44	53.33	49.81	36.93	46.58	48.62	71.99	70.84	66.81	67.32	69.54	69.30
Mean	44.23	51.94	45.42	34.32	41.88		57.27	55.71	53.85	41.19	50.63		72.74	73.20	68.65	68.01	72.49	
	P	I	P at I	I at P	P	I	P at I	I at P	P	I	P at I	I at P	P	I	P at I	I at P	P	I
SED	1.87	0.66	1.54	2.31			1.16	0.78	1.31	1.54			1.64	0.52	0.94	1.60		
CD(P=0.05)	5.19	2.11	3.65	5.93			2.68	1.92	2.88	3.40			3.78	1.28	2.04	4.07		

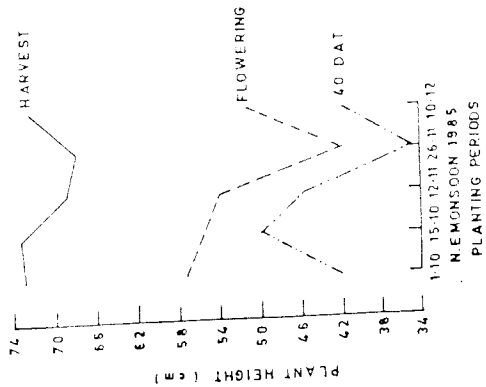


FIG. 12 PLANT HEIGHT (cm) AS INFLUENCED BY DIFFERENT PLANTING PERIODS

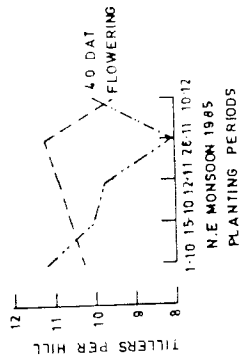


FIG. 13 TILLER PRODUCTION AS INFLUENCED BY DIFFERENT PLANTING PERIODS

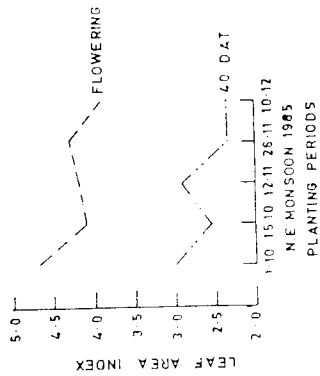


FIG. 14 LEAF AREA AS INFLUENCED BY DIFFERENT PLANTING PERIODS

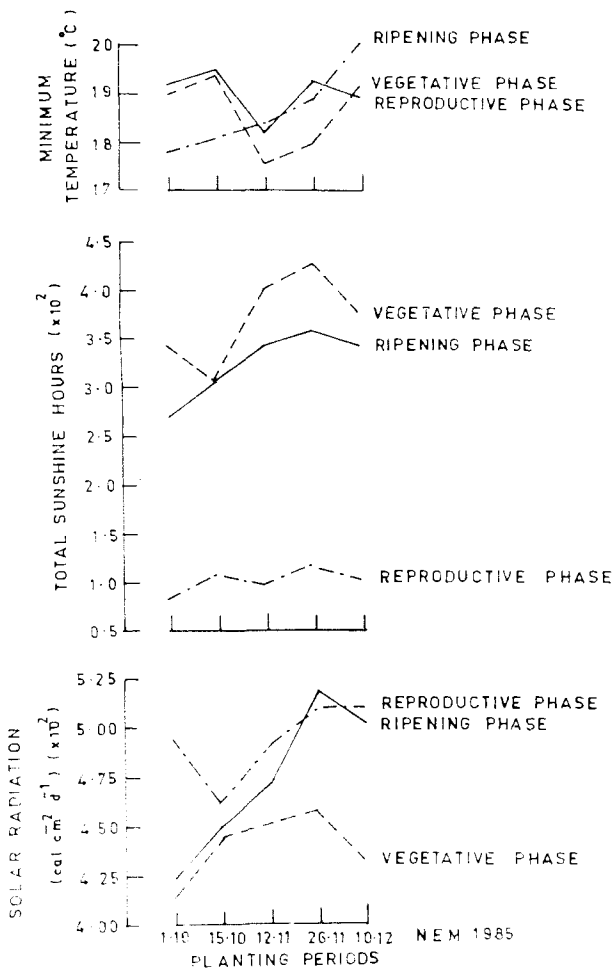


FIG. 17 METEOROLOGICAL PARAMETERS EXPERIENCED BY THE CROP DURING DIFFERENT GROWTH PHASES (NE MONSOON 1985)

were noticed with irrigating three days after disappearance of water (I_4). The role of water in deciding plant height was discussed already.

TABLE 49. CORRELATION COEFFICIENTS BETWEEN PLANT HEIGHT AT HARVEST AND METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Maximum air temperature	P I	0.7566
2. Minimum air temperature	P I	0.8189
3. Total sunshine hours	P II	-0.2975
4. -do-	P III	-0.5034
5. Total solar radiation	P II	-0.1606
6. -do-	P III	-0.5349

P I - Vegetative phase
P II - Reproductive phase
P III - Ripening phase

The planting x irrigation interaction was present at all stages. Submerging one day after disappearance of water with 1st October planting (I_2P_1) at flowering and continuous submergence with 15th October planting (I_1P_2) at 40 DAT and harvest produced tallest plants.

4.1.5.2. Number of tillers per hill

The results presented in Table 50 reveal that number of tillers was highest with 1st October planting at 40 DAT and planting on 26th November gave the lowest.

TABLE 50. NUMBER OF TILLERS, STAGGERING (M. P. MORSBACH, 1985)

40 DAT

FLOWERING

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	12.20	11.41	10.97	8.97	11.66	11.04	11.80	12.25	12.80	13.07	10.72	12.03
I ₂	12.42	11.08	10.57	9.24	11.09	10.88	11.41	12.95	12.71	12.52	10.91	11.90
I ₃	11.25	9.33	9.74	8.23	9.99	9.69	10.29	9.39	9.95	10.84	9.39	10.17
I ₄	10.22	9.21	8.73	7.04	8.54	8.75	9.61	9.69	9.98	10.09	8.99	9.67
Mean	11.52	10.26	10.00	8.37	10.30		10.78	11.07	11.36	11.63	10.00	
	P	I	P at I at P				P	I	F at I at P			
SED	0.30	0.16	0.28	0.37			0.45	0.09	0.30	0.52		
CD(P=0.05)	0.69	0.39	0.61	0.85			1.03	0.23	0.63	1.17		

However, with advancement of age, the latter produced the highest tiller number at flowering which was similar to all other plantings except 10th December wherein the lowest number was noticed. A reduction in tiller number at flowering as plantings are advanced from 26th November could also be seen.

It could be observed from Fig.13 that more tillers per hill are produced with November plantings in NEN 85. During these plantings the minimum temperature is higher than other plantings (Fig.17) thus resulting in more tiller production. Vergara (1970) and Jhildyal (1972) observe that tiller production will be more at initial stages under conditions of high temperature. As a result at flowering stage the crop planted during November are seen to record more tillers per hill. Though the night temperature was higher with 10th December planting, the low light condition resulted in reduced tiller production.

With respect to water management, the tiller production was more with more frequent irrigations i.e., continuous submergence or one day after disappearance of water (I_1 and I_2). Decrease in tiller number with increase in moisture stress was noticed with irrigating two or three days after disappearance of water. The reduction in tiller

number with these irrigation levels compared to continuous submergence was more during flowering stage than at 40 DAT.

Irrigation x planting interactions were present during both the stages. Continuous submergence with plantings done during October at 40 DAT and with November plantings at flowering stages produced the highest number of tillers per hill.

4.1.5.3. Leaf area index (LAI)

Results on LAI presented in Table 51 and Fig.14 indicate that there was difference in LAI with planting periods and water management. Planting done on 1st October had the highest LAI values at both the stages. This was followed by 12th November planting. The lowest LAI value was noticed with transplanting done on 12th December. The LAI decreased with delay in planting from 1st October onwards.

The correlation coefficients worked out between LAI at flowering and solar energy sources (sunshine hours and solar radiation) at vegetative and reproductive stages presented below (Table 52) show that the r value at reproductive phase is lower than that of vegetative phase indicating the importance of these energy sources in maintaining a high LAI at the early growth stage of the crop.

TABLE 51. LEAF AREA INDEX, STAGEIUS (N. S. KRUGON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	3.38	3.13	3.86	2.97	2.97	3.27	5.78	5.35	5.31	5.13	4.87	5.23
I ₂	3.46	3.08	3.40	2.87	2.78	3.12	5.15	4.38	4.84	4.88	4.64	4.78
I ₃	2.95	2.30	2.53	1.87	2.11	2.35	5.48	3.49	3.77	3.36	3.50	3.69
I ₄	2.05	1.57	1.69	1.63	1.46	1.68	3.64	3.22	2.93	2.76	2.60	3.03
Mean	2.96	2.54	2.88	2.34	2.33		4.71	4.11	4.21	4.03	3.90	
	F	I	F at I	I at P			F	I	F at I	I at P		
SED	0.13	0.07	0.13	0.19			0.07	0.08	0.12	0.12		
CD(P=0.05)	0.35	0.16	0.28	0.42			0.17	0.19	0.27	0.25		

TABLE 52. CORRELATION COEFFICIENT BETWEEN LAI AND SUNSHINE HOURS AND SOLAR RADIATION AT VEGETATIVE AND REPRODUCTIVE PHASES

Factor	Phase	r value
1. Total sunshine hours	P I	-0.7792
2. -do-	P II	-0.4362
3. Total solar radiation	P I	-0.7920
4. -do-	P II	-0.1178

P I - Vegetative phase
P II - Reproductive phase

Continuous submergence (I_1) and submerging one day after disappearance of water (I_2) recorded comparable LAI at 40 DAT whereas the former water management was found necessary to record the highest LAI at flowering. A reduction in LAI with less frequent irrigations (I_2 and I_3) were observed, the lowest being noticed with submerging three days after disappearance of water (I_4). The decrease was sharp at flowering stage compared to 40 DAT. Turner (1979) states that adjustment of transpiring leaf area through accelerated senescence of lower leaves, death of tillers and leaf tip death are common phenomena of water stressed rice. Similar reductions in leaf area due to moisture stress are reported by O'Toole and Balida (1982).

Interaction between planting and irrigation was present at both the stages. At 40 DAT, continuous submergence with planting on 12th November and at flowering stage the same irrigation level with 1st October planting recorded highest LAI.

4.1.5.4. Dry matter production (DMP)

Significant difference in DMP with planting dates and water management was noticed. Interaction between them was present during harvest stage only (Table 53).

All the plantings differed significantly in DMP. At 40 DAT the highest DMP was recorded with 12th November planting followed by 26th November planting. At harvest, the latter produced the highest dry matter followed by 12th December planting. The early October plantings resulted in the least DMP during both the stages.

A comparison of the Fig.15 on DMP with tiller production at flowering (Fig.13) indicates that DMP followed more or less a similar trend as of tiller production. The low minimum temperature at the reproductive and ripening phases in the November plantings also helps in conserving photosynthates thereby increasing plant growth and development.

TABLE 53. DRY MATTER PRODUCTION (KG HA^{-1}), STAGE WISE (N. S. RAINSON, 1985)

	FLOWERING					HARVEST						
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	5171	5360	6098	5713	6658	5800	13499	12133	13769	15525	14419	13869
I ₂	5023	5168	5920	5602	6533	5649	12343	11985	12975	14199	13205	12933
I ₃	4919	4987	5749	5383	6360	5480	11047	10833	12510	13225	12685	12060
I ₄	4741	4820	5654	5222	6130	5315	10801	9952	10994	12365	11622	11147
Mean	4963	5084	5855	5480	6422		11922	11286	12562	13818	12982	
	P	I	P at I	I at P			P	I	P at I	I at P		
SED	50.70	39.16	56.73	53.19			186.76	113.59	294.27	238.35		
CD(P=0.05)	115.92	95.81	N.S.	N.S.			430.67	277.95	550.95	510.57		

N.S. - Not significant

Continuous submergence resulted in highest DWP at both the stages. The favourable influence of more water on plant height, tiller production etc., magnified its effect finally resulting in highest DWP with this irrigation level. The same irrigation level with planting on 26th November produced the highest value in the case of interaction.

4.1.5.5. Duration

4.1.5.5.1. Duration upto 50 per cent flowering

The time taken by different plantings for 50 per cent flowering is given in the Table 54 below.

TABLE 54. DURATION UPTO 50 PER CENT FLOWERING AND REPRODUCTIVE PHASES (NEM, 1985)

Date of planting	Duration upto 50 per cent flowering (days)	Duration of ripening phase(days)
1. 1-10-85	70	40
2. 15-10-85	70	42
3. 12-11-85	73	40
4. 26-11-85	71	41
5. 10-12-85	70	39

The duration is longest in 12th November planting consequent on the very low minimum temperature experienced by the crop during vegetative phase. This is in agreement

with the results of Biswas et al. (1975). The correlation coefficients of duration of vegetative phase with maximum and minimum temperature at this phase indicate that the duration is more negatively correlated with minimum ($r = -0.7686$) than maximum temperature ($r = -0.6937$). The duration of other plantings are low due to higher minimum temperature occurred at vegetative phase of these plantings.

4.1.5.5.2. Duration of ripening phase

Table 54 also indicates that the duration of ripening phase was lowest with 12th December planting than other plantings. The duration increased by three days when the planting was done on 15th October. The higher minimum temperature occurred at the ripening phase of the 12th December planting might have caused a reduction of the duration since at higher temperature translocation of photosynthates is faster thus reducing the maturity period.

4.1.5.6. Nutrient uptake (N, P and K)

Nutrient uptake as affected by planting period and water management are presented in Table 55. Nitrogen and phosphorus uptake at flowering was highest with 10th December planting followed by 26th November planting. A considerable decrease in their uptake was noticed with

TABLE 55. NUTRIENT UPTAKE (KG HA⁻¹) BY PLANTS, STAGewise (N.E. MONSOON, 1985)

NITROGEN												
FLOWERING							HARVEST					
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	44.16	44.11	50.00	59.06	68.62	53.25	55.70	48.00	63.05	69.22	59.03	59.00
I ₂	36.05	39.90	47.58	58.28	67.78	49.92	51.21	46.88	59.40	64.68	54.94	55.42
I ₃	33.59	37.04	46.13	56.92	66.07	47.95	45.98	43.15	56.94	60.13	52.82	51.80
I ₄	31.77	34.53	44.53	53.58	64.60	45.80	44.84	39.42	53.38	56.45	49.70	48.76
Mean	36.47	38.89	47.06	56.96	66.67		49.43	44.36	58.19	62.62	54.12	
	P	I	P at I	I at P			P	I	P at I	I at P		
SED	0.46	0.29	0.59	0.55			1.13	0.23	1.13	0.85		
CD (P=0.05)	1.06	0.70	1.29	1.18			2.61	0.56	2.52	1.77		

PHOSPHORUS												
FLOWERING							HARVEST					
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	21.84	22.39	24.67	20.81	26.16	23.17	45.30	45.48	48.22	46.05	43.99	45.81
I ₂	21.32	21.27	24.27	19.67	25.24	22.35	43.39	44.68	47.08	44.42	42.91	44.50
I ₃	19.13	20.14	23.09	18.52	24.25	21.03	41.00	43.05	45.32	43.47	40.41	42.65
I ₄	18.17	19.37	22.49	17.66	23.51	20.24	39.63	41.00	44.34	41.50	38.56	41.01
Mean	20.11	20.79	23.63	19.16	24.79		42.33	43.55	46.24	43.86	41.47	
	P	I	P at I	I at P			P	I	P at I	I at P		
SED	0.26	0.09	0.37	0.34			0.38	0.11	0.46	0.40		
CD (P=0.05)	0.60	0.21	N.S	N.S			0.86	0.26	N.S	N.S		

POTASSIUM												
FLOWERING							HARVEST					
	P ₁	P ₂	P ₃	P ₄	P ₅	Mean	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	73.48	83.84	102.37	96.47	92.54	89.74	103.17	107.33	127.50	115.64	116.34	114.00
I ₂	71.97	81.63	100.36	94.66	90.83	87.89	101.37	106.65	125.95	114.58	115.15	112.74
I ₃	70.92	79.30	98.59	92.09	90.52	86.28	100.23	105.94	125.54	113.82	113.82	111.87
I ₄	70.15	78.35	98.04	91.63	89.95	85.62	98.78	105.03	124.71	112.90	112.87	110.86
Mean	71.63	80.83	99.84	93.71	90.96		100.89	106.24	125.92	114.23	114.55	
	P	I	P at I	I at P			P	I	P at I	I at P		
SED	0.94	0.44	0.81	0.64			0.71	0.32	0.68	0.52		
CD (P=0.05)	0.94	1.08	N.S	N.S			1.64	0.77	N.S	N.S		

N.S - Not significant

advancement of transplanting. During harvest stage the highest uptake of N and P was noticed with 26th and 12th November plantings, respectively. In case of K, planting done on 12th November resulted in highest uptake at both the stages. A reduction in its uptake could be seen with delay or advancement of planting from this date.

Water management affected the nutrient uptake considerably. Continuous submergence recorded the highest N, P and K uptake at both the stages followed by submerging one and two days after disappearance of water. The least uptake was seen in case of submerging three days after disappearance of water.

These results are in agreement of the general finding that continuous submergence increases nutrient availability and their uptake as noticed by Pillai and Se (1979, 1980b) for N, Kakade and Sonar (1983) for P and Patil and Childyal (1983) for K.

4.1.6. Yield and yield attributes

4.1.6.1. Panicles per m²

Production of panicles per m² was affected both by planting periods and water management (Table 56). Panicle number was more and similar with 1st October and 12th November plantings (394 and 391, respectively). The lowest number was noticed with 12th December planting (353).

TABLE 56. NUMBER OF PANICLES M^{-2} (N.W. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	390	330	422	377	356	378
I ₂	402	340	388	378	362	374
I ₃	395	335	383	373	351	367
I ₄	390	325	371	361	344	358
Mean	394	333	391	372	353	
	P	I	P at I	I at P		
SED	2.75	1.67	2.79	3.66		
CD(P=0.05)	6.35	4.08	5.98	8.06		

TABLE 57. NUMBER OF GRAINS M^{-2} (10^4) (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	2.25	1.92	3.06	3.20	2.93	2.69
I ₂	2.25	1.90	2.73	3.26	2.97	2.62
I ₃	2.10	1.83	2.67	3.13	2.89	2.52
I ₄	2.06	1.61	2.43	2.92	2.64	2.33
Mean	2.16	1.81	2.72	3.12	2.86	
	P	I	P at I	I at P		
SED	0.03	0.15	0.03	0.04		
CD(P=0.05)	0.06	0.36	0.07	0.09		

Correlation coefficients worked out between panicles per m^2 and maximum and minimum temperature at vegetative phase indicate that the panicle number was negatively correlated with maximum temperature ($r = -0.6521$) and minimum temperature ($r = -0.7225$). Higher number of panicles per m^2 observed in 1st October and 12th November plantings could be attributed to the low minimum temperature experienced by them during the vegetative phase. Usada et al. (1973) notice production of more panicles due to low temperature during maximum tillering stage.

Production of panicles per m^2 was higher and similar with continuous submergence and submerging one day after disappearance of water (378 and 374, respectively). The three days interval between two irrigations (I_4) after disappearance of water produced 358 panicles per m^2 , the reduction being about 5.3 per cent. Pillai and De (1980a) report increased panicle production with continuous submergence.

4.1.6.2. Grains per m^2

Table 57 on grains per m^2 indicates that the highest number of grains per m^2 is produced when planted on 26th November and followed by 10th December planting. The lowest is seen in case of 15th October planting. In case of water management, continuous submergence and

submerging one day after disappearance of water produced higher number of grains per m^2 .

Correlation coefficients worked out between grains per m^2 and solar energy sources as well as mean relative humidity presented in Table 58 shows that sunshine hours and solar radiation received during the ripening phase exerts a considerable bearing on grain production. Thus the higher sunshine hours and solar radiation received by the crop planted on 26th November resulted in the production of highest number of grains per m^2 . The high negative

TABLE 58. CORRELATION COEFFICIENTS OF GRAINS PER m^2 WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Mean relative humidity	P I + P II + P III	-0.8594
2. Total sunshine hours	P I	0.3227
3. -do-	P II	0.3620
4. -do-	P III	0.7400
5. -do-	P II + P III	0.7044
6. Total solar radiation	P I	0.2174
7. -do-	P II	0.3229
8. -do-	P III	0.8379
9. -do-	P II + P III	0.8061

P I - Vegetative phase
P II - Repro active phase
P III- Ripening phase

correlation between grains per m^2 and relative humidity indicates that a high relative humidity may cause a reduction in grain number.

4.1.6.3. Panicle weight and panicle length

Tables 59 and 60 presented on the weight and length of panicles, respectively, show that planting period and water management influenced these characters. Panicles produced were more lengthy with 26th November and 10th December plantings. The panicle length reduced with early plantings. Irrigation done with three days after disappearance of water (I_3) caused considerable reduction in panicle length. Panicle weight was more with November plantings which also decreased with early two October plantings. Panicle weight with continuous submergence or submerging one day after the disappearance of water was higher and comparable.

Correlation coefficients worked out between panicle weight and meteorological factors are presented in Table 61.

TABLE 61. CORRELATION COEFFICIENTS BETWEEN PANICLE WEIGHT AND METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P II	-0.7546*
2. Total sunshine hours	P II	0.6773
3. -dc-	P III	0.6219
4. Total solar radiation	P III	0.6896

P II - Reproductive phase
 P III - Ripening phase
 * - Significant at 5% level

TABLE 59. WEIGHT OF PANICLE (G), (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	1.98	1.94	2.04	2.01	1.98	1.99
I ₂	1.97	1.91	1.98	2.02	1.95	1.97
I ₃	1.91	1.89	2.00	1.95	1.94	1.94
I ₄	1.84	1.89	1.94	1.96	1.93	1.91
Mean	1.93	1.91	1.99	1.99	1.95	
	P	I	P at I	I at P		
SED	0.02	0.01	0.02	0.02		
CD(F=0.05)	0.04	0.02	0.04	0.05		

TABLE 60. PANICLE LENGTH (CM), (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	19.77	19.65	21.11	22.29	21.90	20.94
I ₂	19.38	19.44	20.53	21.02	21.10	20.30
I ₃	19.16	19.23	20.22	23.17	20.36	20.43
I ₄	18.71	18.31	19.34	19.77	20.09	19.24
Mean	19.26	19.16	20.30	21.56	20.87	
	P	I	P at I	I at P		
SED	0.64	0.37	0.93	1.05		
CD(P=0.05)	1.48	0.90	N.S	N.S		

N.S - Not significant

The minimum air temperature at reproductive phase is negatively correlated with panicle weight indicating that the low minimum temperature of 18.2°C experienced during reproductive phase resulted in higher panicle weight as observed in case of 12th November planting.

