RESPONSE OF SEED PRIMING, NUTRIENT MANAGEMENT AND IRRIGATION ON UPLAND RICE (*Oryza sativa* L.)

By

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2000

DECLARATION

I hereby declare that this thesis entitled "**Response of seed priming, nutrient management and irrigation on upland rice (*Oryza sativa* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Response of seed priming, nutrient management and irrigation on upland rice (*Oryza sativa* L.)**" is a record of research work done independently by Ms. Usha. C. Thomas under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

@	at the rate of
^0C	Degree Celsius
DAS	Days after sowing
DMP	Dry matter production
FYM	Farmyard manure
F	Fertilizer
Fig.	Figure
g	gram
ha	hectare
HI	Harvest index
I	Irrigation
IW/CPE	Irrigation water/ cumulative pan evaporation
kg	kilogram
kg ha^{-1}	kilogram per hectare
RLWC	Relative leaf water content
LAI	Leaf area index
m	meter
mm	millimeter
m^2	square meter
%	per cent
N	Nitrogen
P	Phosphorus
K	Potassium
POP	Package of practices
ppm	parts per million
S	Seed priming
q	Quintal
t	tonnes

INTRODUCTION

1. INTRODUCTION

Rice, which is the staple food of more than 60 per cent of the world population, is the most important and extensively grown food crop of India. Rice is grown under different ecosystems in our country, among which upland rice is an important one.

In India, out of the 42.7 million hectares of land under rice, about 21.9 per cent of the area is exposed to risk prone upland ecology (Mishra, 1999). More than 80 per cent of the upland rice areas are concentrated in Assam, Bihar, Madhya- Pradesh, Orissa, West Bengal and Uttar Pradesh.

In Kerala, out of the total gross cropped area of 30.42 lakh ha, only 22 per cent is under food crops. Kerala, which is chronically short in food grain production is confronted with a serious problem of retaining even this small area cultivated under rice crop. The total rice area witnessed a sharp fall from 8.74 lakh ha in 1972-73 to 4.31 lakh ha in 1998-99 (FIB, 2000). Owing to various socio-economic reasons the upland rice cultivation is almost abandoned in Kerala. Now the policy makers are giving thrust to retain the rice area and to increase the total rice production. The upland areas during monsoon season give vast scope for rice production in the state. The possibility of increasing rice production through upland rice cultivation by judicious management of various production inputs needs urgent attention.

The productivity of upland rice is very low because of a host of problems among which soil moisture stress, poor native soil fertility and heavy weed infestations are the most important ones. At present no specific package of practices recommendation is available for different agronomic aspects of upland rice in Kerala.

Of the various factors that influence the upland rice production, low soil moisture supply is generally the most serious. The rice crop grown under upland situations is generally subjected to different degrees of moisture stress, is shorter and has fewer tillers and less leaf area, higher sterility, produces less dry matter and has lower harvest index and yield (Yoshida and Pandre, 1974). A low supply of moisture to upland even in monsoon season is due to uneven or inadequate rainfall, rapid drainage owing to coarse soil texture or rolling topography, which is further aggravated by the low water holding capacity of the soil.

The nutrient management problems of upland rice soils have received low priority and most of the soils are poor in soil fertility. The percentage of all essential nutrients has been found lower in rice plants grown under upland conditions than in those grown under lowland condition (IRRI, 1975).

Under upland situation, moisture stress is likely to occur during any of the growth stages of the crop which may adversely affect the growth and yield. Seed hardening increases the competitive ability of seedlings. The protoplasm of hardened plants is found to have a lower viscosity and exhibits higher permeability to water and nutrients and is able to hold water against dehydrating forces. Hardening treatment improves germination, promotes plant and root growth and increases crop survival under water stress conditions. One such successful method is pre-treating rice seeds with potassium chloride solution (Sheela and Alexander, 1995).

With the above said points under consideration, the present investigation entitled, 'Response of seed priming, nutrient management and irrigation on upland rice (*Oryza sativa* L.)' was undertaken with the following objectives :

1) To work out optimum nutrient levels and irrigation schedule required for producing maximum rice yield under upland conditions.

2) To investigate the effect of seed priming in inducing stress tolerance.

3) To work out the economics of various treatment combinations.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Upland rice, which accounts 21.9 per cent of our total rice area is an important rice ecosystem of the country and its improvement will help in augmenting the future demand of rice. A brief review on the response of irrigation, nutrient management and seed priming on upland rice is presented in this chapter.

2.1 Effect of irrigation levels on upland rice

2.1.1 Response of upland rice to different irrigation levels

Chandramohan (1965) stated that rice requires more water than any other crop of similar field duration and the requirements vary with soil texture, climate, cultural practices and varietal growth duration. Satyanarayana and Ghildyal (1970) observed that rice produced better shoot growth and higher grain yields when grown under flooded condition than when grown under 60 cb moisture tension or under saturation. Islam *et al.* (1986) reported that rice production was highest under continuous submergence than under soil saturation or under intermittent irrigation. Sharma *et al.* (1987) reported that grain yield in irrigated plots was 78 per cent more than the rainfed crop. Singandhupe and Rajput (1987) noticed that the grain yield in continuous submergence and one day drainage were on par. According to Joseph and Havanagi (1987), submergence and partial submergence levels of irrigation gave higher grain yield in rice than under saturation. Thorat *et al.* (1987) observed that under limited water resources, irrigation at 12 mm CPE, daily irrigations and soil compaction and irrigation at 24 mm CPE were on par in grain yield. Irrigating rice at one to four days after disappearance of ponded water produced comparable yield to that at continuous submergence (Sharma and Rajput, 1990). Kulandaivelu (1990) reported that scheduling irrigation at 1.5 IW/CPE ratio was proved to be inferior in terms of water use efficiency compared to that at an IW/CPE ratio of 1.0 and 0.5. Prasad *et al.* (1992) reported that rice field can be dried even upto seven days after disappearance of irrigation water with a grain yield of 19.13 - 21.29 q ha^{-1} against similar yields at three or five days drying. He also reported that rainfed control showed a significant decrease in grain yield compared with other drying periods. Raju *et al.* (1992) reported that maximum water use efficiency was recorded in alternate wetting and drying regimes and least in continuous submergence of soil.

Ramamoorthy *et al.* (1998) reported a significant depression in grain yield under rainfed treatment compared with higher moisture regimes. He also reported that medium moisture regime (1.5 IW/CPE) saved around 13 per cent irrigation water with higher water use efficiency compared with higher moisture regime of 2.00 IW/CPE. Increasing the water use efficiency of rice with delay in irrigation by medium moisture regime resulting in higher grain yield was also reported by Prasad *et al.* (1990).

Lourduraj and Rajagopal (1998) reported that irrigating one day after disappearance of ponded water is the optimum irrigation regime for rice. Pathak *et al.* (1999) reported that intermittent irrigation of three or six days after disappearance of ponded water significantly improved the growth and yield attributes of the crop compared to rainfed conditions.

2.1.2 Effect of different irrigation levels on growth and growth characters

Choudhury and Gupta (1981) observed that soil moisture stress resulted in reduced plant height of rice. Aragon and De Datta (1982) reported a linear increase in plant height and DMP with increase in total water applied. Cruz and O'Toole (1984) reported that soil moisture stress at the vegetative stage of rice caused a decrease in tiller number, leaf area index, photosynthetic rate and increased the ratio of shoot to root dry mass. Reduced plant height, relative growth rate and daily rate of leaf expansion of rice due to moisture stress during the pre-flowering stage was noticed by Turner *et al.* (1986). Chaudhury *et al.* (1984) noticed that plant height was reduced by widening the irrigation intervals. However, the tillers per hill was not influenced by irrigation intervals.

Ramakrishnayya and Murty (1991) reported from studies on fifty rice varieties that imposition of soil moisture stress caused reduction in plant height and tiller number and further relief of stress caused an increase in tiller number. According to Sheela (1993) the leaf area expansion of rainfed rice was more sensitive to moisture stress. Deka and Baruah (1998) reported that water stress reduced shoot and root dry weight in both drought resistant and susceptible cultivars of rice.

2.1.3 Effect on yield and yield attributes

Chaudhury *et al.* (1984) reported that grain yield was maximum with continuous flooding while yield, sterility percentage and thousand grain weight decreased with increasing irrigation intervals. Lee *et al.* (1985)

indicated that soil moisture stress reduced the number of spikelets panicle^{-1} and filled grain percentage resulting in yield reduction upto 49.3 per cent in rice.

Rahman and Yoshida (1985) observed that panicle exertion showed an inhibitory effect due to water stress under moisture stress conditions. Sudhakar *et al.* (1989) reported that moisture stress during tillering stage resulted in significant reduction in panicle number, while stress during panicle development and ripening reduced the percentage of filled grains in rice. Fussel *et al.* (1991) reported that grain yield in rice was reduced by 45 to 49 per cent under stress, mainly due to reduction in grain yield per panicle rather than reduction in panicle number.

Lenka and Garnayak (1991) reported that grain sterility is directly related to stress during flowering to panicle ripening and prolonged stress during the initial stages increased the crop duration. Ramakrishnayya and Murty (1991) observed that tillers produced till the end of drought were mostly productive and contributed to yield whereas those developed during recovery phase had no influence on yield. Bali and Uppal (1999) reported that schedule of irrigation application after 2 days of infiltration of ponded water produced significantly higher grain yield over that of 4 days after infiltration of ponded water.

2.1.4 Effect on physio-chemical parameters

2.1.4.1 Water relation in plant

The relative water content in leaves of field grown rice ranged from 88 to 96 per cent under saturated conditions compared to 80 to 86 per cent under stress conditions (Nayak *et al.*, 1983). From field trials conducted at IRRI, it was reported that water deficit has no effect on midday water potential of rice (IRRI, 1989). Studies by Agarwal *et al.* (1990) revealed that the upland variety Azucena maintained high leaf water potential throughout the stress period as compared to the low land type, IR-36. Ramakrishnayya and Murty (1991) found that with increase in soil moisture stress there was a decrease in relative water content and water potential of rice leaf. Sheela (1993) observed that the drought tolerant rice varieties maintained higher relative water content under rainfed conditions showing their relative ability to maintain leaf turgor at lower levels of moisture. Similar results were also reported by Pathak *et al.* (1999). Prasad *et al.* (1992) reported that leaf area was minimum in the case of rainfed control whereas all other irrigation levels had almost similar values of leaf area index.

2.1.4.2 Proline content

Several researchers suggested that proline content could be used as a measure of drought resistance (Barnett and Naylor, 1966 and Singh *et al.*, 1972). Parker (1968) suggested that proline accumulation could not be taken as a protective mechanism against drought, but might have resulted from some protein break down or it might simply be a storage compound of nitrogen. Accumulation of proline in wheat leaves under moisture stress was reported by Rajagopal *et al.* (1977). They pointed out that under such conditions, proline accumulation could provide a quick mechanism for maintaining the osmoticum of cells and tissues. But Girou and Curvetto (1990) observed no relationship between proline accumulation during heading and drought resistance in wheat. Sheela (1993) reported that the upland and drought tolerant rice varieties recorded more proline content than the susceptible ones under rainfed low land conditions. Deka and Baruah (1998) also reported that stress resistant cultivars had high proline accumulation.

2.1.4.3 Grain protein and nutrient uptake

Jayabal (1971) observed higher content of nitrogen in drought tolerant rice varieties under upland conditions. Sheela (1993) reported that drought tolerant upland varieties recorded significantly higher protein content under rainfed lowland conditions.

Mali and Varade (1981) reported that rice plants grown at field capacity showed higher concentration of N and K than plants grown under submergence. Islam *et al.* (1986) reported that apparent recovery of applied N was lowest with intermittent irrigation compared with continuous standing water and soil saturation. Ichwantoari *et al.* (1989) observed that uptake of N by rice was more sensitive to drought than other nutrients. It was also reported from Vellayani that increased moisture levels enhanced the root growth and solubility of nutrients which in turn improved nutrient uptake in drought tolerant rice varieties under rainfed conditions (Sheela, 1993). Bali and Uppal (1999) suggested that irrigation at shorter intervals increased nutrient uptake and improved the water use efficiency of rice.

2.2 Effect of nutrient management in upland rice

The percentage of all essential nutrients has been found lower in rice plants grown under upland conditions than in those grown under lowland conditions (IRRI, 1975). The pertinent studies in nutrient management under upland conditions are reviewed here.

2.2.1 Nitrogen management

2.2.1.1 Growth and yield attributes

Munda (1989) reported that increased nitrogen levels significantly improved tiller production in rainfed rice. Increased plant height with higher N levels was reported by Mishra *et al.* (1988) and Sheela (1993). Reddy and Kulandaivelu (1990) observed that high level of applied N increased the root volume and root dry weight in rice.

Sudhakar *et al.* (1986) observed that increasing rates of N enhanced the dry matter production (DMP), panicle number, number of spikelets and grain yield but reduced the percentage of filled grains in rainfed upland rice. Vashney (1986) noticed that optimum dose is between 57 and 62.8 kg under an upland terrace system of rice cultivation in Meghalaya. Dalai and Dixit (1987) reported that grain and straw yields of rice increased appreciably at each successive levels of N and there was increase in the number of panicles per square meter, length of panicle and thousand grain weight which ultimately resulted in higher yield. However, moderate levels of N (30-40 kg ha^{-1}) resulted in better production of yield attributes and yield in upland rice (Chandra *et al.*, 1991). Prasad *et al.* (1992) recorded that in direct seeded rainfed rice, response to N was only upto 80 kg ha^{-1} with a rice yield of 22.19-23.7 q ha^{-1} as compared with 24.1- 25.28 q ha^{-1} at 120 kg N ha^{-1} both being at par with each other. Similarly Kalita and Sarmah (1992) observed that in direct seeded summer rice grain yield was enhanced only upto 60 kg N ha^{-1}. Bhattacharyya and Singh (1992) opined that increased levels of N increased growth and yield components and N uptake upto 80 kg ha^{-1} in upland direct seeded rice. Similar observations were also made by Dwivedi *et al.* (1992). Singh *et al.* (1999) in a study to increase rice production in rainfed uplands of Orissa observed that for semi tall varieties a dose of 45 kg N ha^{-1} was adequate. Singh and Prasad (1998) observed that application of 75 kg N ha^{-1} gave remarkably higher yield over the recommended dose of N (50 kg ha^{-1}) in rainfed upland. Lakpale *et al.* (1999) reported that the grain yield and N accumulation of rainfed rice increased significantly by the application of 120 kg N ha^{-1} as compared with that of 60 kg N ha^{-1}.