4.1.6.4. Number of filled grain per panicle

The data presented in Table 62 show that number of filled grains per panicle was influenced by planting period and water management practices. Transplantings done on 26th November and 10th December produced the highest number of filled grains. A reduction in filled grains with advancement of planting could also be noticed, the least being produced with October plantings.

Higher number of filled grains was produced with continuous submergence (I_1) or irrigating one day after disappearance of water (I_2). Water applied at three days after disappearance (I_4) reduced filled grain number considerably. Less number of filled grains in this irrigation regime might be due to more number of unfilled grains consequent to the inadequate moisture supply at reproductive stage confirming the results of De Datta (1981).

TABLE 62. NUMBER OF FILLED GRAINS (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	57.70	58.23	72.63	85.00	82.37	71.19
I ₂	56.03	55.50	70.27	86.20	82.00	70.00
I ₃	53.20	54.53	69.60	83.87	82.43	68.73
I ₄	52.73	49.40	65.40	80.83	76.83	65.04
Mean	54.92	54.26	69.48	83.98	80.91	
	P	I	P at I	I at P		
SED	1.68	0.59	1.24	1.98		
CD(P=0.05)	3.86	1.45	2.66	4.43		

TABLE 63. PERCENTAGE OF FILLED GRAINS (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	80.92	78.77	80.63	87.03	86.53	82.77
I ₂	77.60	75.23	77.93	85.17	82.43	79.67
I ₃	74.58	71.36	76.33	83.22	81.25	77.35
I ₄	72.07	65.93	74.51	81.28	79.53	74.66
Mean	76.29	72.82	77.35	84.18	82.44	
	P	I	P at I	I at P		
SED	0.51	0.32	0.73	0.81		
CD(P=0.05)	1.18	0.79	1.56	1.75		

4.1.6.5. Percentage of filled grains

The percentage of filled grains as influenced by planting periods and water management is presented in Table 63. Transplanting rice crop done on 26th November produced significantly the highest fertility percentage. This was followed by 10th December planting. The two October plantings caused considerable reduction in fertility percentage.

Correlation coefficients worked out between fertility percentage and meteorological factors at different phases are present in Table 64.

TABLE 64. CORRELATION COEFFICIENTS BETWEEN FERTILITY PERCENTAGE AND METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Mean relative humidity	P II + P III	-0.8397
2. Total sunshine hours	P I	0.6533
3. -do-	P II + P III	0.7137
4. Total solar radiation	P II	0.9261*
5. -do-	P III	0.7987

P I - Vegetative phase

P II - Reproductive phase

P III - Ripening phase

* - Significant at 5% level

Sunshine hours and solar radiation greatly influence the percentage of filled grains. Solar radiation

received during reproductive phase shows a very high significant correlation coefficient with fertility percentage indicating as the reason behind higher fertility percentage in 26th November and 10th December plantings. Mean relative humidity shows its negative association with fertility percentage.

The percentage of filled grains was affected by water management practices also. The highest filled grain percentage was recorded when continuous submergence was adopted. The fertility percentage was lowest with submerging three days after disappearance of ponded water, the reduction being 3.8 per cent. The interaction was significant and shows that continuous submergence with 26th November or 10th December plantings resulted in highest filled grain percentage. Cruz and O'Toole (1984) suggest water stress at flowering stage to be the major cause for spikelet sterility.

4.1.6.6. Thousand grain weight

Results of thousand grain weight presented in Table 65 reveal that planting done on 26th November produced the highest test weight of 19.5 g and 15th October or 12th November the least (19.2 g). A reduction in test weight with advancement of planting was observed.

TABLE 65. 1000 GRAIN WEIGHT (G) (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	19.33	19.32	19.33	19.61	19.42	19.40
I ₂	19.25	19.12	19.30	19.58	19.40	19.33
I ₃	19.30	19.13	18.98	19.56	19.34	19.26
I ₄	18.99	19.09	18.73	19.20	19.15	19.03
Mean	19.21	19.17	19.08	19.49	19.33	
	P	I	P at I	I at P		
SED	0.06	0.04	0.06	0.08		
SD	0.13	0.10	0.13	0.17		
	(P=0.05)					

TABLE 66. CORRELATION COEFFICIENTS OF 1000 GRAIN WEIGHT WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P II	0.6081
2. Total sunshine hours	P I	0.5794
3. Total sunshine hours	P II	0.6687
4. Total sunshine hours	P III	0.7007
5. Total solar radiation	P II	0.6159
6. Total solar radiation	P III	0.6811

P I = Vegetative phase
P II = Reproductive phase
P III = Ripening phase

Test weight was higher and comparable with continuous submergence or submerging one day after disappearance of water. Submerging three days after disappearance of water produced lighter grains. This might be due to lack of adequate moisture which is essential for translocation of metabolites from source to sink.

Correlation coefficients between thousand grain weight and meteorological parameters are presented in Table 66. The various factors do not show any significant relationship with thousand grain weight. However, the fact that 26th November and 10th December plantings gave higher thousand grain weight than other plantings highlights the importance of sunshine hours and solar radiation during reproductive and ripening phases.

Correlation coefficient of solar radiation with 1000 grain weight is much stronger during the P II than P III. Considering the fact that the size of the yield container is decided by the conditions prevailed during this period, the close correlation is understandable.

4.1.6.7. Degree of ripening

The degree of ripening as influenced by the meteorological parameters during different phases under different plantings are studied based on the correlation

coefficients worked out between them and are presented in Table 67.

TABLE 67. CORRELATION COEFFICIENTS OF DEGREE OF RIPENING WITH METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Total sunshine hours	P II	0.5004
2. -do-	P III	0.6735
3. -do-	P II + P III	0.6595
4. Total solar radiation	P II	0.9152*
5. -do-	P III	0.7836
6. -do-	P II + P III	0.9168*

P II - Reproductive phase
 P III - Ripening phase
 * - Significant at 5% level

The degree of ripening is very strongly influenced by solar radiation received during reproductive stage. Degree of ripening being the product of 1000 grain weight and percentage filled grains, behaved in the same way as these characters such that 26th November planting recorded the highest ripening grade.

4.1.6.8. Grain yield

4.1.6.8.1. Response to planting dates

The grain yield data are presented in Table 68. The grain yield was the highest (4.50 t ha⁻¹) with

TABLE 68. GRAIN YIELD (KG HA⁻¹) (N.E. THONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	4440	4061	4499	4715	4450	4433
I ₂	4317	4204	4390	4665	4360	4387
I ₃	4176	3998	4275	4464	4280	4239
I ₄	3977	3828	3986	4164	4140	4019
Mean	4228	4023	4288	4502	4308	
	P	I	P at I	I at P		
SED	37.13	21.04	49.81	58.01		
CD (P=0.05)	85.63	N.S	105.60	125.49		

N.S - Not significant

TABLE 69. CORRELATION COEFFICIENTS BETWEEN YIELD AND YIELD ATTRIBUTES

Factor	r value
Dry matter production at harvest	0.9737**
Grains m ⁻²	0.9210*
Panicle weight	0.7992
Fertility percentage	0.9213*
1000 grain weight	0.8461
Degree of ripening	0.9217*

* - Significant at 5% level

** - Significant at 1% level

transplanting done on 26th November followed by 10th December (4.31 t ha^{-1}). The lowest yield of 4.02 t ha^{-1} was recorded with planting done on 15th October.

A perusal of various growth and yield characters reveal that LAI, number of tillers per hill, grains per m^2 , panicle weight, percentage of filled grains and degree of ripening were very high in the 26th November planting which has resulted in higher grain yield recorded under this planting.

The correlation coefficients worked out between yield and yield attributes are presented in Table 69. It is evident that there exists a very high positive correlation between grain yield and yield attributes considered. The highest correlation is seen between DMP at harvest, degree of ripening and grain yield. As already indicated in case of SWM 85 and Summer 86 seasons degree of ripening exerted a greater influence on grain yield.

The highest significant correlation between grain yield and DMP at harvest (0.9737^{**}) indicates the importance of post flowering dry matter accumulation in enhancing grain yield. This is important because, as suggested by Tanaka et al. (1966) post flowering increase in dry matter is particularly in the form of grain.

Thus the results indicate that transplanting rice during the end of November (26th November) in NEM season result in increase of growth and yield attributes contributing to higher grain yield. Rajagopalan et al. (1973) report higher grain yield for IR 8 rice when transplanted on 21st November under Coimbatore conditions.

4.1.6.8.2. Response to water management

Grain yield presented in Table 68 and Fig.16 indicate that higher and comparable yields are obtained with continuous submergence (I_1) or submerging one day after disappearance of water (I_2). The grain yield under irrigating two (I_3) and three (I_4) days after disappearance of water decreased by 4.38 and 9.34 per cent, respectively, as compared to continuous submergence.

Crop growth was similar in irrigations given as continuous submergence or submerging one day after disappearance of water. These two irrigation levels produced comparable number of panicles per m^2 , panicle weight and number of filled grains per panicle thus leading to comparable yields in these treatments. The reduction in water applied under the I_2 irrigation level did not result in moisture stress. This finding is in line with Kanwar et al. (1974) who report that yield

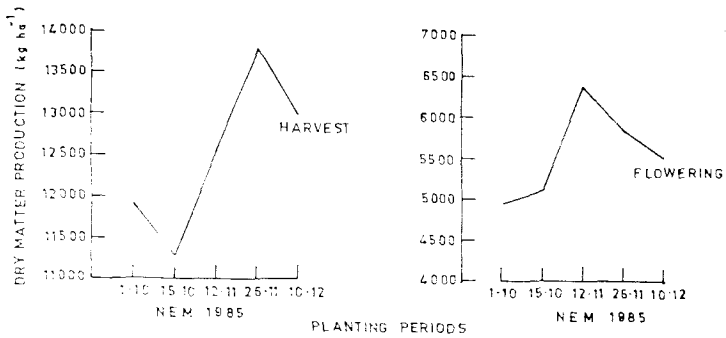


FIG. 15 DRY MATTER PRODUCTION (kg ha^{-1}) AS INFLUENCED BY DIFFERENT PLANTING PERIODS (NE MONSOON 1985)

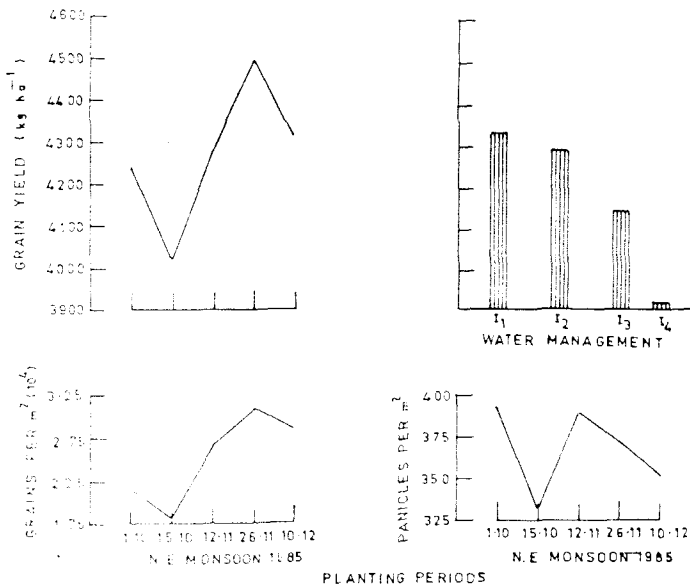


FIG. 16 GRAIN YIELD (kg ha^{-1}) IN RELATION TO YIELD ATTRIBUTES AND WATER MANAGEMENT UNDER DIFFERENT PLANTING PERIODS (NE MONSOON 1985)

obtained was highest with water applied to keep the soil between saturation point and 0.15 atm tension. Kumar and Singh (1978) report similar findings.

Significantly lower yield was obtained with submerging two or three days after disappearance of ponded water (I_3 and I_4) compared to grain yield obtained with I_1 or I_2 levels. The moisture stress in these regimes (I_3 or I_4 levels) caused reduction in number of tillers per hill, photosynthesising surface (LAI), and other yield attributes such as number of panicles per m^2 , percentage of filled grains, panicle weight etc., resulting in reduced grain yield. The influence of moisture stress in affecting growth and yield attributes are pointed out by many workers (Kobata and Takami, 1983; Roychaudhury et al., 1983 and Cruz and O'Toole, 1984).

Under flooded condition the evaporation is 1.24 times greater than under unflooded condition (Saha et al., 1974). Because of the higher depth of water on the soil due to continuous submergence (I_1) more water might have percolated than under submerging one day after disappearance of water (I_2). Evaporation and deep percolation are not directly related to plant growth (IRRI, 1984). However, transpiration rate of the crop which was directly related to productivity was comparable under these two irrigation regimes.

Under continuous submergence a total of 1201 mm of water was consumed by the crop whereas with submerging one, two or three days after disappearance of ponded water it was 854, 697 and 584 mm, respectively (Table 73). The grain yield obtained under each irrigation level was 4.43, 4.34, 4.24 and 4.02 t ha⁻¹, respectively, the yield recorded with I₁ and I₂ being comparable. Thus a saving of 28.9 per cent of water could be achieved with submerging one day after disappearance of ponded water (I₂) without perceptible reduction in grain yield.

Thus the study indicates that even irrigation a day after disappearance of water (I₂) is as efficient as continuous submergence under the low evaporative demand of the atmosphere prevailed during the NEM season. So taking into account the economy of water under scarce situations, scheduling irrigation could be done with I₂. Interaction existed between planting periods and irrigation on grain yield of rice. Transplanting done on 26th November and scheduling irrigation with continuous submergence or irrigating one day after disappearance of water resulted in higher grain yield than other combinations.

4.1.6.8.3. Effect of meteorological parameters

Correlation coefficients were worked out between yield of different plantings with meteorological parameters at various growth stages and presented in Table 70.

TABLE 70. CORRELATION COEFFICIENTS BETWEEN GRAIN YIELD AND METEOROLOGICAL PARAMETERS AT DIFFERENT PHASES

Factor	Phase	r value
1. Minimum air temperature	P I	-0.6395
2. Maximum air temperature	P III	0.6494
3. Mean relative humidity	P II + P III	-0.6311
4. Total sunshine hours	P II	0.8750
5. -do-	P I + P II + P III	0.7652
6. Total solar radiation	P II	0.8919*
7. -do-	P II + P III	0.8664

P I - Vegetative phase

P II - Reproductive phase

P III - Ripening phase

* - Significant at 5% level

Minimum air temperature at vegetative phase is negatively correlated with grain yield. The influence of low temperature in increasing panicle number was discussed already.

The total radiation received during reproductive phase sharply influences grain yield ($r = 0.8919^*$). Total sunshine hours during the same stage also shows a close correlation with grain yield. Thus the higher grain yield recorded in 26th November planting could be ascribed to the favourable environmental conditions received during the reproductive and later at ripening phases which in turn helped in better growth and development of yield components finally resulting in highest grain yield.

4.1.7. Straw yield

The data presented in Table 71 show that straw yield was affected by planting time, irrigation and their interaction as well. Planting done on 26th November resulted in highest straw yield also. This was followed by 1st October or 10th December plantings. The lowest straw yield was recorded with 15th October planting.

Continuous submergence produced the highest straw yield of 5.5 t ha^{-1} . The favourable influence of continuous submergence in plant height and tiller production resulted in highest straw yield.

The interaction of continuous submergence with planting done on 26th November produced the highest straw yield. The next in the order was continuous submergence with 1st October planting.

4.1.8. Water use efficiency

Water use efficiency (WUE) (Table 72) was highest with 26th November planting and the lowest with 1st October planting. The consumptive use of water under each planting and irrigations are presented in Table 73. The quantity of water used under 26th November planting is 732 mm with the highest grain yield of 4.5 t ha^{-1} giving rise to the highest WUE (6.15 kg/mm). Though the quantity

TABLE 71. STRAW YIELD (KG HA⁻¹) (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	5608	5120	5454	5860	5477	5508
I ₂	5285	4910	5110	5459	5235	5200
I ₃	5187	4793	4943	5530	5122	5115
I ₄	5003	4331	4513	4611	5120	4675
Mean	5271	4788	5005	5370	5189	
	P	I	P at I	I at P		
SED	39.58	42.10	79.86	76.71		
CD(P=0.05)	91.28	103.20	173.34	163.28		

TABLE 72. WATER USE EFFICIENCY - GRAIN (KG/MM)
(N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	3.78	3.81	3.70	4.56	3.94	3.96
I ₂	5.66	5.99	4.96	6.43	5.38	5.68
I ₃	6.77	7.05	6.54	8.18	5.97	6.90
I ₄	7.75	7.70	7.71	8.29	8.15	7.92
Mean	5.99	6.14	5.73	6.87	5.86	
	P	I	P at I	I at P		
SED	0.24	0.07	0.25	0.34		
CD(P=0.05)	0.55	0.17	0.53	0.73		

TABLE 73. CONSUMPTIVE USE OF WATER (MM) (N.E. MONSOON, 1985)

	P ₁	P ₂	P ₃	P ₄	P ₅	Mean
I ₁	1175	1067	1215	1033	1130	1124
I ₂	763	702	385	726	810	777
I ₃	617	567	654	546	717	620
I ₄	593	497	517	502	508	507
Mean	767	708	818	702	791	

Not statistically analysed

of water consumed in other treatments are also less the low yield produced by those plantings caused the lower WUE.

The highest WUE is noticed with submerging three days after disappearance of water (I_4) obviously due to the least quantity of water consumed in this treatment. However, the lowest yield obtained under this treatment does not permit scheduling irrigation in this regime.

The interaction shows that $I_4 P_4$ (26th November) combination gave the highest WUE followed by $I_4 P_5$ (10th December) and $I_3 P_4$. Submerging three days after disappearance of water (I_4) could not give higher WUE values with earlier plantings done during October 85.

Experiment 2 (SOUTH WEST MONSOON 1985 and SUMMER 1986)

4.2.1. Growth characters

4.2.1.1. Height of plant (Table 74)

In general there was significant increase in plant height with irrigation and increment in N levels. A linear increase in plant height was noticed due to N application at all stages of growth in both SWM 85 and Summer 86 seasons. A progressive increase in height was also noticed with age of the crop. Increase in plant

TABLE 74. HEIGHT OF PLANT (CM), STAGMINE AND BEAROWNIA
40 DAT
S.W. MONSIEUR, 1965

	I ₁			I ₂			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	35.58	34.15	34.86	34.50	32.74	33.62	35.04	33.45	34.24
M ₁	40.55	42.65	41.59	40.89	41.97	41.45	40.72	42.50	41.51
M ₂	49.52	51.64	50.08	44.78	53.04	48.77	46.45	53.34	49.40
M ₃	52.26	57.60	54.33	49.44	56.06	52.75	50.05	56.05	55.04
Mean	44.23	46.50	45.36	42.30	45.95	44.13	43.27	46.23	
S.E.D.	0.37	0.24	0.24	0.34	0.51	0.49	0.51	0.49	
CD(P=0.05)	0.91	0.58	0.58	0.82	1.3	1.3	1.16	1.00	

SCHOER, 1966

	I ₁			I ₂			I ₃			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	40.51	43.45	42.05	40.95	43.45	42.20	40.58	41.52	40.95	40.71	42.74	41.75
M ₁	43.52	47.98	45.70	41.98	48.13	45.06	42.60	46.84	44.72	42.70	47.62	45.16
M ₂	47.81	50.21	49.01	43.05	47.24	45.54	44.01	47.61	45.82	45.22	48.56	46.78
Mean	43.98	47.18	45.58	42.26	46.27	44.27	42.39	45.26	43.87	42.08	46.24	
S.E.D.	0.46	0.59	0.48	0.84	0.63	0.73	0.55	0.60				
CD(P=0.05)	1.28	1.52	1.08	1.8	1.55	1.60	1.42	1.76				

FLOWERING

S.W. MONSIEUR, 1965

	I ₁			I ₂			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	48.81	49.97	49.39	46.37	46.53	46.45	47.59	48.25	47.92
M ₁	60.33	63.50	61.92	60.37	61.00	60.68	60.35	62.25	61.30
M ₂	66.17	77.20	71.60	62.87	72.40	67.63	64.52	74.80	69.66
M ₃	69.63	86.70	78.25	66.87	76.83	71.70	68.25	84.70	74.98
Mean	61.24	69.38	65.31	59.12	64.12	61.62	60.18	66.75	
S.E.D.	0.42	0.44	0.44	0.63	0.63	0.73	0.63	0.73	
CD(P=0.05)	1.04	1.09	1.09	1.54	1.42	1.67	1.42	2.05	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	59.04	56.99	58.02	59.99	59.13	59.57	59.01	57.68	58.35	59.35	57.95	58.64
M ₁	65.13	79.03	72.08	64.59	74.26	69.33	62.56	68.90	65.73	64.03	74.04	69.05
M ₂	69.50	82.24	75.87	66.37	81.06	73.72	64.13	75.11	69.62	66.67	79.47	73.07
Mean	64.56	72.75	68.66	63.58	71.49	67.54	61.90	67.23	64.56	63.35	70.49	
S.E.D.	0.54	0.92	0.75	1.30	1.12	1.34	0.88	1.10				
CD(P=0.05)	1.43	2.05	1.67	1.8	2.57	2.89	2.05	3.41				

HARVEST

S.W. MONSIEUR, 1965

	I ₁			I ₂			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	64.30	64.05	64.17	60.40	64.33	62.37	62.35	64.18	62.27
M ₁	72.95	75.85	74.33	69.51	74.54	72.03	71.17	75.16	73.18
M ₂	80.57	86.10	83.34	75.59	82.60	79.10	78.08	84.95	81.22
M ₃	84.50	91.21	87.89	82.94	86.62	84.28	83.72	88.49	86.11
Mean	76.55	79.31	74.68	72.11	76.77	74.45	73.93	78.04	
S.E.D.	0.48	0.30	0.30	0.43	0.74	0.73	0.73	0.73	
CD(P=0.05)	1.22	0.74	0.74	1.05	1.66	1.58	1.66	1.49	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean	Y ₁	Y ₂	Mean
M ₀	67.12	74.51	70.92	66.81	72.84	69.89	65.36	70.07	67.70	66.43	72.46	69.45
M ₁	75.23	84.21	79.07	74.17	82.73	78.20	73.82	80.34	77.08	74.64	82.26	78.45
M ₂	82.81	94.07	88.44	78.48	92.22	85.35	76.61	86.86	81.74	79.30	91.05	85.18
Mean	75.24	84.26	79.77	75.15	82.43	77.70	71.93	79.08	75.50	73.46	81.92	
S.E.D.	0.47	0.50	0.43	1.03	0.91	1.00	0.76	0.82				
CD(P=0.05)	1.22	1.26	1.14	2.61	2.34	2.61	1.90	2.08				

height due to N application is well established (Iruthayaraj and Morachan, 1980; Salam, 1984; Ramaswamy, 1985 and Reddy, 1985). Enhanced N uptake at higher N levels promoted efficient photosynthesis and faster growth resulting in increased plant height.