2.2.1.2 Effect on Partitioning of biomass and nutrients

Devi and Nair (1984) reported that N supply did not affect the partitioning of assimilates between leaves and developing panicles. Inocencio *et al.* (1984) reported that crude protein concentration in grains was highest with 90 kg urea ha^{-1}. Rahman and Yoshida (1985) observed that high N increased N content in the culm and sheath at flowering, but at harvest this decreased substantially irrespective of N level or cultivar. Kamiji and Horie (1989) reported that sink capacity is primarily limited by spikelet number, which in turn has a close association with N nutrition of the crop. Deshmukh and Chau (1992) observed that rice grain yield correlated better with source than sink parameters, particularly leaf area index and total chlorophyll content at flowering stage which in turn has a close association with N nutrition of the crop.

2.2.2 Effect of Phosphorus on growth and yield

Patrick and Mahapatra (1968) opined that the availability of phosphorus (P) in upland soils was lower than that of flooded soil. Hence deficiency might be a limiting factor in upland soils especially in strongly acidic oxisols (Ponnamperuma, 1975). Fageria *et al.* (1982) reported from a large number of field experiments that an optimum P level of 44 to 66 kg ha^{-1} was required to produce better yields of rice in rainfed uplands. Trials conducted at Ranchi, on rainfed upland rice (Mahapatra and Srivastava, 1984) revealed that the optimum P requirement of a variety of 100 to 110 days duration was about 40 kg P_2O_5 ha^{-1}. Hung (1986) reported that phosphorus fertilizer promoted tiller development, increased grain yield and shortened growth period in rice. Singh (1985) reported that yield and response of rice increased significantly with 60 kg P_2O ha^{-1} over its no-application. Rajkhowa and Baroova (1998) reported a significant increase in filled grains per panicle, thousand grain weight and yield of rice with the application of P fertilizers upto 38.7 kg ha^{-1} in the rainfed areas of Assam.

2.2.3 Effect of Potassium on growth and yield

Singh (1985) reported that yield and response of rice did not increased favourably with increased potassium (K) levels. Patiram and Prasad (1987) observed that upland rice showed a response upto 30 kg K_2O ha^{-1}. Thakuria and Choudhary (1995) observed that the application of K @ 60 kg ha^{-1} recorded the maximum grain yield under upland situation. Sarmah and Baruah (1997) noticed that the highest grain yield of summer rice was obtained with

49.8 kg K ha^{-1} which was mainly due to increase in number of panicles per square meter. It was also reported that split application of K increased the grain yield as compared with single application as basal dose. Direct seeded summer rice showed response upto 60 kg ha^{-1} of K_2O application (Pathak *et al.*,1999). Thakur *et al.* (1999) reported that number of grains per panicle, grain and straw yields were significantly higher with split application of 30 and 45 kg K_2o ha^{-1}. The highest potassium uptake value of rice from the same experiment was observed at 30 kg K_2O ha^{-1}.

2.2.4 Combined application of nutrients

2.2.4.1 Effect on growth and yield

Randhawa and Singh (1983) reported that for rainfed rice receiving 1400 mm rainfall, a nutrient dose of 60 : 30 : 0 gave better yield from high yielding varieties in K rich soils. Akram *et al.* (1985) reported that in Basmati rice average yield was highest with the fertilizer rate of 90 kg N and 45 kg P_2O ha^{-1} which also gave the highest average protein content (9.34 per cent). Sharma and Choubey (1986) in a work conducted in rainfed upland rice observed that higher yields were obtained with an NPK level of 90 : 60 : 30 than at 30 : 20 : 10 kg ha^{-1} or no NPK. De Datta *et al.* (1988) reported that rice gives good response in yield to complete NPK fertilizers especially in dry season. Deshmukh *et al.* (1988) reported that an NPK level of 80 : 60 : 40 kg ha^{-1} gave maximum yield in early rice varieties raised as rainfed crop. While Pradhan and Das (1990) observed that an NPK level of 90 : 45 : 45 kg ha^{-1} gave highest grain yield in upland rainfed rice. However Singh *et al.* (1990)

noticed from the experiments that upland rice required a low NPK rate of 40 : 13 : 16 kg ha^{-1} which gave a remarkable increase in yield over traditional system in which only FYM was used. Similarly Singh *et al.* (1992) also noticed that recommended NPK dose of 40 : 8.67 : 16.67 kg ha^{-1} was the economic optimum dose for upland rice production. In a study conducted on rainfed rice at Vellayani conditions indicated that 67.5 : 33.75 : 33.75 kg NPK ha^{-1} was sufficient for medium duration rice varieties (Sheela and Alexander, 1995). Roy *et al.* (1997) reported that fertilizer input dose of 90 : 60 : 90 kg NPK ha^{-1} in two or three splits significantly increased the grain yield of upland rice compared to the basal application of 90 kg N ha^{-1} alone in acid sedentary soils of Ranchi. Singh *et al.* (1998) reported higher grain and straw yields of rice to the tune of 6.4 and 4.8 per cent respectively by the application of 125 per cent of the recommended NPK dose. Saha *et al.* (1999) noticed that the balanced application of NPK @ 60 : 13.1 : 25 kg ha^{-1} brought about 12 per cent increase in panicle number per square meter over that of no fertilizer application under rainfed upland situation.

2.2.4.2 Effect on quality, water relations and uptake of nutrients

Nitrogen content of rice straw and grain was positively correlated with the rate of N application (Gu and Wang, 1984). De Datta (1984) reported that under upland conditions increased N levels intensified water stress and decreased water potential in rice. Sheela (1993) reported from Vellayani that the protein content of grains increased with increase in nutrient levels.

Pillai (1971) reported that the recovery of applied N was lower in irrigated upland rice due to alternate wetting and drying of soil, amounting to only 46 per cent compared to 54 per cent under continuous submergence. Kumar and Singh (1984) observed 37 per cent apparent recovery of N with 100 kg applied N ha^{-1} in rainfed uplands. Roy *et al.* (1997) reported that basal dressing of FYM @ 10 t ha^{-1} along with split application of N and K each at 90 kg ha^{-1} resulted in the highest uptake of N and K by the upland rice crop. Choubey *et al.* (1999) opined that application of NPK at 60:30:30 kg ha^{-1} with 6 t FYM ha^{-1} recorded significantly superior uptake of N, P and K in upland rice.

2.3 Effect of seed hardening in upland rice

Under upland condition moisture stress occurring at any stage of rice may adversely affect the growth and yield. Tailoring the plants to withstand moisture stress by seed priming was reported to be effective under such conditions. The influence of seed priming on growth, yield and physiological aspects are reviewed here.

2.3.1 Effect on growth and growth characters

Growth characters like plant height and tiller number were little influenced by soaking paddy seeds in KH_2 PO_4 solution of five to 25 per cent concentration (Mehrotra *et al.*, 1967). Sinha (1969) reported increased plant height, tiller number, leaf number and DMP of rice by pre-sowing seed treatment with NAA and IAA. Devika (1983) observed that pre-sowing seed hardening in water for 48 hours had no effect on plant height of rice, but showed increased tiller production, LAI and dry weight. Increase in plant height and tiller number in rice by seed hardening with Na_2HPO_4, $Al(NO_3)_3$ and water was reported by Singh and Chatterjee (1981). Similar results were also reported by Narayanasamy (1985).