The main effects of irrigation, variety and the interaction either among themselves or with N were also present. A reduction in plant height due to decrease in water application was observed. The reduction in plant height may be attributed to moisture stress in case of I_2 at saturation in Summer 85 and I_3 below saturation condition in Summer 86 seasons, respectively. Similar observations are made by Saha et al. (1974) when irrigation is scheduled at field capacity. Among the varieties CO 37 produced taller plants than IR 50 and it was true with N application also. Varietal behaviour to N levels might be an inherent character of varieties (Iruthayaraj, 1975). For N x irrigation interaction, continuous submergence produced more taller plants with increase in N levels.

4.2.1.2. Number of tillers per hill

The tiller production at 40 DAT and flowering stage of the crop was influenced by the levels of N application and varieties in both the seasons (Table 75) and by irrigation levels in Summer 86. As in case of

TABLE 75. NUMBER OF TILLERS HILL⁻¹, STAGEWISE AND SEASONWISE
40 DAT
S.W. MONSOON, 1965

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	6.30	5.80	6.05	5.90	5.10	5.50	6.10	5.45	5.78
N ₁	7.70	7.00	7.35	8.10	7.10	7.60	7.90	7.05	7.48
N ₂	10.20	8.30	9.25	9.50	8.20	8.85	9.05	8.25	9.05
N ₃	11.20	10.30	10.75	11.00	10.70	10.85	11.10	10.50	10.80
Mean	8.05	7.05	8.35	8.63	7.78	8.21	8.74	7.82	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.16	0.06	0.06	0.09	0.19	0.15	0.19	0.15	
CD (P=0.05)	0.39	N.S	0.15	N.S	0.45	0.31	0.45	0.22	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	8.99	8.72	8.85	8.78	8.13	8.45	8.71	8.67	8.69	8.83	8.51	8.67
N ₁	11.50	9.43	10.47	10.36	9.67	10.01	9.96	9.79	9.88	10.61	9.63	10.12
N ₂	12.34	10.96	11.65	12.29	10.13	11.21	10.47	10.41	10.44	11.70	10.50	11.10
Mean	10.94	9.70	10.32	10.48	9.31	9.89	9.71	9.62	9.67	10.38	9.55	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.19	0.22	0.18	0.32	0.30	0.33	0.25	0.29				
CD (P=0.05)	0.52	0.50	0.41	0.70	0.71	0.71	0.62	0.66				

FLOWERING

S.W. MONSOON, 1965

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	9.20	8.20	8.70	9.40	8.80	9.10	9.30	8.50	8.90
N ₁	12.40	9.50	10.95	12.20	9.80	11.00	12.30	9.65	10.90
N ₂	15.30	12.00	13.65	13.30	11.80	12.55	14.30	11.90	13.10
N ₃	14.10	11.80	12.95	14.30	13.10	13.70	14.20	12.45	13.33
Mean	12.75	10.38	11.57	12.30	10.88	11.59	12.53	10.63	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.12	0.11	0.11	0.15	0.25	0.29	0.25	0.29	
CD (P=0.05)	0.30	N.S	0.26	0.37	0.55	0.61	0.55	0.65	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	10.67	8.71	9.69	9.68	8.89	9.28	10.04	8.00	9.02	10.13	8.53	9.33
N ₁	11.31	10.42	10.87	13.54	9.92	11.73	12.21	9.54	10.88	12.36	9.96	11.16
N ₂	12.08	11.41	11.74	14.65	10.84	12.74	13.67	10.53	12.10	13.46	10.93	12.20
Mean	11.35	10.18	10.77	10.62	9.88	11.25	11.97	9.36	10.67	11.98	9.80	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.13	0.17	0.14	0.24	0.20	0.22	0.17	0.18				
CD (P=0.05)	0.36	0.38	0.31	0.53	0.47	0.49	0.42	0.52				

N.S - Not significant

plant height increase in N application resulted in production of more tillers. Ramasamy (1982) and Sah and Mikkelsen (1983) report increase in tiller production due to N application.

No significant difference was noticed during SWM 85 whereas at both stages of observation in Summer 86 I_1 and I_2 recorded higher and similar number of tillers whereas irrigating three days after disappearance of water (I_3) produced the least number of tillers per hill. Mambani and Lal (1983) are of the opinion that low tillering and less leaf area are the adaptations to moisture stress.

The number of emerging tillers is highest when water temperature is around 31°C both day and night (Matsushira et al., 1964). Thus increase in tiller production under continuous submergence could be attributed to favourable water temperature. Singh et al. (1984) and Reddy (1985) report higher tiller production under continuous submergence.

The variety IR 50 produced more tillers during both the seasons due to its high tillering capacity. Shaik Dawood (1986) reports increase in tiller production for IR 50 compared to IR 20 at higher levels of N application.

The interactions between irrigation x variety, N x irrigation and N x variety are significant at one stage or other in both the seasons. This indicated the same pattern of higher tiller production at higher levels of respective inputs.

4.2.1.3. Leaf area index (LAI) (Table 76)

Leaf area index increased at 40 DAT and flowering stage following N and water application. As the number of leaves per plant increases, the total photosynthesising area available for the plant increases. Leaf photosynthetic rate was linearly related to leaf N (Yoshida, 1981). As N level was increased leaf N increased (Salam, 1984) with corresponding increase in leaf proteins. Thus application of N, a nutrient accelerating vegetative growth had the most marked effect on LAI by both increasing the number of tillers and size of leaves resulting from increased N absorption (Murata and Matsushima, 1978).

LAI recorded at 40 DAT and flowering was more with continuous submergence in SWM 85 season. During Summer 86 it was similar to irrigating one day after disappearance of water at 40 DAT but significantly highest at flowering. Sharma et al. (1975) observe that as soil water declined the average number of leaves per plant increased but area per leaf decreased by almost 50 per cent.

TABLE 76. LSAP AREA INDEX, STAGEWISE AND SEASONWISE
S.W. MONSOON, 1985
40 DAT

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	2.34	2.44	2.39	2.17	2.56	2.37	2.26	2.50	2.38
N ₁	3.23	3.70	3.47	3.10	3.45	3.28	3.17	3.58	3.38
N ₂	4.11	4.15	3.96	3.59	3.82	3.71	3.68	3.99	3.83
N ₃	4.07	5.25	4.71	3.90	4.67	4.27	3.99	4.99	4.49
Mean	3.38	3.91	3.63	3.19	3.62	3.40	3.28	3.77	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.04	0.01	0.01	0.02	0.05	0.03	0.05	0.04	
CD (P=0.05)	0.10	0.03	0.03	0.04	0.11	0.07	0.11	0.05	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	3.05	3.07	3.06	3.06	3.27	3.16	2.86	3.17	3.02	2.99	3.17	3.09
N ₁	3.83	4.30	4.06	3.82	4.06	3.94	3.39	4.05	3.72	3.68	4.14	3.91
N ₂	4.60	5.14	4.87	4.18	5.27	4.72	4.22	5.04	4.63	4.33	5.15	4.74
Mean	3.83	4.17	3.99	3.68	4.20	3.94	3.49	4.04	3.79	3.67	4.35	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.15	0.07	0.06	0.10	0.19	0.12	0.17	0.11				
CD (P=0.05)	0.41	0.15	0.12	0.12	0.47	0.28	0.44	0.12				

FLOWERING

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	4.26	4.86	4.56	4.20	3.66	3.91	4.23	4.26	4.23
N ₁	5.46	5.53	5.50	5.23	4.71	4.97	5.34	5.12	5.23
N ₂	6.52	6.40	6.46	5.86	5.65	5.76	6.19	6.03	6.11
N ₃	7.19	7.61	7.40	6.23	7.39	6.81	6.71	7.50	7.11
Mean	5.86	6.10	5.98	5.38	5.35	5.36	5.62	5.73	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.03	0.04	0.04	0.05	0.06	0.08	0.06	0.08	
CD (P=0.05)	0.07	0.09	0.09	0.13	0.14	0.17	0.14	0.23	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	5.23	5.59	5.41	4.93	5.55	5.24	4.88	5.60	5.24	5.01	5.58	5.30
N ₁	7.16	9.70	8.43	6.75	8.61	7.68	6.25	8.83	7.54	6.72	9.05	7.89
N ₂	7.78	11.30	9.54	7.59	9.53	8.56	6.65	10.19	8.42	7.34	10.34	8.84
Mean	6.73	8.86	7.7	6.42	7.90	7.16	5.93	8.21	7.07	6.36	8.32	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.08	0.11	0.08	0.15	0.13	0.15	0.11	0.12				
CD (P=0.05)	0.22	0.23	0.19	0.33	0.31	0.32	0.27	0.33				

All the interactions were found to be significant. For both varieties higher LAI was recorded with continuous submergence than other levels of irrigation. The interaction between N and irrigation and N x variety gave the same trend of results viz., at higher levels of N and irrigation the values of leaf area were significantly higher with higher levels. Similar results are reported by Pillai and Krishnamurthy (1985). The variety CO 37 was superior at higher N and irrigation levels than IR 50.

4.2.1.4. Maximum root length (Table 77)

Nitrogen and water applications influenced the root length. During Summer 86 it increased with increasing levels of N and under irrigation levels longest roots were noticed in case of irrigating three days after disappearance of water (I_3) at 40 DAT. Sahu and Raut (1969) and Pradhan et al. (1973) mention that the development of root system was more under water stress conditions.

Variety and its interaction with irrigation levels on root length was also observed. The variety CO 37 produced the longest roots individually and in combination with I_3 in Summer 86 than of IR 50 with the same irrigation level.

TABLE 77. ROOT LENGTH (CM), STAGEWISE AND SEASONWISE

40 DAT
S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	20.22	21.34	20.78	20.27	21.89	21.08	20.24	21.62	20.93
N ₁	20.12	21.63	20.88	21.28	20.68	20.98	20.70	21.16	20.93
N ₂	19.18	22.45	20.82	19.94	19.97	19.95	19.56	21.21	20.39
N ₃	21.41	22.69	22.05	20.56	18.68	19.62	20.99	20.69	20.84
Mean	20.23	22.03	21.13	20.51	20.30	20.41	20.37	21.17	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.25	0.11	0.11	0.16	0.31	0.25	0.31	0.25	
CD (P=0.05)	N.S	0.28	0.28	0.39	0.72	0.55	0.72	0.43	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	16.10	18.63	17.37	15.50	18.80	17.15	15.77	19.20	17.48	15.79	18.88	17.33
N ₁	16.32	19.70	18.01	16.10	20.10	18.10	17.50	20.80	19.13	16.63	20.20	18.42
N ₂	17.27	20.70	18.98	17.27	20.90	19.08	18.60	22.80	20.70	17.71	21.47	19.59
Mean	16.57	19.68	18.13	16.29	19.93	18.11	17.28	20.93	19.11	16.71	20.18	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.09	0.28	0.23	0.40	0.26	0.38	0.20	0.31				
CD (P=0.05)	0.25	0.63	0.52	N.S	0.57	0.81	N.S	N.S				

FLOWERING

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	15.53	16.49	15.91	15.04	16.49	15.77	15.18	16.49	15.54
N ₁	17.34	15.90	16.62	13.74	15.24	14.99	15.54	15.57	15.56
N ₂	17.47	17.80	17.63	13.39	18.47	15.93	15.43	18.13	16.78
N ₃	17.96	18.53	18.25	13.82	18.20	16.01	15.89	18.37	17.13
Mean	17.02	17.19	17.10	13.99	17.09	15.55	15.81	17.14	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.14	0.06	0.08	0.12	0.20	0.19	0.20	0.19	
CD (P=0.05)	0.34	0.21	0.21	0.29	0.45	0.42	0.45	0.39	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	17.03	20.43	18.73	17.47	19.80	18.63	16.03	19.67	17.85	16.84	19.77	18.41
N ₁	17.80	21.63	19.72	18.63	20.63	19.63	17.90	21.07	19.48	18.11	21.11	19.61
N ₂	19.27	22.17	20.71	19.20	21.47	20.33	18.73	22.07	20.40	19.07	21.90	20.48
Mean	18.03	21.41	19.72	18.43	20.63	19.53	17.56	20.93	19.24	18.01	20.99	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.10	0.14	0.12	0.20	0.29	0.31	0.22	0.25				
CD (P=0.05)	0.28	0.32	0.26	0.45	N.S	N.S	N.S	N.S				

N.S - Not significant

Interactions of N with irrigation and variety were also present in SWM 85 but N x irrigation alone was significant at 40 DAT in Summer 86. Slight moisture stress (I_2 or I_3) with increasing levels of N produced longest roots.

4.2.1.5. Root dry weight (Table 78)

Root dry weight increased with successive levels of N at different growth stages in both the seasons. A gradual increase in root dry weight was noticed with age of the crop. A favourable influence of N on root dry weight is reported by Salam (1984).

In SWM 85 root dry weight was similar with continuous submergence (I_1) and irrigating one day after disappearance of water (I_2) at 40 DAT and flowering, whereas, during Summer 86 it was highest with irrigating three days after disappearance of water (I_3). In case of continuous submergence more branching and aerenchymatous tissues might have developed but death of roots might occur due to toxic substances produced under continuous submergence. Due to the entry of O_2 into the top layer of soil with disappearance of ponded water production of toxic substances might have reduced, thus resulting in lesser death of roots. Continuous submergence increases soil temperature (Table 2) and more death of roots due to variation in temperature regime

TABLE 7B. ROOT DRY WEIGHT (G) HILL⁻¹, STAGEWISE AND SEASONWISE
40 DAT
S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	0.83	0.92	0.88	0.69	0.69	0.69	0.76	0.81	0.78
N ₁	1.22	1.26	1.24	1.08	1.04	1.06	1.15	1.15	1.15
N ₂	1.51	1.59	1.55	1.42	1.41	1.42	1.47	1.50	1.49
N ₃	1.78	2.12	1.95	1.54	1.97	1.76	1.56	2.05	1.86
Mean	1.34	1.47	1.41	1.18	1.28	1.23	1.26	1.38	
N	I	V	IxV	N at I	I at N	I at V	N at V	V at N	
SED	0.05	0.08	0.08	0.12	0.09	0.12	0.09	0.12	
CD (P=0.05)	0.11	N.S	N.S	N.S	N.S	N.S	0.19	0.46	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.31	1.10	1.21	1.15	1.21	1.18	1.23	1.03	1.13	1.23	1.12	1.17
N ₁	1.36	1.13	1.24	1.34	1.51	1.43	1.49	1.40	1.45	1.40	1.35	1.37
N ₂	1.63	1.26	1.45	1.44	1.59	1.51	1.72	1.59	1.66	1.59	1.48	1.54
Mean	1.43	1.16	1.30	1.31	1.44	1.37	1.48	1.34	1.41	1.41	1.31	
N	I	V	IxV	N at I	I at N	I at V	N at V	V at N				
SED	0.04	0.05	0.04	0.08	0.06	0.07	0.05	0.06				
CD (P=0.05)	0.11	N.S	N.S	0.17	0.14	0.16	N.S	N.S				

FLOWERING
S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	0.94	1.13	1.03	0.76	0.80	0.78	0.85	0.97	0.92
N ₁	1.46	1.33	1.40	1.09	1.15	1.12	1.28	1.24	1.26
N ₂	1.57	1.55	1.56	1.59	1.76	1.65	1.58	1.65	1.61
N ₃	1.97	2.00	1.99	1.84	1.98	1.91	1.91	1.99	1.95
Mean	1.49	1.50	1.50	1.32	1.42	1.37	1.41	1.46	
N	I	V	IxV	N at I	I at N	I at V	N at V	V at N	
SED	0.05	0.05	0.05	0.08	0.07	0.08	0.07	0.08	
CD (P=0.05)	0.15	N.S	N.S	N.S	0.16	0.18	N.S	N.S	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.34	0.93	1.14	1.18	1.12	1.15	1.24	1.16	1.20	1.25	1.07	1.16
N ₁	1.50	1.08	1.29	1.33	1.60	1.47	1.59	1.41	1.50	1.47	1.37	1.42
N ₂	1.71	1.32	1.52	1.60	1.76	1.68	1.91	1.88	1.89	1.74	1.65	1.70
Mean	1.52	1.11	1.31	1.37	1.49	1.43	1.58	1.48	1.53	1.49	1.36	
N	I	V	IxV	N at I	I at N	I at V	N at V	V at N				
SED	0.02	0.10	0.08	0.15	0.09	0.13	0.06	0.11				
CD (P=0.05)	0.06	N.S	N.S	N.S	N.S	N.S	N.S	N.S				

N.S - Not significant

from 27 - 15°C to 37 - 25°C is reported by Kar et al. (1975). Katare and Upadhyay (1981) report more root dry weight under irrigation at field capacity than at continuous submergence. Irrigation x N interaction was present at 40 DAT in Summer 85 and at flowering in SWN 85 seasons. Irrigating three days after disappearance of water (I_3) recorded more root dry weight with N application during Summer 85 whereas continuous submergence recorded more root dry weight with N application, in SWN 85.

4.2.1.6. Dry matter production (Table 79)

Dry matter production (DMP) increased with enhancement in levels of N and higher irrigation water application at 40 DAT and flowering in both the seasons. The higher the doses of N or water, the higher was the DMP. Nitrogen, at the highest dose of 225 kg ha⁻¹ produced 4.99 and 9.88 t ha⁻¹ of dry matter at 40 DAT and flowering during SWN 85 and at 150 kg ha⁻¹ produced 4.93 and 7.70 t ha⁻¹ at 40 DAT and flowering during Summer 86, respectively. Tiller production also followed the same trend. According to Tanaka (1965) the number of leaves in rice being more or less fixed, it should be mainly through an increase in tiller production per unit area that DMP could be increased and the reported trend is in line with this conclusion.

TABLE 79. DRY MATTER PRODUCTION (KG HA⁻¹), STAGewise AND SEASONwise
S.W. MONSOON, 1985

40 DAT

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1158	1494	1326	964	1061	1013	1061	1278	1169
N ₁	2733	2778	2756	2839	2031	2135	2486	2404	2445
N ₂	3742	4333	4338	3261	4231	3746	3502	4582	4042
N ₃	4900	6075	5489	3810	5161	4495	4355	5618	4966
Mean	3133	3820	3477	2719	3120	2845	2851	3471	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	141.06	59.06	59.06	85.53	192.51	170.97	191.51	170.97	
CD (P=0.05)	345.18	144.52	144.52	204.39	N.S	N.S	440.23	299.97	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	3967	4083	4025	3828	3422	3625	3434	2594	3044	3763	3367	3565
N ₁	4333	5006	4669	4317	4400	4359	3872	3672	3772	4174	4359	4267
N ₂	5178	5800	5489	4511	5206	4856	4111	4755	4433	4600	5254	4927
Mean	4492	4963	4728	4219	4343	4289	3826	3674	3749	4179	4327	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	150.59	87.19	71.18	123.29	179.65	131.15	165.76	107.08				
CD (P=0.05)	418.05	194.24	N.S	274.69	N.S	N.S	440.18	122.60				

S.W. MONSOON, 1985

FLOWERING

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	3383	3056	3220	3087	2728	2908	3236	2892	3064
N ₁	5306	5911	5608	5178	4578	4878	5242	5245	5243
N ₂	7567	6965	7266	7178	6661	6920	7372	6813	7093
N ₃	11405	10227	10817	9000	8895	8947	10205	9561	9882
Mean	6915	6540	6727	6111	5715	5913	6613	6128	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	158.59	106.48	106.48	180.59	191.46	168.96	191.46	168.96	
CD (P=0.05)	388.31	260.56	260.56	368.49	447.76	378.21	447.76	362.31	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	6472	6672	6572	4744	5500	5122	4205	4889	4547	5141	5687	5414
N ₁	7278	7778	7528	6194	6711	6453	5383	5850	5617	6285	6780	6532
N ₂	9200	8267	8734	7950	7188	7569	6894	6711	6802	8015	7389	7701
Mean	7650	7572	7611	6296	6467	6467	5494	5817	5656	6480	6619	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	85.03	151.97	124.09	214.92	158.52	202.47	127.20	165.32				
CD (P=0.05)	236.03	338.60	N.S	N.S	N.S	N.S	304.55	584.18				

N.S - Not significant

Variety could exert influence on DMP only during SWM 85. The variety CO 37 produced highest DMP than IR 50 at flowering. Combined effect of irrigation levels with varieties was seen only during early stages of crop growth. Interaction of N x variety was found to occur both during 40 DAT and flowering in SWM 85 and Summer 86 seasons. Dry matter production was highest for CO 37 with higher levels of N application than that of IR 50.

4.2.2. Yield and yield attributes

Data on number of panicles per m^2 , length of panicle, panicle weight, number of filled grains per panicle, percentage sterility, 1000 grain weight, grain and straw yield recorded are presented and discussed in this section.

4.2.2.1. Panicles per m^2 (Table 80)

Nitrogen fertilization increased panicle number with increasing levels of N. Application of N at 150 kg ha^{-1} produced the highest panicle number of 409 and 422 in SWM 85 and Summer 86 which are higher than in lower levels of N. Increased panicle number at enhanced levels of N is observed by Mani (1979) and Pillai and De (1980a).

A significant influence with irrigation levels was noticed only in Summer 86 season. Continuous submergence produced the highest number of panicle per m^2 (377)

TABLE 80. NUMBER OF PANICLES M^{-2} , SEASONWISE
S.W. MONSOON, 1985

	I_1			I_2			Mean		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	222	209	216	226	205	216	224	207	216
N_1	401	360	381	433	335	384	417	348	382
N_2	434	389	411	425	389	407	423	389	409
N_3	396	352	374	382	338	360	389	345	367
Mean	363	328	346	367	317	342	365	322	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	2.09	2.50	2.50	3.53	4.63	5.64	4.63	5.64	
CD (P=0.05)	5.10	N.S	6.10	8.64	N.S	N.S	10.05	14.02	

SUMMER, 1986

	I_1			I_2			I_3			Mean		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	297	286	292	291	281	286	282	279	281	290	282	286
N_1	403	384	394	392	380	386	387	376	382	394	380	387
N_2	461	429	445	435	413	424	400	394	397	432	412	422
Mean	387	366	377	373	358	365	356	350	353	372	358	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	5.70	4.31	3.52	6.10	7.64	7.96	6.00	6.59				
CD (P=0.05)	10.26	9.61	7.84	13.59	N.S	N.S	14.09	14.99				

TABLE 81. LENGTH OF PANICLE (CM), SEASONWISE

S.W. MONSOON, 1985

	I_1			I_2			Mean		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	17.03	16.00	16.52	15.97	15.33	15.65	16.50	15.67	16.08
N_1	17.27	16.83	17.05	16.53	16.77	16.65	16.90	16.80	16.85
N_2	17.60	17.03	17.32	17.10	17.23	17.17	17.35	17.13	17.24
N_3	17.94	17.40	17.67	17.67	17.53	17.60	17.81	17.47	17.64
Mean	17.46	16.82	17.15	16.82	16.72	16.77	17.14	16.77	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.07	0.06	0.06	0.08	0.11	0.11	0.11	0.11	
CD (P=0.05)	0.17	0.14	0.14	0.20	0.24	0.25	0.24	0.27	

SUMMER, 1986

	I_1			I_2			I_3			Mean		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	19.44	18.37	18.91	18.46	18.43	18.44	18.44	17.64	18.04	18.77	18.14	18.46
N_1	19.76	19.70	19.73	19.34	19.12	19.23	20.14	19.14	19.65	19.75	19.32	19.53
N_2	21.19	20.93	21.06	20.33	19.52	19.92	20.18	20.29	20.24	20.57	20.25	20.41
Mean	20.13	19.66	19.90	19.38	19.02	19.20	19.59	19.02	19.31	19.70	19.24	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.14	0.13	0.10	0.18	0.25	0.24	0.20	0.20				
CD (P=0.05)	0.38	0.20	0.23	0.57	0.51	N.S	N.S	N.S				

N.S - Not significant

followed by I_2 and I_3 levels of irrigation. The lower number of panicles in the moisture stress treatments might be due to cyclic drying of top 10-15 cm soil where more roots were concentrated. The roots produced by tillers encountered moisture stress and resulted in lower nutrient uptake (Tables 91a, b and c). Thus most of the late formed tillers might have died. In addition competition of weeds with growing tillers for water and other nutrients under I_2 and I_3 treatments might also result in reduction of panicles per m^2 . Sah and Mikkelsen (1983) observe similar reduction in panicles per m^2 due to moisture stress.

Among the varieties IR 50 produced more number of panicles. It recorded 13.0 and 4.0 per cent more number of panicles than CO 37 during SWM 85 and Summer 86, respectively. Though CO 37 was taller and produced more LAI than IR 50, due to the mutual shading of leaves it could not utilise the inputs available effectively in transforming to more economic produce.

The interactions of variety with N and irrigation are significant in both the seasons. IR 50 produced more panicles per m^2 at all irrigations and N levels tried compared to CO 37.

4.2.2.2. Length of panicle (Table 81)

The panicle length was increased significantly with enhancement in N levels and quantity of irrigation water

applied. This might be due to increased rate of photosynthate formation and translocation. Increased panicle length due to N application is reported by Kalyanikutty (1970), Sheik Dawood (1986) and many other workers.

Continuous submergence was found necessary to produce lengthy panicles in both the seasons. Panicles were lengthy in Summer 86 than in SWM 85. Among the varieties, IR 50 produced panicles with more length than CO 37 in both the seasons. Interaction of variety with irrigation and N are significant during SWM 85 whereas N x irrigation alone is significant in Summer 86. Higher dose of any one factor with another factor gave rise to lengthier panicles.

4.2.2.3. Weight of panicle (Table 82)

Panicle weight increased due to N application. Nitrogen at the highest dose produced panicles with a mean weight of 1.50 and 1.82 g while control recorded 1.15 and 1.46 g in SWM 85 and Summer 86, respectively. Increase in panicle weight due to N application is reported by Sreedharan and Vamadevan (1981).

Effects due to levels of irrigation, variety and irrigation x variety and N x variety interactions were found during Summer 86. Continuous submergence recorded

TABLE 82. WRIGHT OF PANICLE (G), SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.18	1.09	1.14	1.08	1.24	1.16	1.13	1.17	1.15
N ₁	1.27	1.23	1.25	1.14	1.35	1.25	1.21	1.29	1.25
N ₂	1.25	1.41	1.33	1.32	1.50	1.41	1.34	1.46	1.40
N ₃	1.46	1.54	1.50	1.45	1.54	1.42	1.46	1.54	1.50
Mean	1.32	1.32	1.32	1.25	1.41	1.33	1.28	1.36	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.02	0.05	0.05	0.07	0.03	0.06	0.03	0.06	
CD (P=0.05)	0.04	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.35	1.67	1.51	1.41	1.47	1.44	1.31	1.57	1.44	1.36	1.57	1.46
N ₁	1.72	1.80	1.76	1.61	1.80	1.70	1.48	1.73	1.60	1.60	1.78	1.69
N ₂	1.94	1.97	1.95	1.67	1.88	1.78	1.58	1.90	1.74	1.73	1.92	1.82
Mean	1.67	1.81	1.74	1.56	1.72	1.64	1.46	1.73	1.59	1.56	1.75	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.03				
CD (P=0.05)	0.06	0.05	0.04	0.06	0.09	0.07	N.S.	N.S.				

TABLE 83. THOUSAND GRAIN WEIGHT (G), SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	20.08	21.16	20.62	20.08	21.88	20.85	20.08	21.37	20.73
N ₁	20.99	21.79	21.39	20.41	22.37	21.39	20.70	22.08	21.39
N ₂	21.36	22.51	21.93	20.93	22.96	21.95	21.14	22.73	21.94
N ₃	21.59	23.29	22.44	21.69	23.67	22.68	21.64	23.48	22.56
Mean	21.00	22.19	21.60	20.78	22.65	21.71	20.89	22.42	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.17	0.20	0.20	0.29	0.21	0.26	0.21	0.26	
CD (P=0.05)	0.40	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	20.41	21.46	20.94	20.24	21.57	20.91	19.86	21.07	20.47	20.17	21.37	20.77
N ₁	21.75	21.89	21.82	21.59	22.11	21.85	21.55	22.31	21.93	21.63	22.11	21.87
N ₂	22.34	23.44	22.89	22.03	23.78	22.91	21.75	23.34	22.55	22.04	23.52	22.78
Mean	21.50	22.27	21.89	21.29	22.49	21.89	21.05	22.24	21.65	21.28	22.33	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	0.08	0.29	0.24	0.41	0.22	0.36	0.10	0.29				
CD (P=0.05)	0.22	N.S.	0.53	N.S.	N.S.	N.S.	N.S.	N.S.				

N.S. - Not significant

heavier panicles (1.7% g) than in the other two irrigation levels which were comparable. The increase in panicle weight to water depth increase is reported by Galke (1968) and Sheik Dawood (1986). Higher level of irrigation and N have favourably influenced synthate accumulation in the grains which might have increased the panicle weight. This is in conformity with the observations of Place et al. (1970).

4.2.2.4. Thousand grain weight

The data on 1000 grain weight (Table 83) show that N and variety in both the seasons and irrigation x variety interaction in Summer 86 could influence this yield attribute. Highest test weight of 22.56 g was obtained by N at the highest dose compared to 20.73 g of control in SWM 85. In Summer 86 the figures were 22.78 and 20.77 g, respectively.

Enhanced application of N record highest values for both panicle weight and 1000 grain weight. This could be explained on the basis of favourable effect of N application in optimum quantities and at the correct time for influencing the "sink capacity", the formation of the "yield contents" and its effective transformation towards grain, when once the fertilization is over and the accepting capacity is achieved. Sadayappan (1982) and Nareshkumar and Singh (1983) report such increase in test weight with



increase in N fertilization. Grains are heavier with the variety CO 37 than with IR 50.

4.2.2.5. Number of filled grains per panicle (Table 84)

The number of filled grains per panicle increased following N application. Wada (1969) finds that the final number of grains usually is closely related to the amount of total N absorbed upto the flowering stage of the crop. Differentiation of spikelets was strongly supported by N supply and their degeneration was effectively prevented by carbohydrate supply through increased photosynthesis that was favourably influenced by N.

Different levels of irrigation also influenced number of filled grains. Moisture stress due to lower levels of irrigation substantially reduced this yield attribute. Filled grain number indicates the natural capacity of the sink to receive and store the source of the photosynthates supplied from the assimilatory surface of the plants which was favourably influenced by N and irrigation. Fageria (1982) and Reddy (1985) observe decrease in number of filled grains due to moisture stress at reproductive stage of the crop.

Similar to 1000 grain weight, the variety CO 37 has given more number of filled grains than IR 50. The

TABLE 84. NUMBER OF FILLED GRAINS PANICLE⁻¹, SEASONWISE
S.W. MONSOON, 1965

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	53.78	55.04	54.41	47.38	50.51	48.94	50.58	52.78	51.68
N ₁	55.24	55.46	55.35	48.81	52.04	50.43	52.03	53.75	52.89
N ₂	57.61	58.43	58.02	53.82	54.42	54.12	55.71	56.43	56.07
N ₃	59.10	63.13	61.11	55.66	61.13	58.39	57.38	62.13	59.73
Mean	56.43	58.02	57.22	53.41	54.53	53.97	53.92	56.27	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.30	0.27	0.27	0.38	0.42	0.45	0.42	0.45	
CD (P=0.05)	0.75	0.66	0.66	0.93	0.96	0.99	0.96	1.14	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	63.27	74.40	68.83	56.80	66.47	61.64	53.10	56.60	54.65	57.73	65.82	61.77
N ₁	77.60	79.10	78.35	65.43	71.33	68.38	60.94	62.57	61.76	67.99	71.10	69.50
N ₂	82.23	85.40	83.87	68.50	77.23	72.87	67.13	71.50	69.32	72.66	78.04	75.33
Mean	74.40	79.63	77.02	63.58	71.68	67.63	60.39	63.56	61.98	66.13	71.63	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.61	0.94	0.77	1.33	1.06	1.29	0.87	1.05				
CD (P=0.05)	1.69	2.10	1.72	2.97	N.S	N.S	2.11	3.31				

TABLE 85. PERCENTAGE OF STERILITY, SEASONWISE

S.W. MONSOON, 1965

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	18.73	19.13	18.93	20.20	18.33	19.27	19.47	18.73	19.10
N ₁	17.30	16.67	16.98	18.53	15.83	17.18	17.92	16.25	17.08
N ₂	14.43	14.53	14.48	15.60	14.10	14.85	15.02	14.32	14.67
N ₃	14.14	14.47	14.31	15.23	16.71	15.97	14.69	15.59	15.14
Mean	16.15	16.20	16.18	17.39	16.24	16.82	16.78	16.22	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.41	0.60	0.80	1.14	0.57	0.94	0.57	0.94	
CD (P=0.05)	0.99	N.S	N.S	N.S	N.S	N.S	N.S	N.S	

SUMMER, 1966

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	17.63	14.27	15.95	17.40	18.53	17.97	20.90	21.77	21.33	18.64	18.19	18.42
N ₁	13.23	12.53	12.88	15.47	15.20	15.33	19.33	18.23	18.78	16.01	15.32	15.67
N ₂	13.59	12.27	12.90	14.81	14.02	13.90	16.03	15.83	15.93	14.81	14.02	14.42
Mean	14.82	13.00	13.91	15.89	15.92	15.74	18.75	18.61	18.68	16.49	15.84	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.44	0.73	0.60	1.04	0.68	0.90	0.57	0.73				
CD (P=0.05)	1.22	1.63	N.S	2.31	1.62	1.96	1.43	2.79				

N.S - Not significant

interaction between N and variety was pronounced with the different varieties at higher levels of N.

4.2.2.6. Percentage of sterility (Table 85)

Nitrogen alone influenced this character in SWM whereas N and irrigation levels affected percentage sterility during Summer. Enhanced application of N resulted in reduction of sterility compared to no N. Yoshida and Ahn (1968) and Wada (1970) realise the importance of a high rate of DMP after flowering as it is directly reflected in the development of more plumpy grains and in the ultimate grain yield of rice.

Percentage sterility recorded under continuous submergence was lowest compared to other two irrigation levels in Summer 86. Grains are formed and developed during the period between panicle initiation to booting. Moisture stress at this stage due to irrigating one and three days after disappearance of water in I_2 and I_3 might have reduced the number of filled grains. Aspinall et al. (1964) are of the opinion that the organ which was growing most rapidly during the moisture stress would be mostly affected. Subramanian (1975) and Ramasamy (1985) report that irrigation to submergence whenever the soil reaches field capacity or two to four days stress between irrigation throughout the crop growth increased the sterility

percentage as compared to that of continuous or cyclic submergence.

Interactions of N with irrigation and variety were significant. Continuous submergence was found necessary to reduce the sterility percentage at all levels of N tried.

4.2.2.7. Grain yield (Table 86)

Grain yield was influenced by N and variety during SWM 85. All the main effects and the interactions exerted influence on grain yield during Summer 86. Grain yield increased with N application upto 150 kg ha^{-1} beyond which a decline was seen in SWM 85.

The favourable effect of applied N on growth and root production resulted in greater uptake of nutrients which again increased the number of panicles, grain per panicle as well as test weight. The cumulative effect on the growth and yield components with applied N has reflected on the grain yield (Fig.18).

The data further indicate that the increase in grain yield during SWM 85 from 0 to 75 kg N ha^{-1} was 101.0 per cent, from 75 to 150 kg N ha^{-1} it was only 15.5 per cent whereas from 150 to 225 kg ha^{-1} a reduction of 6.0 per cent

TABLE 86. GRAIN YIELD (KG HA⁻¹), SEASONWISE

S. W. MONSOON, 1985

	I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
t ₀	2361	2196	2322	2122	2222	2159
N ₁	4669	4453	4605	4373	4489	4413
N ₂	5366	5145	5300	5090	5195	5118
N ₃	9091	4798	5043	4721	4882	4760
Mean	4372	4148	4260	4077	4197	4113
	N	I	IxV	N at I	N at I	N at V
SED	44.35	25.75	25.75	42.60	51.63	49.06
CD(P=0.05)	108.55	N.S	63.01	N.S	N.S	N.S

SUMMER, 1986

	I ₁		I ₂		I ₃		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	3067	2559	2848	2433	2653	2385	2897	2439
N ₁	4936	4895	4615	4463	4539	3833	4644	4397
N ₂	5625	5580	5428	5389	5409	5191	5441	5387
Mean	4543	4345	4444	4095	4196	4101	4314	4081
	N	I	IxV	N at I	N at I	N at V	N at V	N at V
SED	12.89	12.66	10.34	17.91	21.24	17.57	17.10	17.23
CD(P=0.25)	35.79	28.21	23.03	39.90	49.71	43.18	43.34	36.34

N.S. - Not significant

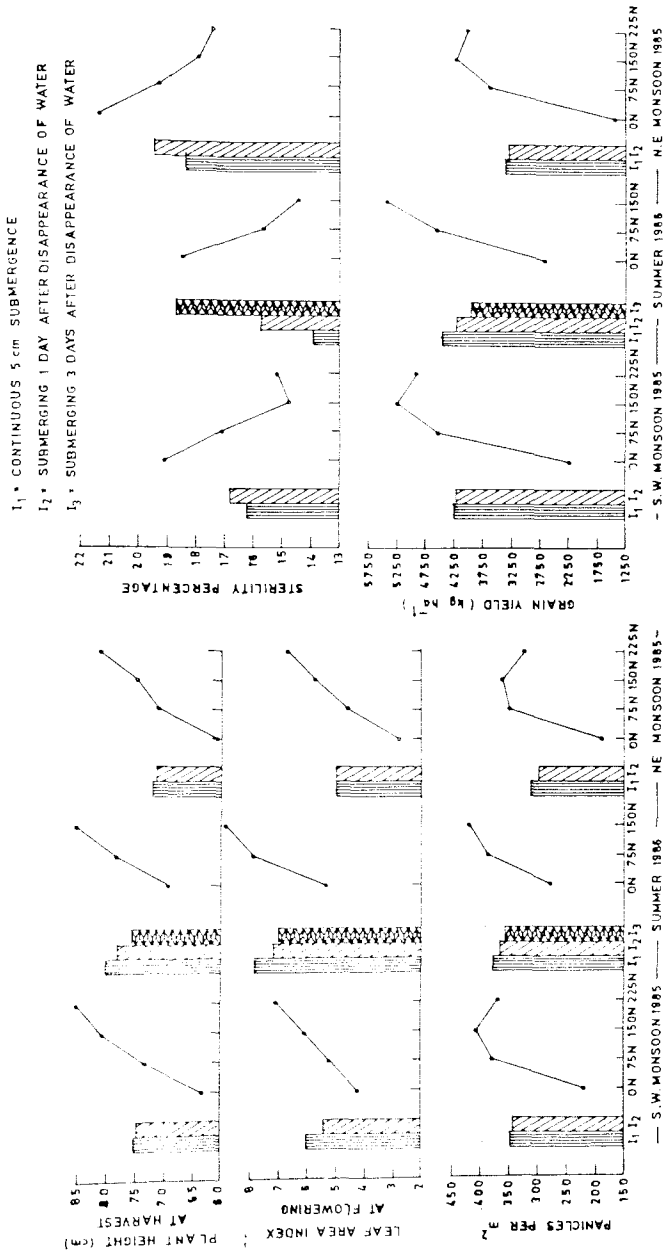


FIG.18 PLANT GROWTH, YIELD ATTRIBUTES AND YIELD AS INFLUENCED BY WATER AND NITROGEN MANAGEMENT

in yield was noticed. In Summer 85 the yield increase from 0 to 75 kg N ha⁻¹ was 70.0 per cent and from 75 to 150 kg N ha⁻¹ was 19.8 per cent.

The favourable effect of N application is in conformity with the findings of Murata (1969) who has listed the beneficial effect of N to (1) expansion of leaf area, (2) increase in N content of leaves and (3) increased "sink capacity" to accommodate greater amounts of photosynthates or "yield contents". All these factors appear to have been operative upto a level of 150 kg N ha⁻¹ beyond which the expansion of leaf area caused mutual shading of leaves resulting in decreased yield at the highest level of N tried in SWM 85.

At low levels of N supply "sink capacity" is a limiting factor in determining the yield. However, with an adequate supply of N it is not difficult to increase the size of the "yield-container". Normally at such higher rate of N application, expansion of leaf area may have a dominant role; as the excessive vegetative growth and leaf area development might result in decreased grain yields due to problems of mutual shading or uptake of excess ammonia disturbing the balance between carbohydrate and protein metabolism (Pillai and De, 1979).

In SWM 85 the irrigation of submerging the field one day after disappearance of ponded water was equally effective as continuous submergence in getting good rice yields (Fig.18).

Continuous submergence with 5 cm consumed a total quantity of 1589 mm of water (Table 87) to produce a grain yield of 4.26 t ha^{-1} compared to 1012 mm in the other irrigation treatment which recorded the yield of 4.20 t ha^{-1} . Thus a saving of about 36.3 per cent of water could be effected by scheduling irrigation at one day after disappearance of ponded water under Coimbatore conditions during SWM 85. Similar results are reported by Rangaswamy et al. (1984) and Shakk Dawood (1986).

However, during Summer 86, highest grain yield was obtained with continuous submergence to 5 cm followed by irrigating one day after disappearance of water and the least by scheduling irrigation three days after disappearance of water. The data indicate that continuous submergence recorded 5.6 and 11.1 per cent more grain yield than the other two irrigation levels. Plant water deficits may be caused either by excessive transpiration, by slow absorption of water, or by the combination of both. Water deficits are more severe in upper leaves receiving high

TABLE 87. QUANTITY OF WATER (MM) CONSUMED
S.W. MORISON, 1985

	I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	1516	1593	955	877	916	1236
N ₁	1536	1636	1051	960	1006	1294
N ₂	1601	1616	1188	928	1058	1395
N ₃	1623	1592	1115	1020	1068	1369
Mean	1569	1609	1077	946	1012	1323

SUMMER, 1986

	I ₁		I ₂		I ₃		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	1715	1669	977	973	975	859	863	1170
N ₁	1607	1517	985	959	971	847	847	1108
N ₂	1553	1588	971	974	973	845	831	1126
Mean	1625	1591	977	969	973	850	847	1135

Data not analysed

solar radiation and wind during Summer than in lower leaves. The transpiration loss of a rice population is at a maximum during the period from booting to heading stage when the LAI is the highest. During this period rice leaves are liable to suffer water deficit. The photosynthesis of rice leaves at booting stage was closely correlated with leaf water content (Murata, 1961). This showed that continuous submergence was essential for getting higher yield under the agro-climatic conditions prevailing during the Summer season in this zone where the rainfall is very low, aridity of the atmosphere as indicated by the atmospheric evaporative demands (Table 1) are higher and the percolation losses from the soil assumes a greater magnitude (Sivanappan and Saifudeen, 1976).

Shallow submergence of 5 cm standing water seems to be ideal for the varieties tested under the conditions of these experimentation during Summer 86 season. Similar findings are reported by Sharma and De (1979), Roychaudhury et al. (1983), Reddy and Hussein (1983) and Prasad and Sharma (1984). The increased rate of growth and DMP where the transpirational transfer of water was more, was also due to the increased rate of nutrient uptake that takes place as a result of mass transfer of ions through the transpirational system. The augmentative effect of irrigation and N on growth characters and yield components

resulted in greater uptake of nutrients which has culminated in increased yields. Similar results are reported by Purushothaman and Morachan (1974), Singh et al. (1983) and Singh and Kumar (1983).

Draining and reflooding the soil as was done in the case of I_2 and I_3 resulted in marked decrease in N uptake, apparently due to the lower N supply available to the crop as a result of possible denitrification losses of N as reported by Patrick and Mahapatra (1968) and this might have been one of the major reasons for a lower growth rate, development of yield components and in a lower grain yield of rice.

IR 50 out yielded CO 37 by 5.3 and 5.4 per cent during SWM 85 and Summer 86 seasons, respectively. This is attributable to higher production of panicles per unit area eventhough its grains were lighter than CO 37. This is in accordance with the observations of Muthukrishnan et al. (1983) who report that IR 50 had given comparable yield with CO 37 variety in Periyar-Vaigai project area. The IR 50 variety yielded well in both kharif and hara seasons in Chinsurah region (Sinha and Biswas, 1985).

The Summer 86 season grain yield at the optimum irrigation and N levels (continuous submergence

and 150 kg ha^{-1}) for both the varieties was higher than SWM 85, the increase being 6.2 per cent. The low temperature prevailed and low solar radiation received during reproductive period in SWM 85 might have retarded the growth as well as tiller productivity and ultimately the LMP and grain yield. Moreover the total leaf area particularly during the flowering phase of rice is a factor generally correlated to grain production as it affects the amount of photosynthates available to panicle. It is known that 75 to 80 per cent of carbohydrates in grain are directly correlated with photosynthates accumulation at flowering phase of rice (Yoshida and Ahn, 1968 and Yoshida, 1981). The LAI was low during SWM 85 compared to Summer 86. Interactions of irrigation with variety and N as well as variety with N were observed on grain yield during Summer 86. At all levels of N, I_1 yielded higher compared to I_2 which in turn was superior to severe moisture stress of I_3 . Similarly at all levels of irrigation, N applied at 150 kg ha^{-1} performed better than the lower level of 75 kg ha^{-1} and no N application. Grain yield obtained with N application at 75 kg ha^{-1} was also higher than with no N application. Subbiah et al. (1979), Singh et al. (1983) and Prihar (1985) report similar results. The variety IR 50 performed better than CO 37 at all levels of N applied.