Chockalingam (1986) reported that seed treatment had no influence in plant height and tiller number in Kharif season. However, during summer season seed treatment with one per cent KCl recorded a profound increase in plant height. Sheela and Alexander (1995) reported that seedling emergence, seedling vigour and grain yield were highest when rice seeds were hardened with 2.5 per cent KCl for 18 hours. Salakinkop *et al.* (1998) reported that KCl seed treatment of dry sown rice recorded higher DMP at all crop growth stages than unhardened treatments due to better shoot vigour. Lee *et al.* (1999) reported that primed seeds showed 7.5 per cent more germination than non-primed seeds.

2.3.2 Effect on yield and yield attributes

According to Urs *et al.* (1970), presowing hardening of rice seeds in water increased yield under normal conditions. Similar results were also reported by Borthakur *et al.* (1973) by treating rice seeds in KH_2PO_4 and sodium molybdate solutions. The positive trend in increasing rice yield by presowing seed hardening was reported with 0.50 per cent hydrogen peroxide (Veliehko *et al.*, 1979) and one per cent KCl (Kalaimani *et al.*, 1979).

Peeran and Natanasabapathy (1980) obtained highest rice yield when the seeds were treated with one per cent KCl. Devika (1983) observed that seed treatment with water for 48 hours increased panicle number, thousand grain weight and grain yield of rice varieties raised during the first crop season at Onattukara. The favourable influence of seed hardening with one per cent KCl solution in increasing thousand grain weight and grain yield of rice was reported by Chockalingam (1986).

Mathew (1989) recorded significant increase in yield components and grain yield of rice by seed hardening with 100 ppm succinic acid. Thakuria and Choudhary (1995) reported that priming rice seeds with 4 per cent KCl solution for 24 hours significantly increased the upland rice yield due to more number of tillers and grains per panicle. Sheela (1993) reported an yield increase of 24 per cent with 2.5 per cent KCl treatment due to increased panicle number, panicle weight, increased number of filled grains and thousand grain weight.

2.3.3 Effect on physio-chemical properties

Singh and Chatterjee (1981) reported that the leaves of rice plants raised from treated seeds had significantly lower water saturation deficit than the leaves of plants raised from untreated seeds. Biswas *et al.* (1982) and Nayak *et al.* (1983) claimed that seed treatment with $CaCl_2$ helped rice to maintain better leaf water potential under moisture stress conditions. Wang and Shen (1991) reported that treating rice seeds with triazole decreased the effect of drought on water potential, but not on osmotic potential. They also reported delayed accumulation of free proline in hardened plants, which became rapid with decrease in water potential. Sheela (1993) observed a favourable influence on relative water content and proline accumulation by seed hardening in drought tolerant rice varieties.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The objective of the investigation was to assess the effect of major nutrients and seed priming on upland rice (*Oryza sativa* L.) under varying levels of irrigation and to work out the economics of different treatment combinations. The experiment was conducted during the late first crop season from June to October in the year 1999. The details of the materials used and methods adopted for the study are presented below.

3.1 Experimental site

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, located at 8.5^0 N latitude and 76.9^0 E longitude, at an altitude of 29 m above the mean sea level.

3.1.1 Soil

The soil of the experimental site was sandy clay loam, belonging to the taxonomical order oxisol.

Table 3.1.1 Physico-chemical properties

Sl. No.	Parameter	Content (per cent)	Methods used
A.	Mechanical composition		
1.	Coarse sand	36.35	Bouyoucos
2.	Fine sand	15.00	Hydrometer method
3.	Silt	17.50	(Bouyoucos, 1962)
4.	Clay	30.50	

Sl. No.	Parameter	Content	Ranking	Methods used
B.	Chemical composition			
1.	Available N (kg ha^{-1})	238	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (kg ha^{-1})	32.8	Medium	Bray calorimetric method (Jackson, 1973)
3.	Available K_2O (kg ha^{-1})	160	Medium	Ammonium acetate method (Jackson, 1973)
4.	Organic carbon (per cent)	1.7		Walkley and black rapid titration method (Jackson, 1973)
5.	Soil reaction (pH)	4.8	Acidic	1: 2 : 5 soil solution ratio using pH meter with glass electrode (Jackson, 1973).

3.1.2 Climate

The area of the experimental site enjoys a humid tropical climate. The data on various weather parameters during the cropping period are presented in Appendix I and illustrated in Fig. 1.

3.1 Season

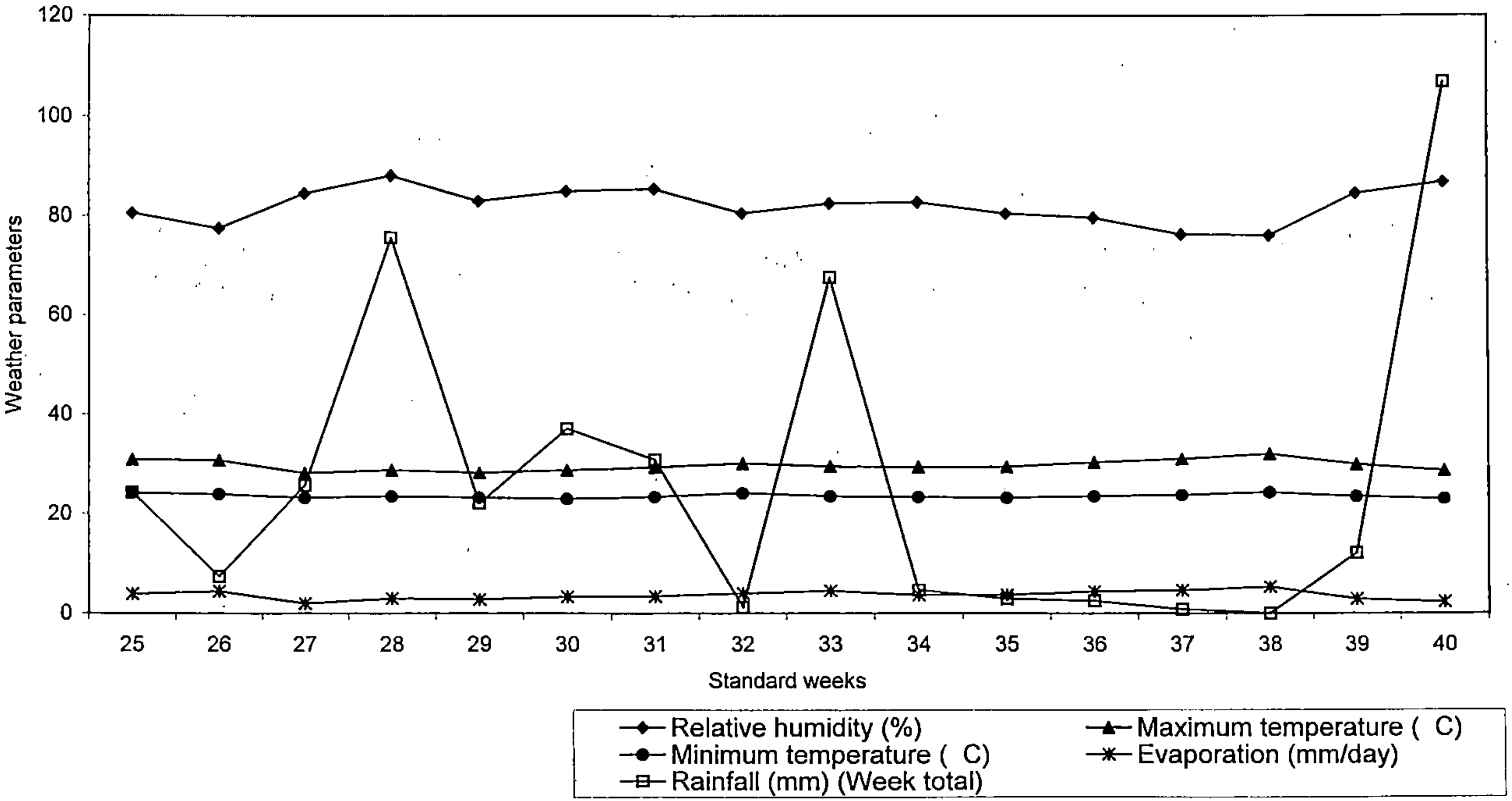
The field experiment was conducted during the late first crop season of 1999.