The variety IR 50 performs well under all irrigation levels when N was not applied. When N was applied at 75 kg ha^{-1} the performance of IR 50 was better with moisture stress situations. At high level of N application (150 kg ha^{-1}) IR 50 performed better under severe stress situation. In all other situations the yield IR 50 was comparable with CO 37. This evidently shows the superiority of IR 50 over CO 37 especially under conditions of moisture stress.

During Summer, 66 continuous submergence required 1608 mm of water while irrigations done at one and three days after disappearance of water, only 973 and 847 mm of water, respectively (Table 87). The corresponding yield for the three irrigation levels were 4.44, 4.20 and 3.96 t ha^{-1} , with yield reduction under I_2 and I_3 being 5.6 and 11.1 per cent. Thus 39.5 per cent of water could be saved if irrigations are done to recoup submergence of 5 cm one day after disappearance of ponded water with grain yield reduction of only 5.6 per cent.

When water is a limiting factor it is desirable to get better benefit through scheduling irrigation of recouping submergence one day after disappearance of water than continuous submergence.

4.2.3. Straw yield (Table 86)

The response to N was positive upto the highest level tried viz., 225 kg ha⁻¹ as compared to the grain yield which tended to decline after 150 kg ha⁻¹ level of N application. Thus the beneficial effect of growth due to N application is realised only in straw yield at the expense of grain yield. Increased straw yield due to enhanced N application is reported by Sharma and De (1976), Pillai and De (1980a) and Somasundaram (1981). Straw yield recorded was the highest with continuous submergence in both the seasons. The straw yield with the variety IR 50 was higher than that of CO 37.

4.2.4. Water use efficiency - grain WUE (Table 89)

The WUE improves with applied N. It was highest with the application of N at 150 kg ha⁻¹ in both the seasons. It was 4.12 and 5.17 kg/mm for SWM 85 and Summer 86, respectively. Highest WUE was noticed with submerging the field one day after disappearance of ponded water in SWM 85.

In Summer 86 as well the WUE was higher with moisture stress, the efficiency being 2.79, 4.31 and 4.69 kg/mm, respectively, for the three irrigation levels. Eventhough WUE was highest with I₃ level of irrigation

TABLE 88. STRAW YIELD (KG HA⁻¹), SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	2478	2339	2408	2459	2377	2418	2468	2358	2414
N ₁	5355	5016	5186	4947	4555	4751	5151	4789	4970
N ₂	5813	5509	5661	5430	5358	5400	5622	5430	5526
N ₃	6170	5893	6032	5513	5651	5582	5842	5772	5807
Mean	4954	4689	4821	4588	4489	4538	4771	4587	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	57.87	53.60	53.80	76.09	81.87	85.02	81.87	89.04	
CD (P=0.05)	141.62	131.65	131.65	186.18	186.16	196.27	196.16	234.35	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	3192	2746	2969	2942	2544	2743	2762	2473	2618	2965	2588	2776
N ₁	5415	5464	5440	4755	4511	4633	4470	4427	4448	4880	4800	4841
N ₂	6792	6654	6724	6113	5733	5923	5492	5484	5488	6132	5957	6045
Mean	5133	4955	5044	4603	4263	4433	4241	4128	4185	4659	4448	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	35.78	54.82	78.69	77.52	88.75	97.98	67.66	80.00				
CD (P=0.05)	99.34	122.13	175.32	172.72	195.09	208.76	154.21	207.76				

TABLE 89. WATER USE EFFICIENCY (KG/HM), SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.56	1.38	1.47	2.43	2.42	2.43	2.00	1.90	1.95
N ₁	3.04	2.72	2.88	4.38	4.56	4.47	3.71	3.64	3.68
N ₂	3.35	3.18	3.26	4.46	5.48	4.97	3.91	4.33	4.12
N ₃	3.14	3.01	3.08	4.52	4.63	4.58	3.93	3.82	3.83
Mean	2.77	2.57	2.67	3.95	4.27	4.11	3.36	3.42	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.13	0.12	0.12	0.17	0.20	0.22	0.20	0.22	
CD (P=0.05)	0.32	0.29	N.S	0.42	0.45	0.49	0.45	0.55	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.79	1.53	1.66	2.92	2.50	2.71	3.09	2.75	2.92	2.60	2.26	2.43
N ₁	3.07	3.23	3.15	4.69	4.65	4.67	5.17	4.52	4.85	4.31	4.13	4.22
N ₂	3.62	3.51	3.57	5.59	5.53	5.56	6.23	6.36	6.30	5.15	5.13	5.14
Mean	2.83	2.76	2.79	4.40	4.23	4.31	4.83	4.54	4.69	4.02	3.84	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.07	0.13	0.11	0.20	0.24	0.27	0.18	0.22				
CD (P=0.05)	0.19	0.31	0.25	0.43	0.51	0.57	0.39	0.58				

N.S - Not significant

the yield reduction with this schedule was 11.1 per cent as compared to continuous submergence. The high efficiency is as a result of considerable reduction in water use.

Nitrogen x irrigation interaction was significant during Summer 86. Applied N improves WUE at all levels of irrigation.

4.2.5. Weed dry weight

Dry weight of weeds increased with enhancement in N levels (Table 90). The degree of water application had an inverse relationship with weed dry matter.

Higher amount of weed dry matter with moisture stress situations were due to unfavourable moisture regime for rice and favourable regime for weeds. Continuous submergence reduced the weed infestation considerably. This is in agreement with the reports of Moody (1977). Dry matter production of weeds was lesser in the case of IR 50 probably due to its quicker establishment and larger canopy in the early growth period as compared to CO 37.

Interactions of irrigation with N and variety were present during Summer 86. Application of both the inputs at higher quantities resulted in more dry weight

TABLE 90. WEED DRY WEIGHT (KG HA⁻¹), SEASONWISE
S.P. KONKUNOON, 1985

	I ₁		I ₂		Mean				
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂			
M ₀	88.10	87.87	87.98	93.57	100.97	97.27	90.85	94.42	92.63
M ₁	92.50	102.10	97.30	107.53	109.73	108.63	100.02	105.92	102.97
M ₂	102.20	112.33	107.27	116.80	119.93	118.37	109.50	116.13	112.82
M ₃	120.30	129.37	124.83	136.60	140.03	138.32	128.45	134.70	131.58
Mean	100.78	107.92	104.35	113.63	117.67	115.65	107.20	112.79	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	1.22	0.96	0.96	1.36	1.56	1.54	1.56	1.54	
CD(P=0.05)	2.98	2.35	2.35	3.33	N.S	N.S	N.S	N.S	

SUMMER, 1986

	I ₁		I ₂		I ₃		Mean					
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂				
M ₀	90.07	93.77	91.92	95.53	96.20	95.87	97.50	105.30	101.60	94.37	98.42	96.39
M ₁	97.73	100.03	98.68	103.20	108.37	105.78	103.27	114.33	108.80	101.40	107.58	104.49
M ₂	105.00	109.37	107.18	115.53	116.80	116.17	122.20	127.97	125.08	114.24	118.04	116.14
Mean	97.60	101.06	99.33	104.76	107.12	105.14	107.66	115.87	111.76	103.34	108.01	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.57	0.65	0.53	0.92	0.93	1.01	0.75	0.83				
CD(P=0.05)	1.40	1.45	1.19	2.05	2.13	2.18	N.S	N.S				

N.S - Not significant

of weeds. The weed infestation was heavier with CO 37 at all levels of irrigation than IR 50.

4.2.6. Nutrient uptake by rice (Tables 91a, b and c)

4.2.6.1. Nitrogen: The uptake of N during flowering and harvest stages were found to increase with enhancement in levels of N. The higher uptake of N noticed might be due to higher DMP and also more root growth which might have increased the absorption. Similar results are reported by several workers (Mani, 1979; Salam, 1984 and Haddy, 1985).

Water controls the degree of availability, form, rate of movement and extent of uptake of nutrients. The uptake of N was highest with continuous submergence and it was very much reduced when intervals between irrigations were increased. Draining and reflooding the soil caused a marked decrease in N uptake by rice plants. This decrease was apparently due to the lower N supply available to the crop as a result of denitrification brought out by draining and reflooding. NO_3^- formed where the soil became aerated was probably lost through denitrification as well as leaching when the soil was reflooded. Such decreased N uptake is reported by several workers (Patrick et al., 1967; Joshi and Sharma, 1980 and Erickson et al., 1985). The decrease in uptake with increase in stress could also

TABLE 91a. NITROGEN UPTAKE (KG HA⁻¹), STAGewise AND SEASONWISE
S.W. MONSOON, 1985
FLOWERING

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	50.87	58.67	54.77	52.05	54.60	53.72	51.85	56.63	54.24
N ₁	64.33	68.03	66.58	61.27	65.00	63.13	62.80	66.92	64.86
N ₂	78.53	80.90	79.72	67.27	77.40	72.33	72.90	79.15	76.03
N ₃	87.53	94.47	91.00	77.43	80.60	79.02	82.48	87.53	85.01
Mean	70.32	75.72	73.02	64.70	69.40	67.05	67.51	72.56	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	1.61	0.59	0.59	0.84	1.90	1.39	1.90	1.39	
CD (P=0.05)	3.93	1.45	1.45	N.S	4.47	2.99	N.S	N.S	

SUMMER, 1985

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	69.43	70.73	70.08	68.47	62.03	65.25	58.03	54.63	56.33	65.33	62.47	63.89
N ₁	82.00	80.70	81.35	72.40	78.53	75.47	67.67	58.43	63.05	74.02	72.56	73.29
N ₂	97.77	96.40	97.08	82.77	91.63	87.20	73.57	63.60	68.59	84.70	83.88	84.29
Mean	83.07	82.61	82.84	74.55	77.40	75.98	66.42	58.89	62.66	74.68	72.97	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	1.04	1.64	1.34	2.31	1.66	1.08	1.39	1.70				
CD (P=0.05)	2.90	3.65	N.S	5.16	3.92	4.53	N.S	N.S				

S.W. MONSOON, 1985

HARVEST

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	68.63	71.77	70.20	62.87	66.00	64.43	65.75	68.88	67.32
N ₁	82.70	88.47	85.58	81.13	83.33	82.23	81.92	85.90	83.91
N ₂	99.10	102.17	100.63	98.13	97.13	97.63	98.62	99.65	99.13
N ₃	116.53	126.93	121.68	108.17	114.53	111.35	112.35	120.68	116.52
Mean	91.74	97.31	94.53	87.58	90.25	88.91	89.66	93.78	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	1.04	0.88	0.88	1.25	1.33	1.34	1.33	1.34	
CD (P=0.05)	2.56	2.16	2.16	N.S	3.09	3.02	3.09	3.46	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	78.65	81.37	80.00	66.60	76.33	71.47	74.90	71.20	73.05	73.38	76.30	74.84
N ₁	95.60	108.00	101.80	85.65	93.37	89.50	87.17	89.10	88.23	89.47	96.89	93.18
N ₂	127.13	136.70	131.92	116.70	119.37	117.53	112.17	113.40	112.78	118.67	127.82	120.74
Mean	100.46	108.69	104.57	89.64	96.02	92.83	91.41	91.30	91.36	93.84	98.67	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	1.22	1.52	1.24	2.15	1.73	1.96	1.96	1.60				
CD (P=0.05)	3.58	3.59	2.77	4.79	4.42	4.25	3.93	4.43				

N.S - Not significant

be attributed to decreased transpiration and possibly more on the physiological impairment of the nutrient absorption and transport mechanism in the roots (Tangullig et al., 1985). The N uptake at flowering was higher with CO 37 during SWM 85 whereas it was non significant between varieties in Summer 86. The N uptake with CO 37 was higher than IR 50 during both the seasons though the DWP was higher with IR 50 at flowering in SWM 85, evidently the increase in uptake was due to its nutrient content.

Interactions of irrigation with variety and N as well as N with variety were found to be present in one or the other stages in SWM 85 or Summer 86 season. For both irrigation and N levels, higher uptake was noticed when they were applied at their respective higher levels. The variety CO 37 recorded more N uptake than IR 50 either with higher levels of irrigation or N. It could be pointed out here that the water stress due to irrigating three days after disappearance of water occurred in Summer 86 at a very sensitive yield determining stage like flowering had a very detrimental effect on yield (Haiao, 1982) and the interaction of irrigation and N uptake, foliage development and resulting stress severity may be more closely related to yield loss (O'Toole and Padilla, 1984).

4.2.6.2. Phosphorus: Application of N increased P uptake. Nitrogen at the highest dose recorded the highest uptake in both the seasons followed by the other N levels. Continuous submergence of fields resulted in higher uptake and the lowest was seen in case of irrigating three days after disappearance of water. The latter might be due to reduction in the solubilization of phosphates under inadequate moisture conditions and poor growth of root and shoot. Iruthayaraj (1975) and Kakade and Sonar (1983) observe that P uptake was higher with continuous submergence than with other irrigation levels. The variety IR 50 registered an increase in P uptake over CO 37 during SWM 85 whereas the reverse was the case during Summer 86.

4.2.6.3. Potassium: The K uptake was higher with CO 37 than IR 50 at flowering as well as during harvest. However, during SWM 85 the uptake at harvest between two varieties was comparable. N applied at the highest dose and continuous submergence recorded the highest K uptake at flowering and harvest stages during SWM 85 and Summer 86 seasons. Increased K uptake was due to increased DMF with higher levels of N as reported by Balasubramanian (1978) and Mani (1979). Patil and Ghildyal (1983) find that maximum uptake of K was with submergence compared to unsaturated conditions.

TABLE 91 b. PHOSPHORUS UPTAKE (KG HA^{-1}), STAGEWISE AND SEASONWISE
S.W. MONSOON, 1965
FLOWERING

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	5.53	4.73	5.13	5.50	4.23	4.87	5.52	4.48	5.00
N ₁	5.83	4.80	5.32	5.80	4.70	5.25	5.82	4.75	5.28
N ₂	6.40	5.20	5.82	6.30	5.13	5.72	6.35	5.18	5.77
N ₃	6.57	5.57	6.07	6.57	5.32	5.95	6.57	5.43	5.98
Mean	6.38	5.08	5.73	6.34	4.97	5.63	6.36	4.95	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	
CD (P=0.05)	0.06	0.04	0.04	0.06	0.08	0.07	N.S.	N.S.	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	7.47	7.33	7.40	6.37	7.43	6.90	7.07	6.53	6.80	6.97	7.10	7.03
N ₁	7.77	7.50	7.63	7.10	7.57	7.33	7.37	7.07	7.22	7.14	7.38	7.39
N ₂	8.33	8.13	8.23	7.43	8.53	7.98	8.20	8.17	8.18	7.99	8.28	8.13
Mean	7.86	7.66	7.76	6.97	7.84	7.41	7.54	7.26	7.40	7.46	7.59	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.04	0.03	0.03	0.05	0.07	0.06	0.06	0.06	0.06			
CD (P=0.05)	0.12	0.07	0.06	0.10	0.16	0.14	0.14	0.09				

S.W. MONSOON, 1965
HARVEST

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	17.70	14.80	16.25	18.17	16.63	17.40	19.73	15.72	16.83
N ₁	21.30	16.40	18.85	19.60	18.60	19.10	20.45	17.50	18.98
N ₂	21.43	18.40	19.92	23.30	22.27	22.78	22.37	20.33	21.35
N ₃	22.47	18.20	20.33	24.10	23.37	23.73	23.28	20.78	22.03
Mean	20.73	16.95	18.84	21.29	20.22	20.75	21.01	18.58	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.04	0.02	0.02	0.02	0.05	0.04	0.05	0.04	
CD (P=0.05)	0.09	0.04	0.04	0.06	0.11	0.08	0.11	0.07	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	19.37	19.23	19.30	18.37	20.17	19.27	19.23	18.73	18.98	18.99	19.38	19.18
N ₁	20.23	19.63	19.93	18.77	21.47	20.12	20.17	19.07	19.62	19.72	22.06	19.99
N ₂	23.47	22.20	22.83	21.40	24.57	22.98	22.37	21.70	22.03	22.41	22.82	22.62
Mean	21.02	20.36	20.69	19.51	22.07	20.79	20.59	19.83	20.21	20.37	20.75	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.11	0.07	0.05	0.09	0.13	0.09	0.12	0.08				
CD (P=0.05)	0.30	0.15	0.12	0.21	0.32	0.20	N.S.	N.S.				

N.S - Not significant

TABLE 91c. POTASSIUM UPTAKE (KG HA⁻¹), STAGEWISE AND SEASONWISE
FLOWERING
S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	55.50	55.90	55.70	57.17	55.77	56.47	56.33	55.83	56.08
N ₁	65.33	71.40	68.37	64.47	76.63	67.55	64.90	71.02	67.96
N ₂	89.00	91.00	90.00	78.37	84.47	81.42	83.68	87.73	85.71
N ₃	92.50	96.13	94.32	83.67	93.74	88.70	88.98	94.93	91.51
Mean	75.58	78.61	77.10	70.92	76.15	73.53	71.25	77.38	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	1.39	0.98	0.98	1.38	1.71	1.56	1.71	1.56	
CD (P=0.05)	3.41	2.39	2.39	N.S	3.98	3.48	3.98	3.46	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	77.97	82.47	80.22	71.40	70.33	71.07	64.70	72.03	68.37	71.36	75.08	73.22
N ₁	90.97	93.27	92.12	87.47	93.47	90.77	78.93	76.63	77.88	85.79	88.02	86.91
N ₂	113.00	111.50	112.25	102.27	109.37	106.12	89.93	97.00	93.47	101.73	106.16	103.95
Mean	93.98	95.74	94.86	87.04	91.56	89.30	77.86	81.96	79.91	86.29	89.75	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	0.84	1.22	1.00	1.73	1.62	1.85	1.29	1.51				
CD (P=0.05)	2.33	2.73	2.23	N.S	3.69	3.98	N.S	N.S				

HARVEST

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	68.93	70.47	69.70	63.23	65.97	64.60	66.08	68.21	67.15
N ₁	79.23	82.07	80.65	71.47	79.73	75.60	75.35	80.90	78.13
N ₂	97.70	96.97	97.33	97.77	96.27	97.02	97.73	96.62	97.18
N ₃	114.77	113.00	113.88	112.23	111.43	111.83	113.50	112.22	112.85
Mean	90.16	90.63	90.39	86.18	88.35	87.26	88.17	89.49	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.49	1.09	1.09	1.54	1.08	1.61	1.08	1.61	
CD (P=0.05)	1.21	2.67	N.S	N.S	N.S	N.S	2.36	6.18	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	96.27	107.20	101.73	83.93	94.00	88.97	93.17	92.83	93.00	91.12	98.01	94.57
N ₁	100.63	117.57	109.10	99.07	98.40	98.73	96.60	97.87	97.23	98.77	104.61	101.69
N ₂	119.73	131.40	125.57	112.07	113.57	112.82	110.97	111.20	111.08	114.26	118.72	116.45
Mean	105.54	118.72	112.13	98.36	101.99	100.17	100.24	100.63	100.44	101.38	107.11	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	1.33	2.27	1.85	3.21	1.93	2.66	1.66	2.17				
CD (P=0.05)	3.69	5.05	4.13	1.75	N.S	N.S	N.S	N.S				

N.S - Not significant

4.2.7. Response to N and percentage recovery of applied N

4.2.7.1. Response to N (Table 92)

The response was not increased substantially beyond 75-150 kg N ha⁻¹. Further increase in N resulted in a decrease in grain production per kg of applied N. Similar decrease in response at higher levels of N is reported by Pillai and De (1980b).

Submerging the field three days after disappearance of ponded water (I₃) resulted in very low response to N in Summer 86. This was due to the fact that it also recorded lowest N uptake and grain yield. The variety CO 37 registered more response to applied N than IR 50 in both the seasons.

Data on interaction effect between irrigation and N reveal that 75 kg N ha⁻¹ with either of irrigation levels (continuous submergence or irrigating one day after disappearance of water) produced the highest grain yield per kg applied N. This beneficial effect was not pronounced at higher levels of N. With regard to the interaction of variety with irrigation or N observed during Summer 86 it was seen that CO 37 was having high response to applied N than IR 50 with either of the irrigation levels or N applied.

TABLE 92. RESPONSE TO APPLIED N, SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	30.77	30.09	30.43	30.44	30.01	30.23	30.61	30.05	30.33
N ₂	20.05	19.56	19.85	19.85	19.79	19.82	19.94	19.73	19.83
N ₃	12.13	11.56	11.85	12.09	11.55	11.82	12.11	11.56	11.83
Mean	20.96	20.44	20.71	20.79	20.45	20.62	20.89	20.45	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.22	0.39	0.39	0.55	0.46	0.60	0.46	0.60	
CD(P=0.05)	0.62	0.96	N.S	N.S	1.06	1.38	1.06	2.06	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	24.92	31.15	28.04	23.56	27.07	25.32	17.53	19.31	18.42	22.00	25.84	23.92
N ₂	17.05	20.14	18.60	17.20	19.71	18.46	18.11	18.71	18.41	17.45	19.52	18.49
Mean	20.99	25.65	23.32	20.38	23.39	21.89	17.82	19.01	18.42	19.73	22.68	
	N	I	V	IxV	N at I	I at N	N at V	V at N				
SED	0.14	0.22	0.18	0.31	0.20	0.25	0.17	0.21				
CD(P=0.05)	0.60	0.50	0.40	0.70	0.64	0.56	0.62	0.67				

N.S - Not significant

TABLE 93. RESPONSE EQUATIONS OF RICE TO N UNDER DIFFERENT WATER MANAGEMENT PRACTICES, SEASONWISE

S.W. MONSOON, 1985

		Quadratic response equations		Economic optimum dose (kg ha ⁻¹)
a. IR 50 (V ₁)	I ₁ Continuous submergence	Y = 23.932 + 0.37679 X - 0.001148 X ²		151.0
	I ₂ Submerging one day after disappearance of water	Y = 23.538 + 0.3721 X - 0.001129 X ²		151.5
b. CO 37 (V ₂)	I ₁ Continuous submergence	Y = 22.223 + 0.3737 X - 0.001157 X ²		148.5
	I ₂ Submerging one day after disappearance of water	Y = 21.444 + 0.3755 X - 0.001164 X ²		148.4
SUMMER, 1986				
a. IR 50 (V ₁)	I ₁ Continuous submergence	Y = 28.05 + 0.3279 X - 0.001049 X ²		142.0
	I ₂ Submerging one day after disappearance of water	Y = 26.361 + 0.2992 X - 0.000848 X ²		158.7
	I ₃ Submerging three days after disappearance of water	Y = 20.50 + 0.3071 X - 0.0008 X ²		173.2
b. CO 37 (V ₂)	I ₁ Continuous submergence	Y = 21.922 + 0.4210 X - 0.001468 X ²		133.4
	I ₂ Submergence one day after disappearance of water	Y = 21.847 + 0.3443 X - 0.00098 X ²		160.1
	I ₃ Submerging three days after disappearance of water	Y = 24.664 + 0.2864 X - 0.000747 X ²		171.7

Y = Grain yield (q ha⁻¹)
X = Nitrogen (kg ha⁻¹)

Economic optimum dose = $\frac{1}{2c} \left(\frac{a}{p} - b \right)$
Where p = Price of 1 unit of output (grain) = Rs.150 q⁻¹
q = Price of 1 unit of input (N) = Rs.4.5 kg⁻¹
b and c are the regression coefficients

The underlying relationship between the grain yield and response and the dose of N was studied with the help of a second degree polynomial. The actual response to added N at incremental doses of N application was worked out and presented in Table 93. Under the assumption that the response curve is a second degree parabola, $Y = bx + cx^2$, the optimum dose of N application for each irrigation level and variety was worked out seasonwise and the response equations and the optimum doses are presented in Table 93.