3.2 Materials

3.2.1 Crop variety

The rice variety selected for the experiment was Matta Triveni (PTB-45), released from Regional Agricultural Research Station (RARS), Pattambi, having a duration of 95-105 days. The grains are red, long and bold. The variety is tolerant to BPH and susceptible to blast and sheath blight.

Fig. 1 Weather parameters during the cropping period (June 20 to October 10, 1999)



3.2.2 Source of seed material

The seeds for the experiment were obtained from RARS, Pattambi.

3.2.3 Manures and fertilizers

Well-decomposed and dried farmyard manure (0.4, 0.3 and 0.2 per cent N, P_2O_5 and K_2O respectively) was used for the experiment. Urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used for the experiment.

3.2.4 Chemical used for seed priming

The potassic fertilizer, muriate of potash analysing 60 per cent K_2O was used for seed priming.

3.3 Methods

3.3.1 Design and layout

The layout plan of the experiment is given in Fig. 2.

Design	: Split split plot design
Treatment combinations	: 18
Number of replications	: 3
Plot size	
Gross	: 5 x 4 m
Net	: 4.6 x 3.8 m
Spacing	: 20 x 10 cm
Total number of plots	: 54

Two rows of plants were left as border rows on all the sides and the observations were taken from the randomly selected plants from the net plot area.

Fig. 2 Layout plan of the experiment

Replication I			Replication II			Replication III		
$I_1F_1S_2$	$I_3F_2S_1$	$I_2F_1S_1$	$I_3F_3S_1$	$I_1F_2S_2$	$I_2F_3S_1$	$I_3F_1S_1$	$I_1F_2S_1$	$I_2F_1S_1$
$I_1F_3S_1$	$I_3F_1S_2$	$I_2F_3S_1$	$I_3F_1S_2$	$I_1F_3S_1$	$I_2F_2S_1$	$I_3F_3S_2$	$I_1F_1S_2$	$I_2F_3S_2$
$I_1F_2S_2$	$I_3F_3S_1$	$I_2F_2S_2$	$I_3F_2S_1$	$I_1F_1S_1$	$I_2F_1S_2$	$I_3F_2S_1$	$I_1F_3S_1$	$I_2F_2S_1$
$I_1F_1S_1$	$I_3F_2S_2$	$I_2F_3S_2$	$I_3F_1S_1$	$I_1F_3S_2$	$I_2F_2S_2$	$I_3F_1S_2$	$I_1F_2S_2$	$I_2F_1S_2$
$I_1F_2S_1$	$I_3F_1S_1$	$I_2F_1S_2$	$I_3F_3S_2$	$I_1F_1S_2$	$I_2F_3S_2$	$I_3F_2S_2$	$I_1F_1S_1$	$I_2F_2S_2$
$I_1F_3S_2$	$I_3F_3S_2$	$I_2F_2S_1$	$I_3F_2S_2$	$I_1F_2S_1$	$I_2F_1S_1$	$I_3F_3S_1$	$I_1F_3S_2$	$I_2F_3S_1$

3.3.2 Treatments

Main plot treatment : Irrigation levels (3)

I_1 : Irrigating the crop at an IW/CPE ratio of 1.5

I_2 : Irrigating the crop at an IW/CPE ratio of 1.0

I_3 : Rain fed

Depth of irrigation : 50 mm

Sub plot treatments : Nutrition levels (3)

F_1 : 20 : 10 : 15 kg ha^{-1} NPK

F_2 : 40 : 20 : 30 kg ha^{-1} NPK

F_3 : 60 : 30 : 45 kg ha^{-1} NPK

(F_2 is the present package of practices recommendation).

Sub sub plot treatments : Seed priming (2)

S_1 : Seed priming with 1.0 per cent KCl for 15 hours

S_2 : Seed priming with 2.5 per cent KCl for 15 hours

3.4 Field culture

3.4.1 Land preparation

The experimental area was ploughed, levelled and laid out as per the design. Initial soil samples were taken for analysis. The individual plots were perfectly levelled before sowing.

3.4.2 Application of manures and fertilizers

Farmyard manure (FYM) @ 5 t ha^{-1} was applied uniformly to all the plots and mixed well with the top soil. Nitrogen was applied in three equal split doses, first as basal dressing, second at tillering stage and the third at panicle initiation stage. Full dose of phosphorus was applied at the time of land preparation as basal dressing. Potassium was applied in two split doses, half as basal and half at the panicle initiation stage.

3.4.3 Seeds and sowing

The seeds of the rice variety, Matta Triveni were immersed in one and 2.5 per cent KCl solution for 15 hours. Then it was drained and the seeds were dried under shade. Pre-germinated seeds @ 85 kg ha^{-1} were dibbled at 20 x 10 cm spacing. Sowing was done on June 20, 1999.

3.4.4 After cultivation

Thinning and gap filling were done in few plots 12 days after sowing (DAS) for uniform plant population. Two hand weedings were done at 15 and 30 DAS. Periodic weeding was done to the plot bunds and irrigation channels.

3.4.5 Irrigation

Irrigation was scheduled to the crop as per the treatments.

3.4.6 Plant protection

Spraying with metacid was done immediately after flowering against rice bug. No disease attack was noticed on magnitudes requiring chemical control.

3.4.7 Plant sampling

Samples were collected from the area left for sampling at 30 DAS, 60 DAS and at harvest. Five plants were selected randomly from the net plot area and tagged as observational plants. Two rows from all the sides were left as border rows and the net plot area was 4.6 x 3.8 m.

3.4.8 Harvest

The crop was harvested at full maturity i.e., 114 days after sowing on October 18, 1999. The border and sample rows were harvested separately. Net plot area of individual plots was harvested and the weights of grain and straw were recorded.

3.5 Observations

3.5.1 Observations on growth characters

3.5.1.1 Height of plant

The mean value of the height of five randomly selected observational plants from the net plot area was computed at 30 and 60 DAS and at harvest and expressed in cm. The height was measured from the base to the tip of the top most leaf. At harvest, the height was recorded from the base of the plant to the tip of the longest panicle.

3.5.1.2 Tiller number per hill

Tiller number was counted at 30 and 60 DAS and at harvest from the sample hills, the mean values were worked out and recorded.

3.5.1.3 Leaf area index (LAI)

The leaf area of two hills from each plot was measured at 60 DAS using LI – 3100 leaf area meter and expressed in square centimeter. LAI was then computed using the equation,

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.5.1.4 Dry matter production (DMP)

DMP was estimated at 30 and 60 DAS and at harvest. At each observation, four sample hills were uprooted, washed, sun dried, oven dried at 80^0C to constant weight and DMP was expressed in kg ha^{-1}.

3.5.2 Observation on yield attributes and yield

3.5.2.1 Number of productive tillers per hill

At harvest, productive tillers were counted in four sample hills and the mean number was worked out.

3.5.2.2 Length of panicle

Ten panicles were collected from each plot, length was measured from the neck to the tip and the average was expressed in cm.

3.5.2.3 Weight of panicle

Ten panicles were separately weighed from each plot, the mean weight was worked out and expressed in grams.

3.5.2.4 Number of spikelets per panicle

The spikelets were removed from each panicle, counted and the mean number of spikelets per panicle was recorded.

3.5.2.5 Number of filled grains per panicle

The filled grains were separated from each panicle, counted and the mean number was recorded.

3.5.2.6 Chaff percentage

The chaff percentage was worked out using the formula,

$$\text{Chaff percentage} = \frac{\text{Number of unfilled grains}}{\text{Total number of grains}} \times 100$$

3.5.2.7 Thousand grain weight

The weight of one thousand grains from the cleaned produce drawn from each plot was recorded in grams.

3.5.2.8 Grain yield

The grains harvested from each net plot area were dried to constant weight, cleaned, weighed and expressed in kg ha^{-1}.

3.5.2.9 Straw yield

The straw harvested from each net plot area was dried to constant weight under sun and the weight was expressed in kg ha^{-1}.

3.5.2.10 Harvest index

Harvest index (HI) was calculated using the formula,

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

3.5.3 Physiological and chemical estimations

3.5.3.1 Relative leaf water content (RLWC)

The method proposed by Weatherly (1950) which was later modified and described in detail by Slatyer and Baars (1965) was used to determine

RLWC. It was calculated as,

$$\text{RLWC} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.5.3.2 Proline content

Proline content was estimated from the fully opened second leaf from the top at the panicle emergence stage by the technique suggested by Bates *et al.* (1973).

3.5.3.3 Protein content of grains

Protein percentage was computed by multiplying the nitrogen content of the grain with the factor 6.25 (Simpson *et al.*, 1965).

3.5.3.4 Partitioning of biomass

Partitioning of biomass was estimated at the harvest stage. For that, weights of panicle, shoot and roots were recorded separately.

3.5.3.5 Nutrient uptake

The nitrogen, phosphorus and potassium uptake by crop at 60 DAS and at harvest were worked out as the product of content of these nutrients and respective dry weight of plant samples and expressed in kg ha^{-1}.

3.5.4 Root studies

3.5.4.1 Root length

After harvest the roots of each hill were removed carefully, washed, maximum length was measured and expressed in cm.

3.5.4.2 Root volume

Volume of roots per hill was estimated by the displacement method and expressed in cm^3 per hill.

3.5.4.3 Root weight

Roots removed from each hill were dried and then dry weight was recorded in grams per plant.

3.5.4.4 Root spread

Roots of each hill after washing were placed as such on a plain paper and maximum width of the root system was measured and expressed in cm.

3.5.4.5 Root shoot ratio

Root and shoot weights were recorded separately from each hill and root to shoot ratio was worked out.

3.5.5 Soil moisture estimation

3.5.5.1 Total water supplied in each experiment

The irrigation was scheduled to the crop one week after sowing as per the treatments. Measured quantity of water was given to the plots according to the treatments at an IW/CPE ratio of 1.5 and 1.0 to a depth of 50 mm in the treatments I_1 and I_2 respectively. The data on total quantity of water received by each irrigation treatment during the crop period is given in Appendix II.

3.5.5.1 Water use efficiency (kg ha^{-1} cm^{-1})

Field water use efficiency was calculated by dividing the economic crop yield by total quantity of water received (including irrigation water and effective rainfall) in field and expressed in kg ha^{-1} cm^{-1}.

3.5.6 Economic analysis

3.5.6.1 Benefit cost ratio (BCR)

The economics of cultivation was worked out considering the total cost of cultivation and prevailing market price of the produce and benefit cost ratio was calculated as follows.

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.5.7 Disease incidence

The disease spread never reached the threshold level and hence uniform score was given to all plots.

3.5.8 Statistical analysis

Data relating to each character was analysed by applying the Analysis of Variance Technique (ANOVA) as suggested by Panse and Sukhatme (1985).

RESULTS

4. RESULTS

A field experiment was conducted at the Instructional Farm attached to the college of Agriculture, Vellayani during the late first crop season of 1999 to study the effect of nutrient management and seed priming on upland rice under varying levels of irrigation. The experimental data collected were analysed statistically and the results are presented below.

4.1 Growth characters

Observations were collected from randomly selected five hills in the net plot area to compute the plant height, number of tillers per hill, leaf area index (LAI) and dry matter production (DMP).

4.1.1 Plant height

Plant height as influenced by irrigation levels (I), nutrient management (F) and seed priming (S) are presented in Table 4.1.1. There was a progressive increase in plant height in all treatments at different stages of crop growth. The effect of irrigation treatment was visible only after 60 DAS whereas that of nutrient levels was significant through out the crop growth. Irrigating the crop at an IW /CPE ratio of 1.5 (I_1) and an NPK level of 60 : 30 : 45 kg ha^{-1} recorded the highest plant height and was significantly superior than other levels. The impact of seed priming was noticed at 30 DAS only and S_1 recorded the highest plant height. The interaction effects failed to exert any significant influence on plant height.

Table 4.1.1 Effect of irrigation, nutrients and seed priming on plant height (cm)

Treatments	30DAS	60DAS	Harvest
Irrigation			
I_1	31.23	65.31	68.59
I_2	30.73	57.89	63.68
I_3	31.04	54.32	55.74
$F_{(2, 4)}$	0.152	14.601*	35.245**
CD	-	5.758	4.286
nutrients			
F_1	28.7	51.65	56.9
F_2	30.67	59.92	63.26
F_3	33.64	65.96	67.86
$F_{(2, 16)}$	11.569**	32.456**	11.327 **
CD	2.194	3.78	4.901
Seed priming			
S_1	34.39	60.15	61.63
S_2	30.61	58.2	60.71
$F_{(1, 34)}$	5.648*	1.492	1.007
CD	3.347	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.1.2 Number of tillers per hill

The influence of irrigation, nutrients and seed priming levels on number of tillers per hill are given in Table 4.1.2. The data revealed that both irrigation and nutrition levels had significant influence on number of tillers per hill. The influence of irrigation treatments was noticed at harvest and I_1 recorded the highest number of tillers per hill which was on par with I_2 and I_3. The impact of NPK levels was significant from 60 DAS and F_3 recorded the highest number of tillers per hill.

4.1.3 Leaf area index (LAI)

The mean values of LAI at 60 DAS as influenced by treatments are presented in Tables 4.1.3.a. and 4.1.3.b. The data indicated that the main effect of all the three factors profoundly influenced LAI. The treatment levels I_1, F_3 and S_1 recorded the highest values. The interactions I x F and I x F x S also influenced the LAI. Among the treatment combinations I_1 F_3 and I_1 F_3 S_1 registered the highest values.