The economic optimum dose of N was more or less similar for the same variety under the two irrigation levels in SWM 85. For IR 50 with continuous submergence and submerging one day after disappearance of water the economic optimum doses of N (kg ha^{-1}) were 151.0 and 151.5 whereas for CO 37 they were 148.5 and 148.4, respectively.

During Summer 86 season the economic optimum dose of N (kg ha^{-1}) under continuous submergence was lower for both the varieties than observed during SWM 85. But with less frequent irrigations a higher dose was required to obtain the economic optimum values. For IR 50 the economic optimum doses of N under continuous submergence, and irrigating one and three days after disappearance of

water were 142.0, 158.7 and 171.7 kg ha⁻¹, respectively. For the variety CO 37 the doses were 133.4, 160.1 and 173.2 kg ha⁻¹, respectively. The high economic optimum dose noticed during Summer 86 may be due to more mineralisation and uptake taking place in this season.

A comparison between seasons indicate that the response of rice to N was high in the Summer 85. At the early stage of plant growth, high temperature, low sunshine hours per day and more cloudy day exist during SWM 85, whereas during Summer 86 sometimes the temperature is also wide. Alternating temperature between 30-20°C has been reported to accumulate more protein N in the rice plant than at 30-18°C (Iakesima et al., 1961). Thus application of N during Summer 86 season enhances more rapidly the growth of the plant and thereby the response to applied N is increased.

4.2.7.2. Percentage recovery of applied N (Table 94)

The percentage recovery of applied N was found to be not affected by levels of N in both the seasons. However, N applied at 75 or 150 kg ha⁻¹ recorded the highest N recovery. Continuous submergence resulted in 16.0 and 29.7 per cent more recovery than irrigating at one or three days after disappearance of water during Summer 86.

TABLE 94. PERCENTAGE RECOVERY OF APPLIED N SEASONWISE

S. W. MORISON, 1985

	I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₁	18.80	22.30	24.37	23.13	23.75	21.58
N ₂	20.30	20.27	20.53	20.30	21.92	20.42
N ₃	21.30	24.50	22.90	21.57	20.87	20.73
Mean	20.13	22.36	21.24	21.67	22.18	20.91
	N	I	IxV	N at I	N at I	N at V
SED	0.64	0.72	1.01	0.83	0.93	0.83
CD(P=0.05)	N.S	N.S	N.S	2.10	2.19	2.10

SUMMER, 1986

	I ₁		I ₂		I ₃		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₁	22.63	31.07	26.85	25.37	19.07	22.22	19.47	20.80
N ₂	32.33	36.90	34.62	33.40	28.03	30.72	26.40	28.13
Mean	27.48	33.98	30.73	29.38	23.55	26.47	22.93	24.47
	N	I	V	IxV	N at I	N at I	N at V	N at V
SED	1.95	1.10	0.89	1.55	2.06	1.23	2.01	1.01
CD(P=0.05)	N.S	2.44	N.S	1.99	N.S	N.S	N.S	N.S

N.S = Not significant

The low recovery noticed in these treatments may be due to poor root growth as a result of frequent soil drying cycle. Mohankumar and Singh (1984) report such reduction due to soil drying. The interactions of N with irrigation or variety was present during SWM 85. Application of 75 kg N ha^{-1} with either of the irrigation levels produced comparatively more percentage recovery of applied N. The variety CO 37 recorded more recovery with the application of N than that of IR 50.

4.2.8. Economics of production

4.2.8.1. Gross return, net return and benefit cost ratio

(Table 95)

Substantial increase in gross return was noticed due to N application upto 150 kg ha^{-1} beyond which a decline was seen during SWM 85. Continuous submergence resulted in higher gross return due to higher grain yield. The variety IR 50 had higher gross return in both the seasons compared to CO 37.

Net return also increased due to N application upto a level of 150 kg ha^{-1} after which a reduction occurred. Net return was highest with I_2 wherein irrigation was given one day after disappearance of ponded water. This was due to comparatively higher grain yield with less amount of water required in this treatment.

Table 95. CROSS RETURN (RS BA⁻¹), SEASONWISE

S.W. MONSOON, 1905

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	3913	3645	3779	3852	3540	3696	3981	3593	3778
N ₁	7867	7432	7650	7650	7243	7447	7759	7350	7548
N ₂	8921	8544	8733	8765	8438	8602	8843	8491	8667
N ₃	8562	8081	8322	8341	7929	8160	8477	8005	8241
Mean	7316	6926	7121	7345	6791	6976	7241	6877	7057
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y
SD	60.66	55.72	55.72	78.51	90.57	99.33	90.57	90.57	99.33
CD(P=0.05)	149.45	135.05	135.05	192.12	204.54	219.42	204.50	204.50	251.00

SHOWR, 1906

	I ₁			I ₂			I ₃			Mean	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	2079	4250	4666	4713	4031	4372	4394	3948	4171	4729	4076
N ₁	8216	8162	8189	7636	7371	7504	7243	6414	6829	7690	7316
N ₂	9456	9368	9412	9059	8943	9001	8727	8609	8668	9081	8973
Mean	7584	7260	7432	7136	6782	6959	6708	6324	6556	7169	6789
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y		
SD	24.09	22.59	18.43	31.95	40.83	39.96	33.52	32.63			
CD(P=0.05)	66.87	50.34	41.09	71.19	94.97	85.18	81.86	66.64			

NET RETURNS (RS BA⁻¹), SEASONWISE

S.W. MONSOON, 1905

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	-353	-698	-526	147	-87	30	-103	-393	-248
N ₁	3244	2708	2976	3511	3195	3353	3378	2952	3165
N ₂	3895	3503	3699	4152	4085	4119	4024	3794	3909
N ₃	3176	2726	2951	3513	3146	3350	3345	2936	3147
Mean	2491	2060	2275	2831	2595	2708	2661	2323	
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y
SD	103.82	95.75	95.75	110.43	126.08	117.36	126.08	117.36	
CD(P=0.05)	254.09	234.32	234.32	270.22	294.47	284.54	294.47	278.87	

SHOWR, 1906

	I ₁			I ₂			I ₃			Mean	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	614	-169	223	986	308	647	785	331	558	795	197
N ₁	3521	3557	3539	3569	3324	3445	3307	2478	2895	3464	3120
N ₂	4478	4355	4417	4663	4544	4604	4457	4368	4413	4533	4422
Mean	2871	2581	2726	3071	2725	2898	2850	2392	2621	2931	2566
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y		
SD	20.13	20.41	16.67	28.87	42.26	42.40	33.10	34.60			
CD(P=0.05)	55.87	45.48	37.13	64.31	94.77	89.84	77.49	75.85			

BENEFIT COST RATIO, SEASONWISE

S.W. MONSOON, 1905

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	0.92	0.84	0.88	1.04	0.98	1.01	0.98	0.91	0.95
N ₁	1.70	1.57	1.64	1.95	1.79	1.82	1.78	1.68	1.73
N ₂	1.77	1.69	1.73	1.90	1.84	1.82	1.74	1.82	1.83
N ₃	1.59	1.51	1.55	1.72	1.66	1.69	1.66	1.58	1.62
Mean	1.50	1.40	1.45	1.63	1.59	1.61	1.57	1.50	
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y
SD	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	
CD(P=0.05)	0.05	0.04	0.04	0.05	0.07	0.07	0.07	0.08	

SHOWR, 1906

	I ₁			I ₂			I ₃			Mean	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	1.14	0.96	1.05	1.26	1.08	1.17	1.22	1.09	1.16	1.21	1.04
N ₁	1.78	1.77	1.76	1.88	1.82	1.85	1.84	1.63	1.74	1.82	1.74
N ₂	1.90	1.87	1.89	1.91	2.03	1.92	2.04	2.00	2.04	1.92	1.98
N ₃	1.60	1.53	1.57	1.65	1.64	1.65	1.70	1.58	1.64	1.65	1.59
N	I	Y	z ₁ Y	N at I	I at N	N at Y	Y at N	Y at I	Y at Y		
SD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD(P=0.05)	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01

The variety IR 50 recorded higher net return than CO 37 in both the seasons. Benefit cost ratio was also influenced due to N and irrigation treatments. A similar trend as that of net return was found with respect to benefit cost ratio in both the seasons.

Crops raised during Summer 86 season had more gross and net returns and benefit cost ratio compared to SWN 85 and this was due to the higher grain and straw yield recorded in spite of higher water consumed during the Summer 86 season.

4.2.8.2. Economics of water and nitrogen (Table 96)

The net return per rupee invested on water decreased with higher levels of irrigation. Submerging one or three days after disappearance of ponded water recorded an increase in return of Rs.1.18 and 1.38 during SWN 85 and Summer 86 season, respectively, over continuous submergence. Application of N at 150 kg ha^{-1} also resulted in higher return per rupee invested on water in both the seasons. The data also revealed that there were interactions of N with irrigation and varieties in both the seasons.

In the case of net return per rupee invested on N also a similar trend was noticed with respect to irrigation. Submerging one day after disappearance of ponded water

TABLE 96. RETURN PER RUPEE ON WATER, SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	0.77	0.56	0.67	1.15	0.90	1.03	0.96	0.73	0.85
N ₁	3.17	2.65	2.88	4.34	4.33	4.34	3.73	3.49	3.61
N ₂	3.43	3.17	3.30	4.49	5.40	4.95	3.96	4.29	4.12
N ₃	2.96	2.71	2.84	4.15	4.08	4.12	3.56	3.40	3.48
Mean	2.57	2.27	2.42	3.53	3.68	3.60	3.05	2.98	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.07	0.09	0.09	0.12	0.17	0.21	0.17	0.21	
CD (P=0.05)	0.17	0.21	N.S	0.30	0.38	0.46	0.38	0.52	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.36	0.90	1.13	2.01	1.32	1.67	1.91	1.38	1.65	1.76	1.20	1.48
N ₁	3.19	3.34	3.27	4.63	4.47	4.55	4.90	3.92	4.41	4.24	3.91	4.08
N ₂	3.88	3.74	3.81	5.80	5.67	5.74	6.27	6.35	6.31	5.32	5.25	5.29
Mean	2.81	2.66	2.74	4.15	3.82	3.99	4.36	3.88	4.12	3.77	3.45	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.10	0.14	0.11	0.19	0.23	0.25	0.18	0.20				
CD (P=0.05)	0.27	0.31	0.25	0.43	0.51	0.53	0.40	0.52				

RETURN PER RUPEE ON N, SEASONWISE

S.W. MONSOON, 1985

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	10.60	9.01	9.81	11.39	10.45	10.92	11.00	9.73	10.37
N ₂	6.77	6.19	6.48	7.15	7.05	7.10	6.96	6.62	6.79
N ₃	4.14	3.69	3.92	4.47	4.11	4.29	4.31	3.90	4.11
Mean	7.17	6.30	6.73	7.67	7.20	7.44	7.42	6.75	
N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.16	0.18	0.18	0.26	0.28	0.32	0.28	0.32	
CD (P=0.05)	0.45	0.44	0.44	0.63	0.66	0.71	0.66	0.85	

SUMMER, 1986

	I ₁			I ₂			I ₃			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	11.42	11.52	11.47	11.54	10.83	11.19	10.78	8.33	9.56	11.25	10.23	10.7
N ₂	7.63	7.45	7.54	7.91	7.73	7.82	7.60	7.47	7.54	7.71	7.55	7.6
Mean	9.53	9.49	9.51	9.73	9.28	9.51	9.19	7.90	8.55	9.48	8.89	
N	I	V	IxV	N at I	I at N	N at V	V at N					
SED	0.04	0.08	0.06	0.11	0.09	0.10	0.07	0.08				
CD (P=0.05)	0.18	0.17	0.14	0.24	0.24	0.23	0.21	0.27				

N.S - Not significant

resulted in higher net return per rupee invested on N in both the seasons. A reduction in net return per rupee invested on N was observed with increase in level of N beyond 75 kg ha⁻¹.

Return per rupee invested on water and N was high during Summer 86 than in SWM 85. Thus during Summer for profitable use of water, higher dose of N should be applied compared to SWM season. From the data it could be suggested that a higher application of N need be done for profitable use of water when the availability of water is not so abundant.

NORTH EAST MONSOON 1985

The experiment conducted during SWM 1985 was repeated with the same irrigation and N treatments with a change of varieties accommodating medium duration rice cultures IR 20 and CO 44.

4.2.9. Growth characters

4.2.9.1. Height of plant (Table 97)

An increase in plant height due to N application was noticed in all stages. The plant height increased with the age of the crop. Irrigation influenced the plant height during flowering and harvest stages. Continuous

TABLE 97. — HEIGHT OF PLANT (CM), STAGE WISE (N.E. MONSOON, 1965)

40 DAT									
	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	46.81	44.62	45.72	45.45	44.35	44.90	46.13	44.49	45.31
N ₁	57.49	58.11	58.03	55.15	54.99	55.07	56.57	56.55	56.56
N ₂	60.13	61.31	60.72	60.71	59.03	59.87	60.42	60.17	60.30
N ₃	63.06	65.93	64.90	68.53	63.14	65.84	65.80	65.54	65.17
Mean	56.99	57.49	57.24	57.46	55.38	56.42	57.23	56.44	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.30	0.34	0.30	0.48	0.58	0.63	0.58	0.63	
CD(P=0.05)	0.35	N.S	N.S	1.18	1.32	1.40	N.S	N.S	

FLOWERING									
	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	57.33	56.29	56.81	55.94	54.90	55.42	56.64	55.60	56.12
N ₁	62.41	61.74	62.08	63.27	63.81	63.54	62.84	62.78	62.81
N ₂	68.21	66.21	67.81	67.06	65.27	66.17	67.64	65.74	66.69
N ₃	70.43	73.56	71.99	70.69	69.38	70.04	70.56	71.47	71.02
Mean	64.60	64.45	64.52	64.22	63.34	63.79	64.42	63.90	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.67	0.29	0.29	0.41	0.86	0.70	0.86	0.70	
CD (P=0.05)	1.65	0.70	N.S	N.S	1.98	1.52	N.S	N.S	

HARVEST									
	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	60.34	59.81	60.08	59.11	63.58	61.35	59.73	61.70	60.71
N ₁	73.02	68.35	70.19	73.25	67.12	70.19	72.63	67.74	70.19
N ₂	75.58	74.83	75.20	76.18	70.64	73.41	75.88	72.74	74.31
N ₃	81.92	80.91	81.42	81.18	76.76	78.97	81.55	78.84	80.19
Mean	72.46	70.98	71.72	72.43	69.53	70.98	72.45	70.25	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.83	0.25	0.25	0.35	0.93	0.58	0.93	0.58	
CD (P=0.05)	2.07	0.61	0.61	0.87	2.21	1.25	2.21	0.68	

N.S - Not significant

submergence proved beneficial in increasing the plant height. The variety IR 20 was taller than CO 44 at the time of harvest. Interactions among irrigation, variety and N were noticed during one stage or other. The variety IR 20 produced plants with more height at all levels of irrigation and N levels than CO 44. Plant height was found to increase with increase in the levels of inputs like water and N. The augmentative effect of water and N on plant height was well established.

4.2.9.2. Number of tillers per hill (Table 98)

The tiller production was influenced by N application and variety during 40 DAT and flowering stage and it was similar in case of irrigation levels. The tiller production was more with increase in application of N, but at 225 kg N ha^{-1} the tillers were fewer than at 150 kg ha^{-1} . The variety CO 44 produced more tillers than IR 20.

Interactions of irrigation with variety and N were present during 40 DAT and flowering stages, respectively. CO 44 at continuous submergence and N application produced more tillers than IR 20 with the same irrigation or N level.

TABLE 11. MEAN OF TILLERS HILL⁻¹, STAGE WISE (N.E. MONSOON, 1965)
40 DAT

	I ₁		Mean	I ₂		Mean	Mean		Mean	
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	V ₁	V ₂
N ₀	7.25	7.48	7.37	6.92	7.25	7.09	7.09	7.09	7.37	7.25
N ₁	8.05	9.32	8.69	7.65	9.33	8.58	7.94	9.33	8.64	8.64
N ₂	9.33	10.32	9.83	9.42	10.12	9.77	9.58	10.22	9.90	9.90
N ₃	10.05	11.36	10.71	9.75	10.65	10.20	9.90	11.01	10.46	10.46
Mean	8.67	9.62	9.15	8.43	9.34	8.91	8.65	9.48		
	N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.15	0.09	0.09	0.12	0.20	0.18	0.20	0.18		
CD (P=0.05)	0.38	N.S	0.25	0.29	N.S	N.S	N.S	N.S		

FLOWERING

	I ₁		Mean	I ₂		Mean	Mean		Mean	
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	V ₁	V ₂
N ₀	7.67	7.58	7.63	8.00	8.00	8.00	7.83	7.79	7.61	7.61
N ₁	8.33	9.58	8.96	9.75	9.67	9.71	9.04	9.63	9.33	9.33
N ₂	8.83	12.17	10.50	10.08	11.50	10.79	9.46	11.83	10.65	10.65
N ₃	11.33	13.17	12.25	10.85	12.25	11.54	11.00	12.71	11.90	11.90
Mean	9.04	10.63	9.83	9.67	10.35	10.01	9.35	10.49		
	N	I	V	IxV	N at I	I at N	N at V	V at N		
SED	0.23	0.15	0.15	0.21	0.27	0.22	0.27	0.22		
CD (P=0.05)	0.56	N.S	0.36	0.50	0.63	0.50	0.63	0.46		

N.S = Not significant

4.2.9.3. Leaf area index (LAI) (Table 99)

Application of N and water favourably influenced LAI at 40 DAT and flowering stages. A linear increase in LAI with N fertilization was noticed. Continuous submergence recorded greater LAI than irrigating one day after disappearance of ponded water. The variety IN 20 had higher LAI than CO 44 either individually or in combination with inputs like water and N.

If we ignore the varietal differences the LAI produced at 40 DAT was more than either during SWM 85 or Summer 86 seasons. Later at flowering stage a reduction in LAI during NEM 85 compared to these seasons was noticed.

4.2.9.4. Maximum root length (Table 100)

Root length was affected only by the application of N. A slight increase in root length was noticed at flowering stage compared to 40 DAT. However, there was no appreciable change in root length with N applied at 225 kg ha^{-1} between these two stages.

4.2.9.5. Root dry weight (Table 100)

Dry weight of root increased with N application and irrigation levels. Recouping 5 cm submergence one day after disappearance of ponded water (I_2) was found to record

TABLE 99. ISAP AREA INDEX, STAGEWISE (N.E. MONSOON, 1985)
40 DAT

	I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	2.62	2.39	2.04	3.08	2.53	2.74
N ₁	4.09	3.24	3.66	4.40	3.68	3.73
N ₂	5.86	4.43	4.53	5.05	5.20	4.74
N ₃	6.74	5.51	5.33	5.25	6.04	5.30
Mean	4.83	3.94	3.89	4.36	4.36	4.15
	N	I	Y	I x Y	N at I	I at N
SED	0.07	0.08	0.08	0.11	0.10	0.12
CD (P=0.05)	0.17	0.20	0.20	0.28	0.23	0.27
					N at Y	Y at N

	I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	2.89	2.67	3.37	2.54	2.96	2.61
N ₁	4.61	4.57	4.68	4.50	4.59	4.54
N ₂	6.63	5.69	5.31	5.18	5.25	5.44
N ₃	7.47	6.92	6.54	6.02	6.28	6.47
Mean	5.40	4.96	4.97	4.56	4.77	4.76
	N	I	Y	I x Y	N at I	I at N
SED	0.08	0.05	0.05	0.07	0.10	0.09
CD (P=0.05)	0.19	0.13	0.13	0.18	0.21	0.20
					N at Y	Y at N

FLOWERING

TABLE 100. ROOT LENGTH (CM), STAGNITE (H. B. MONSOON, 1985)

40 DAT

	I ₁		I ₂		Mean		I ₁		I ₂		Mean		I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	15.87	15.29	16.07	15.34	15.98	15.66	16.10	15.63	15.87	1.06	1.10	1.08	1.00	1.09	1.05	1.03	1.10	1.06
N ₁	17.63	16.74	17.19	17.58	17.26	17.42	17.60	17.30	1.93	1.82	1.80	2.05	2.58	2.32	1.99	2.20	2.10	2.10
N ₂	18.83	18.41	18.62	18.63	18.70	18.67	18.73	18.56	2.31	2.25	2.28	2.41	2.88	2.64	2.36	2.56	2.46	2.46
N ₃	20.56	19.56	20.07	20.17	19.83	19.99	20.36	19.69	2.54	2.81	2.67	2.78	3.28	3.03	2.66	3.05	2.95	2.95
Mean	18.47	17.50	17.98	17.93	17.94	17.94	18.20	17.72	1.96	1.99	1.98	2.06	2.46	2.26	2.00	2.23	2.00	2.23
N	I	V	IxV	N at I	I at N	V at N	IxV	N at I	I at N	V at N	I	V	IxV	N at I	I at N	V at N	I	V
SED	0.31	0.45	0.48	0.67	0.39	0.56	0.39	0.56	0.07	0.09	0.09	0.13	0.12	0.15	0.12	0.15	0.12	0.15
CD(P=0.05)	0.77	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.17	0.22	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

ROOT DRY WEIGHT (G) HILL⁻¹, STAGNITE (H. B. MONSOON, 1985)

40 DAT

	I ₁		I ₂		Mean		I ₁		I ₂		Mean		I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	18.51	17.47	17.99	17.22	17.30	17.26	17.87	17.39	17.63	1.23	1.44	1.33	1.31	1.76	1.54	1.27	1.60	1.43
N ₁	18.33	18.34	18.64	17.87	18.78	18.33	18.40	18.56	18.48	1.65	2.55	2.10	2.60	2.29	2.45	2.12	2.42	2.27
N ₂	19.48	19.67	19.58	19.08	19.26	19.17	19.28	19.47	19.37	2.21	3.15	2.66	2.84	2.75	2.79	2.53	2.95	2.74
N ₃	20.06	20.41	20.24	19.58	20.41	19.99	19.82	20.41	20.11	2.48	3.55	3.02	3.55	3.31	3.43	3.01	3.43	3.22
Mean	19.25	18.97	19.11	18.44	18.94	18.69	18.84	18.96	1.89	2.67	2.28	2.57	2.53	2.55	2.23	2.60	2.23	2.60
N	I	V	IxV	N at I	I at N	V at N	IxV	N at I	I at N	V at N	I	V	IxV	N at I	I at N	V at N	I	V
SED	0.23	0.56	0.56	0.79	0.32	0.62	0.32	0.62	0.08	0.04	0.04	0.05	0.11	0.09	0.11	0.09	0.05	0.09
CD(P=0.05)	0.57	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.19	0.09	0.09	0.13	N.S	N.S	N.S	N.S	N.S	N.S

FLOWERING

FLOWERING

	I ₁		I ₂		Mean		I ₁		I ₂		Mean		I ₁		I ₂		Mean	
	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂	V ₁	V ₂
N ₀	18.51	17.47	17.99	17.22	17.30	17.26	17.87	17.39	17.63	1.23	1.44	1.33	1.31	1.76	1.54	1.27	1.60	1.43
N ₁	18.33	18.34	18.64	17.87	18.78	18.33	18.40	18.56	18.48	1.65	2.55	2.10	2.60	2.29	2.45	2.12	2.42	2.27
N ₂	19.48	19.67	19.58	19.08	19.26	19.17	19.28	19.47	19.37	2.21	3.15	2.66	2.84	2.75	2.79	2.53	2.95	2.74
N ₃	20.06	20.41	20.24	19.58	20.41	19.99	19.82	20.41	20.11	2.48	3.55	3.02	3.55	3.31	3.43	3.01	3.43	3.22
Mean	19.25	18.97	19.11	18.44	18.94	18.69	18.84	18.96	1.89	2.67	2.28	2.57	2.53	2.55	2.23	2.60	2.23	2.60
N	I	V	IxV	N at I	I at N	V at N	IxV	N at I	I at N	V at N	I	V	IxV	N at I	I at N	V at N	I	V
SED	0.23	0.56	0.56	0.79	0.32	0.62	0.32	0.62	0.08	0.04	0.04	0.05	0.11	0.09	0.11	0.09	0.05	0.09
CD(P=0.05)	0.57	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.19	0.09	0.09	0.13	N.S	N.S	N.S	N.S	N.S	N.S

N.S - Not significant

more root dry weight than continuous submergence. The favourable influence of soil drying on root weight was discussed already.