4.1.4 Dry matter production (DMP)

The mean values of DMP at different growth stages as influenced by the factors (I, F, S) and its interactions (I x F, I x F x S) are summarised in Tables 4.1.3. a and 4.1.3.b. The data showed that DMP was influenced by all the treatments. The impact of irrigation treatment was noticed at 30 DAS and at harvest. Both the irrigation treatments (I_1 and I_2) registered a significant influence on DMP over the control treatment (rainfed). The I_1 treatment gave the highest DMP. Though not significant similar differences were also noticed

4.1.2 Effect of irrigation, nutrients and seed priming on number of tillers $hill^{-1}$

Treatments	30DAS	60DAS	Harvest
Irrigation			
I_1	11.22	9.89	10.11
I_2	11.72	9.22	9.56
I_3	11.61	9.88	9.44
$F_{(2, 4)}$	0.103	0.744	8.1*
CD	-	-	0.796
Nutrients			
F_1	10.67	8.78	9.33
F_2	11.17	9.5	9.33
F_3	12.72	10.7	10.4
$F_{(2,16)}$	2.989	7.014 **	4.189*
CD	-	1.113	0.940
Seed priming			
S_1	11.04	9.74	9.74
S_2	12.00	9.59	9.67
$F_{(1,34)}$	2.45	0.107	0.033
CD	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.1.3 a Effect of irrigation, nutrients and seed priming on LAI and DMP (kg ha^{-1})

Treatments	LAI 60DAS	DMP		
		30 DAS	60DAS	Harvest
Irrigation				
I_1	2.62	1991.95	4463	23,499.45
I_2	2.27	1916.67	4283	20575
I_3	1.09	1630.56	3229	11925
$F_{(2, 4)}$	11502 **	18.415**	4.309	234.99**
CD	0.029	23.50	-	105.90
Nutrients				
F_1	1.832	1808.60	3290	14,455
F_2	1.982	1552.78	4070	16,965
F_3	2.174	2177.78	4640	24,435
$F_{(2, 16)}$	385.63 **	60.997**	22.41**	145.941**
CD	0.026	21.01	18.90	35.50
Seed priming				
S_1	2.10	2050	4150	18675
S_2	1.89	1642.8	3840	18560
$F_{(1, 34)}$	426.4**	77.59**	0.624	0.016
CD	0.021	19.50	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.1.3 b Interaction effect of irrigation, nutrients and seed priming on LAI and DMP (kg ha^{-1})

Treatments	LAI 60DAS	DMP		
		30 DAS	60DAS	Harvest
$I_1 F_1$	2.89	1065	3640	19285
$I_1 F_2$	2.03	1775	4065	23740
$I_1 F_3$	2.93	2630	5490	29365
$I_2 F_1$	2.19	1575	3865	27050
$I_2 F_2$	2.25	2065	4440	13490
$I_2 F_3$	2.35	2105	4915	18915
$I_3 F_1$	0.863	1550	2370	10640
$I_3 F_2$	1.205	1675	3715	8240
$I_3 F_3$	1.23	1665	3565	16890
F(4, 16)	475.8**	33.27**	0.631	17.817**
CD	0.045	0.398	-	4.463
$I_1F_1S_1$	3.38	1485	4465	15820
$I_1F_1S_2$	2.4	650	2815	22750
$I_1F_2S_1$	2.87	2285	4385	22200
$I_1F_2S_2$	1.2	1270	3750	25285
$I_1 F_3S_1$	3.71	3050	4685	34600
$I_1F_3S_2$	2.15	2215	6200	22500
$I_2F_1S_1$	2.35	1600	3265	10615
$I_2F_1S_2$	2.03	1550	4465	16265
$I_2F_2S_1$	1.97	2250	4685	258.5
$I_2F_2S_2$	2.54	1885	4195	11985
$I_2F_3S_1$	2.65	2000	58.30	33115
$I_2F_3S_2$	2.06	2215	4000	23615
$I_3F_1S_1$	0.45	1450	2625	8185
$I_3F_1S_2$	1.27	1650	2115	13100
$I_3F_2S_1$	0.73	2100	3265	5085
$I_3F_2S_2$	1.68	1250	4165	11400
$I_3F_3S_1$	0.79	2230	4285	22735
$I_3F_3S_2$	1.67	1100	2850	10.5
F(4, 34)	214.981**	9.89**	1.977	9.028**
CD	0.062	4.87	-	4.52

* Significant at 5 per cent ** Significant at 1 per cent

at 60 DAS. The influence of NPK levels on DMP was significant through out the crop growth. The F_3 treatment gave the highest DMP throughout the crop growth. The impact of seed priming treatment was noticed at 30 DAS only, S_1 recorded the highest value. The interactions I x F and I x F x S were significant at 30 DAS and at harvest. The treatment combinations I_1 F_3 and I_1 F_3 S_1 registered the highest DMP.

4.2 Yield and yield attributing characters

4.2.1 Number of productive tillers hill^{-1}

The mean values of number of productive tillers per hill are given in Table 4.2.1. Number of productive tillers per hill was influenced by irrigation and nutrient treatments only. Treatment levels I_1 and F_3 recorded highest number of productive tillers per hill and was significantly superior to other levels.

4.2.2 Length of panicle

The data on length of panicle as influenced by the treatments are presented in Table 4.2.1. The length of panicle was not influenced by the treatments I, F and S or its interactions. However the highest levels of irrigation and nutrients tend to increase the panicle length.

4.2.3 Weight of panicle

The data on weight of panicle as influenced by the levels of irrigation, nutrients and seed priming are presented in Table 4.2.1. Data revealed that irrigation levels alone exerted a marked difference in the weight of panicle.

Table 4.2.1 Effect of irrigation, nutrients and seed priming on number of productive tillers hill^{-1}, length of panicle (cm) and weight of panicle (g)

Treatment	Number of productive tillers hill^{-1}	Length of panicle (cm)	Weight of panicle (g)
Irrigation			
I_1	11.22	19.83	2.33
I_2	8.94	19.056	2.03
I_3	5.8	15.78	0.89
F(2, 4)	15.297*	5.046	36.514**
CD	2.715	-	0.493
Nutrients			
F_1	7.7	17.056	1.585
F_2	8.11	18.83	1.84
F_3	10.22	18.8	1.82
F(2, 16)	6.426**	1.111	2.144
CD	1.615	-	-
Seed priming			
S_1	8.3	18.78	1.78
S_2	9	17.67	1.72
F (1,34)	0.954	1.365	0.219
CD	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

Irrigation at an IW/CPE ratio of 1.5 and 1.0 were on par with each other and were significantly superior to the control.

4.2.4 Number of spikelets per panicle

The data on number of spikelets per panicle as influenced by different levels of I,F and S are summarised in Tables 4.2.2.a and 4.2.2.b. The data indicated that irrigation and nutrient levels had significant influence on the number of spikelets per panicle. The irrigation treatment I_1 and NPK level F_3 produced highest number of spikelets per panicle and were on par with I_2 and F_2 respectively. The interaction between I and F also was significant. The treatment combinations I_1 F_3 and I_2 F_2 produced highest number of spikelets per panicle and were on par with each other.

4.2.5 Number of filled grains per panicle

The data on number of filled grains per panicle are given in Tables 4.2.2.a and 4.2.2.b. The data showed that both irrigation and nutrient levels had significant influence on number of filled grains per panicle. Irrigation treatments I_1 and I_2 were on par with each other and were significantly superior to I_3. Similarly F_2 and F_3 were on par with each other and were significantly superior to F_1. The interactions I x F and I x F x S also were significant. Treatment combinations I_2 F_2 and I_2 F_2 S_2 recorded the highest number of filled grains per panicle.