The variety CO 44 produced more root dry weight than IR 20 either singly or in combination with water during the flowering stage.

4.2.9.6. Dry matter production (Table 101)

Dry matter production increased consequent on N application and irrigation. Nitrogen applied at 225 kg ha⁻¹ and continuous submergence produced the highest dry matter. The variety IR 20 recorded more DMP during flowering stage.

A comparison of DMP by NEM 85 crops with SWM 85 and Summer 86 indicate that even though the varieties used in this season were of medium duration, a higher LAI observed during 40 DAT in NEM 85 might have decreased the light transmission resulting in reduced net photosynthetic rate beyond an optimal LAI. The shaded lower leaves drain photosynthetic products from the photosynthesising organs (Navasero and Tanaka, 1966). This condition was further aggravated during NEM 85 where only reduced light is available. Similar reports of reduced DMP during kabi from Hyderabad is available (Venkateswarlu et al., 1977). It could also be noticed during flowering stage that even

TABLE 101. RBY WATER PRODUCTION (KG HA⁻¹), STAGEWISE (N.E. MONSOON, 1995)
40 DAT

	I ₁		Mean	I ₂		Mean	Mean		
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
N ₀	245.0	232.4	238.9	1708	1979	1844	2079	2154	2117
N ₁	340.4	234.6	317.5	2838	274.6	2802	3131	2846	2998
N ₂	464.0	458.9	463.9	4096	3863	3179	4393	4225	4309
N ₃	557.9	548.1	553.3	4783	5620	5202	5181	555.4	5363
Mean	403.1	393.8	393.4	3361	3892	3457	3696	3695	
	N	I	V	IxV	Nat I	I at N	Nat V	V at N	
SEL	177.43	186.05	186.65	258.30	251.23	257.50	232.23	257.50	
CD(P=0.05)	434.32	446.94	N.S	N.S	N.S	N.S	N.S	N.S	

FLOWERING

	I ₁		Mean	I ₂		Mean	Mean		
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
N ₀	383.8	346.7	365.2	3804	305.4	3429	3820	3620	3541
N ₁	677.1	556.3	616.7	5229	484.6	5538	6500	5204	5492
N ₂	736.3	692.0	709.2	7713	588.8	6300	7098	6354	6696
N ₃	871.3	805.0	838.6	7970	669.6	7333	5342	7377	7060
Mean	667.1	597.7	632.3	6179	512.1	5650	6425	5549	
	N	I	V	IxV	Nat I	I at N	Nat V	V at N	
SED	74.90	182.99	182.99	258.78	124.92	220.17	124.92	220.17	
CD(P=0.05)	185.29	147.77	147.77	N.S	277.99	515.20	277.99	1403.31	

N.S. = Not significant

N applied to the highest level could not produce comparable (not statistically) DMP of SWM 85 probably because of low temperature prevailing during this stage of crop growth.

4.2.10. Yield and yield attributes

4.2.10.1. Panicles per m² (Table 102)

Nitrogen alone influenced this character considerably. Its interaction with irrigation and varieties were also present. A progressive increase in panicle number with N could be seen upto 150 kg ha⁻¹ beyond which a drastic reduction occurred. Use of higher quantities of N with more irrigation water or with any of the varieties resulted in production of more panicles. Favourable influence of N application on panicle production was discussed already.

4.2.10.2. Length of panicle (Table 102)

Length of panicle increased with the application of graded levels of N. However, the successive increase was at a decreasing rate. The interactions of N with irrigation and varieties were also seen to occur. In general application of more N with continuous submergence resulted in panicles with more length.

TABLE 100. YIELD ATTRIBUTES (N.E. MARRAS N, 1948)

	NUMBER OF PANICLES M ⁻²										LENGTH OF PANICLE (CM)									
	I ₁		I ₂		Mean		V ₁		V ₂		I ₁		I ₂		Mean		V ₁		V ₂	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	197	167	182	181	173	177	189	180	185	175.53	174.47	17.50	18.23	18.20	18.22	17.88	17.84	17.66		
N ₁	341	352	343	353	351	352	350	351	351	19.07	18.50	18.79	19.50	19.70	19.60	19.29	19.10	19.20		
N ₂	366	360	376	354	348	351	360	367	364	19.83	19.57	19.70	19.65	20.40	20.03	19.74	19.99	19.80		
N ₃	314	340	327	313	309	311	314	325	320	20.40	20.30	20.35	20.10	19.90	20.00	20.25	20.10	20.18		
Mean	305	310	312	303	292	298	304	305	305	19.21	18.96	19.09	19.37	19.55	19.46	19.39	19.26			
SE	N	I	V	IxV	N at I	N at V	N at V	N at V	N	N	I	V	IxV	N at I	N at V	N at V	N at V			
SD	5.79	5.48	5.48	7.76	9.18	10.30	9.18	10.30	9.18	0.14	0.15	0.15	0.21	0.20	0.23	0.20	0.23			
CD (P=0.05)	14.18	N.S.	N.S.	20.55	22.66	20.55	25.90	20.55	25.90	0.33	N.S.	N.S.	N.S.	0.45	0.52	0.45	0.52			

WEIGHT OF PANICLE (G)

	NUMBER OF FILLED GRAINS PANICLE ⁻¹										THOUSAND GRAIN WEIGHT (G)									
	I ₁		I ₂		Mean		V ₁		V ₂		I ₁		I ₂		Mean		V ₁		V ₂	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	1.26	1.15	1.21	1.08	1.11	1.10	1.17	1.13	1.15	59.10	62.40	60.75	58.07	59.37	58.72	58.59	60.89	59.74		
N ₁	1.45	1.31	1.38	1.28	1.30	1.29	1.37	1.31	1.34	65.47	63.10	64.28	64.32	61.43	62.68	64.30	62.77	63.58		
N ₂	1.63	1.49	1.56	1.47	1.42	1.45	1.55	1.46	1.50	68.83	66.33	67.58	67.13	65.87	66.50	67.98	66.10	67.04		
N ₃	1.76	1.68	1.72	1.72	1.63	1.68	1.74	1.66	1.70	72.67	69.93	71.30	71.87	68.26	70.07	72.37	69.10	70.68		
Mean	1.53	1.41	1.47	1.39	1.37	1.38	1.46	1.39	1.43	66.52	65.52	66.02	65.35	63.73	64.54	65.94	64.63			
SE	N	I	V	IxV	N at I	N at V	N at V	N at V	N	N	I	V	IxV	N at I	N at V	N at V	N at V			
SD (P=0.05)	0.05	0.04	0.04	0.06	0.06	0.06	0.06	0.06	0.06	1.00	1.13	1.13	1.60	1.45	1.71	1.45	1.71			
CD (P=0.05)	0.12	N.S.	N.S.	0.14	0.14	0.14	0.14	0.15	0.15	2.45	N.S.	N.S.	N.S.	3.28	3.84	3.28	5.23			

PERCENTAGE OF STERILITY

	NUMBER OF PANICLES M ⁻²										LENGTH OF PANICLE (CM)									
	I ₁		I ₂		Mean		V ₁		V ₂		I ₁		I ₂		Mean		V ₁		V ₂	
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂
N ₀	20.04	22.72	21.38	20.42	21.87	21.15	20.23	22.30	21.26	18.35	19.28	18.82	17.48	18.45	17.97	17.92	18.87	18.39		
N ₁	18.65	19.77	19.21	19.21	19.13	19.17	18.93	19.45	19.19	18.80	19.69	19.25	18.60	19.49	19.05	18.70	19.59	19.15		
N ₂	15.08	18.68	16.88	18.80	18.45	18.63	16.94	18.37	17.75	19.29	20.24	19.76	19.38	19.74	19.56	19.34	19.99	19.66		
N ₃	16.03	16.15	16.09	16.65	16.59	16.62	17.34	17.39	17.36	20.01	20.88	20.45	20.14	20.07	20.10	20.08	20.48	20.28		
Mean	17.45	19.33	18.39	19.27	19.21	19.39	18.36	19.43	19.43	19.11	20.07	19.57	18.90	19.44	19.17	19.01	19.73			
SE	N	I	V	IxV	N at I	N at V	N at V	N at V	N	N	I	V	IxV	N at I	N at V	N at V	N at V			
SD (P=0.05)	0.63	0.41	0.41	0.58	0.80	0.72	0.80	0.72	0.80	0.10	0.17	0.17	0.24	0.15	0.22	0.15	0.22			
CD (P=0.05)	1.55	N.S.	1.01	1.43	1.84	1.60	1.84	1.51	1.51	0.24	0.41	0.58	0.34	0.51	0.34	0.51	0.34	0.58		

N.S. - Not significant

4.2.10.3. Weight of panicle (Table 102)

Heavier panicles were produced with increase in N application. Combined effects of N with irrigation and varieties were present. A trend similar to panicle length was seen. A general comparison of weight of panicles produced by NEM 85 and Summer 86 season indicate that panicles with lesser weight was noticed during the former season.

Availability of high solar energy is essential for increase in photosynthesis. The starch which accumulates in the grain comes from two sources i.e., that accumulated in the straw before heading and that from products assimilated after flowering. With low N the former provides as much as 40 per cent of the total starch in the grain but at a high N level, it provides less than 10 per cent (Murayama et al., 1955). This seems to have an important bearing on the translocation of assimilatory products from the straw to panicle. Under high N conditions plants have to depend on photosynthesis after flowering for carbohydrate requirements. In NEM 85 season sufficient solar energy is not available for manufacturing more of its own photosynthesis leading to production of panicles with less weight compared to Summer 86 season.

4.2.10.4. Thousand grain weight (Table 102)

Thousand grain weight was favourably influenced by N application. A test weight of 20.2 g was seen when N was applied at 225 kg ha⁻¹, the increase being 10 per cent over control. The variety CO 44 produced heavier grains than that of IR 20.

4.2.10.5. Number of filled grains per panicle and percentage of sterility (Table 102)

Application of N significantly influenced the number of filled grains per panicle and percentage of sterility. Nitrogen applied at 225 kg ha⁻¹ produced panicles with an average of 71 filled grains which was 18 per cent more than control. Similarly application of higher dose of N reduced the percentage of sterility considerably. The variety IR 20 recorded lower percentage of sterility than CO 44. Favourable influence of N in increasing the plant photosynthesis and its translocation to the sink is well established.

It is interesting to note that the sterility is greater with CO 44 as compared to IR 20. However, at the highest level of N application the sterility percentage was more or less similar. CO 44 has poor exertion of panicles. Probably at higher level of N

application the panicle exertion is complete resulting in low percentage of sterility. At 75 and 150 kg ha⁻¹ of N application under continuous submergence the sterility percentage with CO 44 is higher whereas under I₂ regime under all the N applied levels the sterility percentage is comparable between two varieties. The low solar radiation and low temperature increased sterility. This was more so with CO 44 than with IR 20.

Though the varieties used during NCM 85 season were medium in duration and occupied more days in the field, they had a high percentage of sterility compared to SWM 85 or Summer 86 season at any level of N fertilization. This could be ascribed to seasonal effect on this character. Ota and Yamada (1965) are of the opinion that sterility is always high under tropical conditions because the major cropping season is wet. The high sterility according to them is caused by the factors of reduced light, high N supply, mutual shading either individually or in combination. However, in this study higher N favoured better grain filling.

4.2.10.6. Grain yield (Table 103 and Fig.)

Grain yield was affected by N application. Application of N increased grain yield upto the level of 150 kg ha⁻¹, thereafter it declined. The increase in yield

TABLE 103. GRAIN YIELD (KG HA⁻¹), (N.E. MONSOON, 1955)

	I ₁		Mean	I ₂		Mean	Mean		Mean
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂	
	N	I		IX	N at I		N at V	V at N	
N ₀	1450	1418	1434	1420	1380	1400	1435	1399	1417
N ₁	3619	3627	3623	3518	3592	3585	3599	3610	3605
N ₂	4200	4282	4241	4132	4234	4182	4166	4258	4212
N ₃	3978	4125	4052	3992	3960	3976	3985	4043	4014
Mean	3312	3363	3338	3281	3293	3286	3296	3326	
SED	30.63	25.26	25.26	35.72	48.93	53.11	48.93	53.11	
CD(P=0.05)	74.95	N.S	N.S	N.S	109.43	N.S	109.43	N.S	

N.S - Not significant

by application of N at 75 kg ha⁻¹ over control and 150 kg ha⁻¹ over 75 kg ha⁻¹ were 154.4 and 16.8 per cent, respectively. The yield decline with the highest dose of N noticed was 4.8 per cent.

Influence of irrigation schedule or varieties were not present. Interactions of N with irrigations or varieties were observed. Under I₁ or I₂ level of irrigation, N applied at 150 kg ha⁻¹ recorded the highest yield. Similarly both the varieties performed better at 150 kg level of N application.

The varieties used for the study during NEM 85 are different, however, on a comparison of total duration between NEM 85 and SWM 85 or Summer 86, it could be seen that these varieties occupied more days in the field and they being high yielding varieties could not make use of the inputs like water and N supplied in sufficient quantities in a most effective manner. This was probably due to the unfavourable environmental conditions like low temperature, solar energy and sunshine hours prevailed during the cropping period. The low temperature that prevailed during the early growth stages has restricted the growth as well as tiller productivity and ultimately the DMF. This negative effect in the early vegetative

phase could be attributed as the prime reason for the low productivity during NEM season 85.

Apart from this the solar radiation was comparatively lower during the ripening phase of the crop and the sterile spikelets were also higher during this season. Murata (1966) states that the carbohydrate to be translocated and stored in the grain are generally manufactured during the six odd weeks to two weeks before and four weeks after heading. Relatively short duration of day length at the grain filling stage experienced by the crop during the NEM 85 season (8.3) as compared to Summer 86 (10.2) might have contributed to greater sterility and thereby reducing the grain yield (Fig.18).

Sunlight has a direct effect on N utilisation and grain yield. Increased light makes the plant more responsive to higher levels of N (Stansel, 1966; De Datta and Malabuyoc, 1976). For the same amount of N, grain yield and N response are higher during SWM 85 or Summer 86 than NEM 85 season. This indicates a direct response to solar energy values and higher grain yield of these seasons compared to NEM 85 season.

No difference in grain yield due to water management was noticed. The yield obtained under continuous submergence and irrigating one day after disappearance of water

were 3.34 and 3.29 t ha⁻¹, respectively. The respective quantities of water consumed were 1382 and 941 mm. The saving in water was 32.0 per cent. As in case of SWM 85, the evaporative demand is lower in this season also. As such irrigation one day after disappearance of water takes care of the full water requirement of the crop dispensing the need for continuous submergence.

4.2.11. Straw yield (Table 104)

Progressive increase in straw yield due to N application was noticed. Nitrogen applied at 225 kg ha⁻¹ recorded a straw yield of 4.69 t ha⁻¹. Straw yield enhanced by 294 kg ha⁻¹ with continuous submergence over irrigating one day after disappearance of ponded water. The interaction of N with irrigation and varieties were present. Application of higher quantities of N with continuous submergence produced higher straw yields.

4.2.12. Water use efficiency (Table 104)

Water use efficiency recorded an increase of 2.33 kg/mm with N applied at 150 kg ha⁻¹ over control. Irrigating one day after disappearance of ponded water gave an increase of 1.04 kg/mm compared to continuous submergence. The higher WUE noticed when N applied at 150 kg ha⁻¹ was due to higher yield and low water requirement. The yield

TABLE 104. STRAW YIELD (KG HA⁻¹), (N.E. MONSOON, 1985)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1604	1690	1647	1635	1527	1581	1620	1609	1614
N ₁	4444	4345	4394	4184	3909	4047	4313	4127	4220
N ₂	4728	4466	4597	4422	4690	4556	4557	4578	4577
N ₃	5049	4892	4970	4322	4577	4450	4686	4685	4685
Mean	3956	3848	3902	3641	3676	3659	3799	3750	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	66.29	46.84	46.84	66.24	78.71	69.96	78.71	69.66	
CD(P=0.05)	162.22	114.61	N.S.	N.S.	184.69	157.83	184.69	157.71	

WATER USE EFFICIENCY (KG/MM), (N.E. MONSOON, 1985)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1.05	1.04	1.05	1.62	1.60	1.61	1.34	1.32	1.33
N ₁	2.76	2.75	2.76	3.88	3.93	3.91	3.32	3.34	3.33
N ₂	2.99	3.03	3.01	4.27	4.36	4.32	3.63	3.70	3.66
N ₃	2.79	2.88	2.84	3.95	3.95	3.95	3.37	3.42	3.39
Mean	2.40	2.43	2.41	3.43	3.46	3.45	2.92	2.95	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.09	0.06	0.06	0.09	0.14	0.15	0.14	0.15	
CD(P=0.05)	0.21	0.14	N.S.	N.S.	0.32	0.33	0.32	0.32	

N.S = Not significant

QUANTITY OF WATER (MM) CONSUMED, (N.E. MONSOON, 1985)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	1375	1367	1371	875	864	870	1125	1116	1120
N ₁	1310	1321	1316	921	913	917	1116	1117	1117
N ₂	1407	1415	1411	968	972	970	1188	1194	1191
N ₃	1426	1431	1429	1010	1003	1006	1218	1217	1218
Mean	1380	1384	1382	944	938	941	1162	1161	
	Data not analysed								

obtained under irrigation with one day after disappearance of water was comparable with continuous submergence, but the water used is considerably low (Table 104) thus resulting in higher WUE. Interactions of N with irrigation and varieties were present. Application of water one day after disappearance with N at 150 kg ha^{-1} recorded highest WUE. The WUE was similar for both the varieties.

4.2.13. Weed dry weight (Table 105)

Dry matter production of weeds was influenced by N and water management practices. Highest weed dry weight was noticed when N was applied at 225 kg ha^{-1} , the increase being 33.3 per cent over control. Submerging one day after disappearance of water resulted in more weed dry weight than continuous submergence. The favourable influence of continuous submergence on weed control is well established. The weed infestation was heavier with CO 44 at all levels of irrigation than IR 20.

4.2.14. Nutrient uptake by rice

Nitrogen, phosphorus and potassium (Table 106)

Uptake of nutrients increased progressively with increase in levels of N applied at both the stages. Nitrogen applied at 225 kg ha^{-1} resulted in more uptake of nutrients during harvest stage than N applied at lower levels.

TABLE 105. WARD DRY WEIGHT (KG HA⁻¹), (N.E. MONSOON, 1975)

	I ₁		Mean	I ₂		Mean	Mean	
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂
W ₀	73.77	83.07	83.42	95.53	89.53	87.53	82.15	83.80
W ₁	95.40	95.27	90.33	94.43	103.07	88.75	89.32	99.17
W ₂	97.23	108.27	102.75	103.73	112.93	108.33	100.48	110.60
W ₃	109.17	114.53	111.65	114.43	117.83	116.13	111.80	116.18
Mean	92.64	101.53	97.09	99.53	105.84	102.69	96.09	103.69
SED	0.75	0.41	0.41	1xV	V at I	I at W	V at V	V at V
CD (P=0.05)	1.34	1.00	1.00	1.41	2.91	2.80	2.81	2.62

Irrigation influenced the nutrient uptake significantly. Continuous submergence resulted in more uptake than irrigating one day after disappearance of ponded water. Favourable influence of N and more water in increasing the nutrient uptake was already discussed. Continuous submergence increases soil temperature thereby enhancing the nutrient uptake even though the atmospheric temperature is low during this season.

Low air temperature prevailed in NEM 85 during the peak absorption period of the nutrients has lowered the uptake of nutrients thereby resulting in lower accumulation compared to the SWM 85 or Summer 86 seasons.

Varietal influence on uptake of nutrients was observed. Uptake of P was more in case of IR 20 in both the stages whereas CO 44 registered more N and K uptake during harvest. The difference in nutrient uptake between varieties could be attributed to the difference in DWP between the varieties.

4.2.15. Response to N and percentage recovery of applied N (Table 107)

The response to N decreased considerably with application of more N. Higher the N, lower was the response. The highest response was noticed with N applied at 75 kg ha⁻¹. Whereas the percentage recovery of applied N

TABLE 107. RESPONSE TO APPLIED N (KG GRAIN/KG N), (N.E. MONSOON, 1985)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	28.32	29.45	29.19	28.77	29.49	29.10	28.85	29.47	29.16
N ₂	18.33	19.09	18.71	18.68	19.05	18.86	18.51	19.06	18.79
N ₃	11.24	12.03	11.64	11.43	11.47	11.45	11.34	11.75	11.55
Mean	19.50	20.19	19.85	19.63	20.00	19.81	19.57	20.09	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.36	0.25	0.25	0.35	0.45	0.40	0.45	0.40	
CD (P = 0.05)	0.99	N.S	N.S	N.S	1.15	0.92	1.15	0.82	

PERCENTAGE RECOVERY OF APPLIED N, (N.E. MONSOON, 1985)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₁	23.73	29.30	26.52	29.27	20.10	24.68	26.50	24.70	25.60
N ₂	25.05	29.73	27.38	26.00	27.87	26.94	25.52	28.80	27.16
N ₃	27.43	28.30	27.87	28.07	29.67	28.87	27.75	28.98	28.37
Mean	25.40	29.10	27.26	27.78	25.88	26.83	26.59	27.49	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.83	0.64	0.64	0.90	1.00	0.90	1.00	0.90	
CD (P=0.05)	N.S	N.S	N.S	2.20	N.S	N.S	2.59	1.96	

N.S - Not significant

RESPONSE EQUATIONS OF RICE TO N UNDER DIFFERENT WATER MANAGEMENT PRACTICES (N.E. MONSOON, 1985)

		Quadratic response equations			Economic optimum dose (kg ha ⁻¹)
a. IR 20	Continuous submergence	I ₁	Y = 14.8925 + 0.34789 X - 0.001063 X ²		149.5
	Submerging one day after disappearance of water	I ₂	Y = 14.6550 + 0.34007 X - 0.001021 X ²		151.9
b. CO 44	Continuous submergence	I ₁	Y = 14.5510 + 0.35360 X - 0.001052 X ²		153.8
	Submerging one day after disappearance of water	I ₂	Y = 14.1270 + 0.36036 X - 0.001105 X ²		149.5

increased with enhanced N application. However, the increase was only marginal. The economic optimum dose of N (kg ha^{-1}) presented in Table 107 shows that the dose increased from 149.5 to 151.9 for IR 20 whereas it decreased from 153.8 to 149.5 for CO 44 under continuous submergence and submerging one day after disappearance of water, respectively.

4.2.16. Economics (Table 108)

4.2.16.1. Gross income, net income and benefit cost ratio

Gross and net income and benefit cost ratio recorded with application of N at 150 kg ha^{-1} were the highest being Rs.7004/- and Rs.2389 ha^{-1} and 1.52, respectively. Nitrogen applied beyond this level, however, caused a reduction in gross and net returns and benefit cost ratio. Continuous submergence resulted in higher gross income since this treatment produced higher grain and straw yields whereas net income and benefit cost ratio were more with irrigating one day after disappearance of water. This was due to the lower quantity of water required in this treatment compared to continuous submergence. Nitrogen x irrigation interaction was present for all cases. Continuous submergence with higher doses of N gave more gross return compared to the other N and irrigation treatments whereas submerging one day after disappearance was found to record more net return and benefit cost ratio with higher N levels.

TABLE 10B. GROSS INCOME (RS HA⁻¹) (N.E. MONSOON, 1995)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	2416	2381	2399	2375	2299	2337	2396	2340	2368
N ₁	6095	6092	6094	5995	5974	5985	6045	6033	6039
N ₂	7039	7093	7051	6801	7055	6958	6935	7074	7004
N ₃	6724	6921	6823	6636	6627	6631	6680	6774	6727
Mean	5561	5622	5592	5467	5489	5478	5514	5555	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	48.34	41.55	41.55	58.76	75.54	82.34	75.54	82.34	
CD (P=0.05)	118.28	101.67	N.S	N.S	169.40	180.26	N.S	N.S	

NET RETURNS (RS HA⁻¹) (N.E. MONSOON, 1995)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	-1709	-1736	-1723	-1250	-1315	-1283	-1480	-1526	-1503
N ₁	1694	1683	1689	1975	1973	1974	1838	1828	1832
N ₂	2177	2253	2215	2468	2658	2563	2323	2456	2389
N ₃	1535	1727	1631	1863	1861	1862	1699	1794	1747
Mean	924	962	953	1264	1294	1279	1094	1138	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	80.20	55.40	55.40	78.34	107.40	103.55	107.40	103.55	
CD (P=0.05)	196.25	135.55	N.S	N.S	246.38	227.82	N.S	N.S	

BENEFIT COST RATIO, (N.E. MONSOON, 1995)

	I ₁			I ₂			Mean		
	V ₁	V ₂	Mean	V ₁	V ₂	Mean	V ₁	V ₂	Mean
N ₀	0.59	0.58	0.59	0.66	0.64	0.65	0.63	0.61	0.62
N ₁	1.38	1.38	1.38	1.49	1.49	1.49	1.44	1.44	1.44
N ₂	1.45	1.47	1.46	1.56	1.60	1.58	1.51	1.54	1.52
N ₃	1.40	1.33	1.37	1.39	1.39	1.39	1.35	1.36	1.36
Mean	1.18	1.19	1.19	1.28	1.28	1.28	1.23	1.24	
	N	I	V	IxV	N at I	I at N	N at V	V at N	
SED	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	
CD (P=0.05)	0.04	0.02	N.S	N.S	0.05	0.05	N.S	N.S	

N.S - Not significant

4.2.16.2. Economics of water and N use (Table 109)

Return per rupee invested on water was influenced by N and irrigation levels. Application of N at 150 kg ha⁻¹ was found to effectively use the water applied. The return per rupee on water decreased drastically thereafter with more N application. Submerging one day after disappearance of water recorded an increase of 17.2 per cent in return per rupee on water due to the lower water required in this treatment. The return per rupee invested on N behaved differently compared to return per rupee invested on water such that highest return was observed with application of N at 75 kg ha⁻¹. This was because of lower recovery percentage of N at higher rates of N application.

General discussion

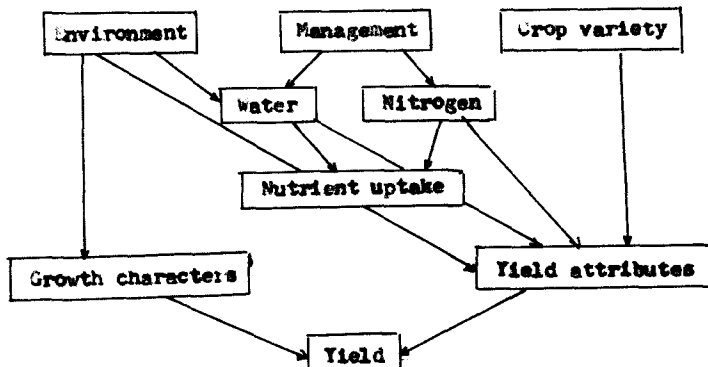


TABLE 10.3. RETURN PER RUPEE INVESTED ON WATER, (N.E. MONSOON, 1985)

	I ₁		Mean	I ₂		Mean	Mean	
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂
N ₀	-0.24	-0.27	-0.26	-0.43	-0.52	-0.43	-0.54	-0.49
N ₁	2.30	2.27	2.23	3.16	3.16	3.16	2.73	2.72
N ₂	2.55	2.59	2.57	3.55	3.73	3.64	3.05	3.11
N ₃	2.08	2.21	2.14	2.84	2.86	2.85	2.46	2.50
Mean	1.67	1.70	1.69	2.28	2.31	2.29	1.98	2.01
	N	I	V	IxY	M at I	I at N	N at V	V at N
SED	0.08	0.05	0.05	0.07	0.13	0.14	0.13	0.14
CD (P=0.05)	0.19	0.12	N.S	N.S	0.29	0.30	N.S	N.S

RETURN PER RUPEE INVESTED ON N (N.E. MONSOON, 1985)

	I ₁		Mean	I ₂		Mean	Mean	
	V ₁	V ₂		V ₁	V ₂		V ₁	V ₂
N ₁	6.02	5.98	6.00	6.84	6.84	6.84	6.43	6.42
N ₂	4.23	4.34	4.28	4.64	4.94	4.79	4.44	4.54
N ₃	2.52	2.70	2.61	2.84	2.84	2.84	2.68	2.77
Mean	4.26	4.34	4.30	4.77	4.87	4.82	4.52	4.62
	N	I	V	IxY	M at I	I at N	N at V	V at N
SED	0.19	0.10	0.10	0.14	0.19	0.19	0.19	0.19
CD (P=0.05)	0.33	N.S	N.S	N.S	N.S	N.S	0.45	0.44

N.S - Not significant

A. Influence of meteorological factors on rice crop

1) Solar energy

Solar energy influences various growth and yield attributes and yield of rice. Results of the first experiment indicate that the vegetative growth characters like plant height and LAI show a negative relationship with solar energy. They increase under conditions of low light intensity. Yield attributes such as panicles per m^2 , grains per m^2 , panicle weight, fertility percentage were positively correlated with solar radiation and sunshine hours at one phase or other during reproductive and ripening phases. The correlation coefficients worked between solar radiation and grain yield for a period of seven weeks before the harvest of the crop, show that as the period advances towards maturity the relationship of yield with solar radiation becomes stronger. Murata (1966) showed that grain yield is related to solar radiation during the later part of reproductive phase since the accumulation of starch in the leaves and culms begins at about 10 days before heading. This in turn is dependent on the extent of solar energy receipt. According to Yamakata et al. (1967) the dry matter production after flowering is primarily in the form of grain and hence receipt of high amount of solar energy during this period is highly essential for better grain production.

Apart from the growth and yield characters, the nutrient uptake was also closely correlated with solar energy suggesting that an optimum nutrient application rate could be based not only on soil fertility level and variety but also on the solar radiation level.

ii) Air temperature

The influence of temperature is complex compared to solar radiation. Temperature upsets the balance between photosynthesis and respiration.

A high night temperature during vegetative phase influences the growth characters such as plant height and tiller production favourably. Yield attributes such as panicles per m^2 , filled grain percentage and degree of ripening was seen to be negatively correlated with minimum temperature indicating that lower the minimum temperature higher will be their values.

In this experiment it was seen that the duration of the crop upto 50 per cent flowering was not affected by minimum temperature. However, there exists a negative relationship between minimum temperature and duration of ripening phase.

The temperature summation is almost the same in the different plantings in each season. This indicates that a particular variety will reach maturity only if exposed to a minimum heat requirement.

iii) Relative humidity

The study reveals that most of the growth and yield attributes are not influenced by relative humidity. Its effect on plant height and panicles per m^2 has been masked by sunshine hours. Even though there exists a negative relationship between relative humidity and grains per m^2 , the partial correlation coefficient shows that relative humidity as such has no effect. Similarly there exists a negative association between relative humidity and grain yield, but solar radiation at reproductive and ripening phases confounds its negative ripening phases confounds its negative influence on grain yield. The results, therefore, points out that relative humidity per se does not influence growth and yield attributes of the rice crop.

iv) Planting time

In the present day emphasis on multiple cropping rice is being grown not only in traditional seasons, but also during off seasons in many places. However, agro-climatological indications of the performances of the high yielding, fertilizer responsive and photo insensitive types of rice are scanty under Indian conditions.

From the results of the experiment (1), it is seen that among the BWH 85 plantings, 16th July planted crop

gave the highest yield followed by 2nd July planting. This is the usual planting period for kuruvai season in Coimbatore and climatic conditions during these plantings are quite favourable for higher grain production. In the late plantings grain yield show a reduction due to unfavourable climatic conditions experienced by the crop.

In NEM 85, the highest yield was obtained in 26th November planting. From 15th October planting an increase in grain yield was noticed upto 26th November. Grain yield declined with early December planting since it was subjected to cool weather conditions during tis growth and development phases.

In Summer 86 the highest grain yield was seen with 26th February planting. Here also grain yield increased from 29th January planting which decreased with 12th March planting.

The favourable climatological conditions prevailing during the crop growth period especially at reproductive and ripening phases contributed for better growth and development of the crops resulting in higher grain yield in the seasons. A comparatively low temperature accompanied by a comparatively higher solar radiation and sunshine hours provides a most congenial condition for grain production and

ripening. As a result yield attributes such as panicles per m^2 , grains per m^2 , fertility percentage, degree of ripening etc., are influenced favourably leading to higher yield.

B. Agronomic Management

1) Water management

The response of rice crop to water management practices is seen to be influenced by climatological factors directly or indirectly. During Summer season when the evaporative demand of the atmosphere is greater, continuous submergence favourably influenced the yield attributes resulting in higher grain yield. Whereas during SW monsoon and NE monsoon periods when the evaporative demand is not that high irrigating one day after disappearance of ponded water was as effective as continuous submergence in providing a good environment for higher productivity.

Even though higher yields are obtained with continuous submergence, higher WUE was noticed with submerging one day (SWM 85 and NEM 85) and three days (Summer 86) after disappearance of water.

Continuous submergence recorded highest uptake of nutrients. There was decrease in response or percentage recovery of N with lower irrigation levels.

11) Nitrogen

The response to N under the monsoon conditions are very low compared to dry and sunny weather conditions prevailed during Summer season. The growth attributes like plant height, LAI and tiller production were higher in Summer 86 season than in SWM 85. Application of N influenced the yield attributes such as panicles per m^2 , panicle weight, 1000 grain weight favourably and gave the highest yield in all the seasons at 150 kg ha^{-1} for the experiment (2). A dose beyond this level caused a considerable reduction in yield in the two monsoon seasons.

Application of N increased the nutrient uptake and the response to applied N was the highest with 75 kg ha^{-1} in all the seasons. The reduction in response to the next higher dose of 150 kg ha^{-1} of N was more in case of SWM 85 and NEM 85 (35 and 36 per cent, respectively) compared to 23 per cent in Summer 86. However, the per cent recovery of N behaved differently with N application in each of the season.

The economic optimum dose of N did not vary between irrigation levels for the different varieties tried in SWM 85, whereas, in NEM 85 submerging one day after disappearance of water showed a higher economic optimum dose of N for IR 20 while in CO 44 continuous submergence showed

a higher value. In Summer 86 the economic optimum dose of N increased with moisture stress for both the varieties.

C. Variety

With the introduction of high yielding varieties, rice production has increased considerably. However, selection of a specific variety that can be successfully grown in a particular season is very important. With low light conditions prevailing during monsoon seasons, the variety selected should be able to tolerate such unfavourable conditions and at the same time producing higher grain yield. It should be fertilizer responsive also.

SUMMARY AND CONCLUSION

V. SUMMARY AND CONCLUSIONS

Field experiments were conducted in three seasons, viz., South West Monsoon (SWM), North East Monsoon (NEM) and Summer seasons of 1985-86 at the wetlands of Tamil Nadu Agricultural University, Coimbatore to evaluate the influence of meteorological factors on crop growth and grain yield and its effect on water requirement of the crop. Another experiment was conducted with the aim to identify the factors responsible for difference in yield between seasons.

In the first experiment crop growth period was divided into three phases viz., vegetative, reproductive and ripening. Correlation coefficients were worked out between growth and yield parameters, yield and meteorological factors prevailing during each growth phase so as to identify the weather element that influence the growth and yield at a particular phase. The results obtained under two studies are summarised and presented separately.

Experiment 1

The growth characters like plant height and LAI were seen to be negatively correlated with the energy sources (sunshine hours and solar radiation) during the later phases of crop growth. A high night temperature

(minimum temperature) during the early growth period was found to increase plant height and production of tillers.

Yield attributes such as panicles per m^2 and grains per m^2 were positively correlated with solar radiation and sunshine hours during both the reproductive and ripening phases. The panicle weight was correlated with solar radiation during ripening and with sunshine hours at both the stages. Percentage of filled grains was positively correlated with solar radiation at reproductive and ripening phases whereas it is correlated with sunshine hours for both stages taken together.

Minimum air temperature was negatively correlated with panicles per m^2 at vegetative phase indicating that lower the minimum temperature higher the panicle production. The percentage of filled grains and panicle weight are negatively correlated with minimum temperature during reproductive and ripening phases. The thousand grain weight was not affected by any of the weather parameters at any of the growth phase. The degree of ripening (% fertility x 1000 grain weight) showed a negative association with minimum air temperature during reproductive and ripening phases. The solar energy sources were found to be positively associated with the degree of ripening during these two phases.

Grain yield recorded a positive correlation with sunshine hours and solar radiation during reproductive and ripening phases. The correlation coefficients are found to increase from one stage to another. Correlation coefficients worked out between grain yield and total solar radiation at weekly intervals for seven weeks before harvest for SWM and Summer seasons together showed that there existed a positive correlation between them upto five weeks before harvest in case of IR 50, the short duration variety used in these seasons.

The duration upto 50% flowering was not affected by maximum or minimum air temperature. However, the maximum : minimum air temperature ratio showed a positive association with duration of flowering phase. The ripening period duration was negatively correlated with minimum air temperature at this phase.

The relative humidity showed a negative relationship with panicles per m^2 , grains per m^2 , fertility percentage and grain yield and a positive association with plant height at harvest. However, its effect was noticed to be masked by either solar energy or temperature.

The uptake of nutrients (N & P) at flowering and harvest stages were positively correlated with maximum air temperature, solar radiation and sunshine hours.

In case of K, a negative relation existed between its uptake and the meteorological factors.

In NEM season plant height showed a positive association with maximum or minimum air temperature at vegetative phase. The correlation coefficient increased from one stage to another in case of solar energy sources which showed a negative relationship with plant height. The LAI was more negatively correlated with sunshine hours or solar radiation at vegetative phase than at reproductive phase.

The yield attribute, panicles per m^2 was negatively correlated with minimum temperature at vegetative phase. Grains per m^2 and panicle weight were found to be positively associated with sunshine hours and solar radiation at ripening phases. The percentage fertility showed a positive correlation with sunshine hours at reproductive phase and with solar radiation for reproductive and ripening phases taken together.

The degree of ripening showed a close positive association with total solar radiation at reproductive and ripening phases than that of sunshine hours received during these phases.

Grain yield was well correlated with yield attributes like grains per m^2 , panicle weight, fertility

percentage, 1000 grain weight and positively with solar energy sources at reproductive phase. The correlation between yield and solar radiation is significant at reproductive phase.

The duration of vegetative phase was more negatively correlated with minimum air temperature of this phase than with maximum temperature.

Plant growth and yield attributes as well as yield [✓] did not differ between continuous submergence and submerging one day after disappearance of ponded water during SWM and NEM seasons. However, continuous submergence favoured better plant growth and development and yield during Summer. Thus scheduling irrigation one day after disappearance of ponded water during SWM and NEM when the evaporative demand of the atmosphere is low is indicated.

In SWM plantings highest grain yield was obtained with 16th July planting and in Summer, 26th February planting recorded the highest yield. Summer season plantings produced more grain yield than SWM. In the case of NEM, the highest yield was obtained with 26th November planting where all these plantings experienced a low minimum air temperature and received a high solar energy during the reproductive and ripening phases of the crop growth. These plantings took lesser duration in the main field also. Thus

for getting higher yields in any of the seasons, plantings are to be adjusted in such a way that the crop experiences a high solar radiation and sunshine hours during the reproductive and ripening phases.

Experiment II

Growth attributes like plant height, tillers and LAI increased with N application and showed higher values in Summer than in SWM at all levels of N and irrigation. They were low in NEM season also. Root length was not affected by N in SWM whereas it showed a progressive increase with N application in the other two seasons. The dry matter production increased with N application at all stages in the three seasons.

Application of N had given a progressive increase in panicle per m^2 and grain yield upto the level of 150 kg ha^{-1} , whereas panicle weight, 1000 grain weight and number of filled grains increased upto 225 kg ha^{-1} . The grain yield showed a decline after 150 kg ha^{-1} in SWM and NEM seasons. However, straw yield registered increases upto 225 kg ha^{-1} of N application.

Summer season recorded more grain yield under optimum water and N (continuous submergence and 150 kg ha^{-1}) than SWM, the increase being 6.2 per cent. The decrease in grain yield in NEM was directly related to reduction in growth

characters and yield attributes such as panicle per m^2 and increased sterility.

Highest WUE was noticed with 150 kg ha^{-1} of N in all the seasons. Weed dry weight increased progressively with N application. The highest level of N recorded the highest weed dry weight in all the seasons.

Uptake of nutrients (N, P and K) increased with increase in level of N in both the flowering and harvest stages. The uptake was more in SWM compared to Summer. The response per kg of applied N was maintained at a very high level at 75 kg N ha^{-1} in all the seasons. It decreased as the N level increased. The percentage recovery of applied N varied with N application in each season. It was high with 75 kg ha^{-1} in SWM, 150 kg ha^{-1} in Summer and 225 kg ha^{-1} in NEM.

Gross and net income and benefit cost ratio increased with N application upto a level of 150 kg ha^{-1} in all the seasons. They decreased after this N level in SWM and NEM seasons.

Highest return per rupee invested on water was noticed with 150 kg N ha^{-1} in all the seasons. The return per rupee invested on N was high with 75 kg ha^{-1} . Summer season recorded more return on N than the other two seasons.

Growth characters such as plant height, tiller production (except SWM and NEM), LAI, root length and dry matter production were affected by moisture stress. Increased values were obtained with continuous submergence for these parameters.

Yield attributes like panicle per m², panicle weight, and 1000 grain weight were not affected by irrigation treatments in SWM or NEM. However, all of them were affected in Summer due to moisture stress experienced in I₂ or I₃ levels of irrigation.

Grain yield was more with continuous submergence in Summer. There was no difference in yield in case of irrigation levels in SWM and NEM seasons. Straw yield recorded was highest with continuous submergence in all the seasons. Water use efficiency was lowest with highest irrigation level. Weed dry weight increased with less frequent irrigation. Uptake of nutrients registered significant increase with continuous submergence compared to other irrigation levels.

The response to applied N and recovery were affected by irrigation level in Summer only. A decrease in response or percentage recovery with less frequent irrigation was noticed.

The gross and net returns and benefit cost ratio were high with continuous submergence in SWM and Summer seasons whereas they were not affected by irrigation levels in NEM.

The return per rupee on water and N were high with irrigation of 5 cm submergence one day after disappearance of ponded water in all the seasons.

In the case of varieties, IR 50 performed better than CO 37 with respect to growth and yield characters and recorded more grain yield in SWM and Summer seasons. The variety CO 44 performed slightly better than IR 20 in NEM season.

On conclusion from the two field experiments, the most suitable time for transplanting rice was found to be mid July (SWM); end of November (NEM) and end of February (Summer), in terms of better growth and development resulting in highest grain and straw yield. The most economic irrigation schedule for low land rice could be recouping 5 cm submergence one day after disappearance of ponded water in terms of higher savings of water and low reduction in grain yield and high return per rupee on water and N. A fertilizer dose of 150 kg N ha⁻¹ was found to be the most advantageous with respect to growth and yield attributes, yield and in

terms of other economic considerations. The variety IR 50 was found to be most suitable than CO 37 in SWM and summer seasons. The variety CO 44 was more adaptable than IR 20 in NBN season.

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* Originals not seen