4.2.2.a Effect of irrigation, nutrients and seed priming on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and chaff percentage

Treatment	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Chaff percentage
Irrigation			
I_1	119	101	14
I_2	116	101	13
I_3	91	42	63
$F_{(2, 4)}$	6.771*	43.8**	511.67**
CD	22.82	20.69	4.97
Nutrients			
F_1	91	71	25.55
F_2	115	87	30.11
F_3	120	89	34.39
$F_{(2, 16)}$	14.923**	7.649**	10.764**
CD	12.121	10.231	4.031
Seed priming			
S_1	109	79	32.07
S_2	109	85	27.96
$F_{(1, 34)}$	0.001	1.539	5.421*
CD	-	-	3.584

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.2.2.b Interaction effect of irrigation, nutrients and seed priming on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and chaff percentage

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Chaff percentage
$I_1 F_1$	110	101	9.83
$I_1 F_2$	112	96	13.83
$I_1 F_3$	136	113	17.33
$I_2 F_1$	91	79	13
$I_2 F_2$	139	121	14.67
$I_2 F_3$	118	104	12.83
$I_3 F_1$	72	34	53.83
$I_3 F_2$	95	43	75.17
$I_3 F_3$	107	49	60.17
F(4, 16)	14.9**	4.37*	6.997**
CD	12.121	17.721	6.9
$I_1F_1S_1$	107	97	8.33
$I_1F_1S_2$	113	105	11.33
$I_1F_2S_1$	113	102	9.67
$I_1F_2S_2$	110	90	18
$I_1 F_3S_1$	142	115	19
$I_1F_3S_2$	129	110	15.67
$I_2F_1S_1$	93	80	13.33
$I_2F_1S_2$	89	78	12.67
$I_2F_2S_1$	110	94	17.67
$I_2F_2S_2$	167	148	10.67
$I_2F_3S_1$	128	116	10.67
$I_2F_3S_2$	107	92	15
$I_3F_1S_1$	73	33	56
$I_3F_1S_2$	70	34	51.67
$I_3F_2S_1$	99	36	91.33
$I_3F_2S_2$	91	50	59
$I_3F_3S_1$	113	42	62.67
$I_3F_3S_2$	101	57	57.67
F(4, 34)	2.649	3.696*	4.173**
CD	-	27.45	10.17

* Significant at 5 per cent   ** Significant at 1 per cent

4.2.6 Chaff percentage

The data on chaff percentage as influenced by different levels of I, F and S and its combinations are presented in Tables 4.2.2.a and4.2.2.b. The data revealed that all the three treatments and its interactions had significant influence on chaff percentage. Both the irrigation treatments I_1 and I_2 registered less chaff percentage as compared to rainfed treatment. The nutrient level F_3 produced significantly higher values of chaff percentage than F_2 and F_1. The seed priming treatment S_2 recorded lowest value of chaffiness. Among the I x F combinations, I_1 F_1 recorded the lowest value and was on par with I_1 F_2, I_2 F_1, I_2 F_2 and I_2 F_3. The three factor interaction I_1 F_1 S_1 registered the lowest chaff percentage and the highest value was given by I_3 F_2 S_1.

4.2.7 Thousand grain weight

Data pertaining to the thousand grain weight are presented in Tables 4.2.3.a and 4.2.3.b. The impact of irrigation and nutrient levels and interaction effect of I x F and I x F x S were significant on this character. Among the irrigation treatments, I_1 recorded significantly higher test weight over I_2 and I_3. Similarly the highest level of NPK (F_3) also produced higher test weight over F_2 and F_1. The interaction effect of I x F indicated that the highest levels tested in the trial (I_1 F_3) gave the highest test weight and was on par with I_1 F_2 and these two combinations were superior than all other treatment combinations. Among the I x F x S combinations, I_1 F_2 S_1 recorded the highest test weight and was on par with I_1 F_2 S_2.

4.2.8 Grain yield

The influence of different levels of irrigation, nutrients and seed priming and the interactions between I, F and S on grain yield are presented in Tables 4.2.3.a and 4.2.3.b. Data indicated that the factors, irrigation and nutrients and the interaction I x F had significant influence on grain yield. I_1 gave the highest grain yield (2676 kg ha^{-1}) which was significantly superior to I_2 (2145 kg ha^{-1}) and I_3 (371 kg ha^{-1}). Among the nutrient levels tested, F_3 recorded the highest grain yield of 2094 kg ha^{-1} which was significantly superior than F_2 (1798 kg ha^{-1}) and F_1 (1299 kg ha^{-1}). Among the I x F combinations I_1 F_3 registered the highest grain yield of 3223 kg ha^{-1}.

4.2.9 Straw yield

The data pertaining to the mean values of straw yield as influenced by I, F and S and its interactions are furnished in Tables 4.2.3.a and 4.2.3.b. The irrigation and nutrient treatments alone influenced straw yield. The highest straw yield was obtained at irrigation level I_1 (7004 kg ha^{-1}) and at NPK level F_3 (7120 kg ha^{-1}) which were superior to all other levels.

4.2.10 Harvest index (HI)

The mean values of HI as influenced by the treatments are summarised in Table 4.2.3.a. The data revealed that the irrigation and nutrient levels appreciably influenced the HI. Irrigation at an IW/CPE ratio of 1.5 recorded the highest value of HI and was significantly superior to I_2 and I_3. Among the NPK levels tested F_2 produced the highest HI and was higher than F_1 and F_3, which were on par with each other. The seed priming treatment and the

4.2.3.a Effect of irrigation, nutrients and seed priming on thousand grain weight (g), grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index

Treatment	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Irrigation				
I_1	22.44	2675.9	7004	0.271
I_2	21.58	2144.6	6640	0.235
I_3	17.07	370.8	4700	0.083
$F_{(2, 4)}$	990.5 **	2163.2**	44.4**	206.2**
CD	0.351	101.8	73.7	0.027
Nutrients				
F_1	19.76	1299.4	5070	0.195
F_2	20.65	1798.2	6180	0.199
F_3	20.68	2093.7	7120	0.195
$F_{(2, 16)}$	83.5**	53.1**	4.4*	50.2**
CD	0.154	165.1	142.7	0.027
Seed priming				
S_1	20.29	1736.4	6007	0.198
S_2	20.3	1724.5	6240	0.194
$F_{(1, 34)}$	0.194	0.036	0.25	0.248
CD	-	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.2.3.b Interaction effect of irrigation, nutrients and seed priming on thousand grain weight (g), grain yield (kgha^{-1}), straw yield (kg ha^{-1}) and harvest index

Treatment	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
$I_1 F_1$	21.11	2155	5690
$I_1 F_2$	23.14	2650	6810
$I_1 F_3$	23.45	3223	8610
$I_2 F_1$	21.73	1431	5240
$I_2 F_2$	21.20	2386	7010
$I_2 F_3$	21.80	2617	7650
$I_3 F_1$	16.43	313	4200
$I_3 F_2$	17.60	358	4710
$I_3 F_3$	17.20	441	5100
F(4, 16)	53.616**	11.106**	0.522
CD	0.367	286.05	-
$I_1F_1S_1$	21.63	2029	5560
$I_1F_1S_2$	20.60	2279	5820
$I_1F_2S_1$	23.25	2599	6270
$I_1F_2S_2$	23.00	2701	7360
$I_1 F_3S_1$	22.40	3276	8070
$I_1F_3S_2$	22.50	3169	9140
$I_2F_1S_1$	22.47	1355	4520
$I_2F_1S_2$	21.00	1506	5970
$I_2F_2S_1$	21.40	2742	7300
$I_2F_2S_2$	21.00	2030	6700
$I_2F_3S_1$	22.20	2828	7400
$I_2F_3S_2$	21.40	2406	7900
$I_3F_1S_1$	15.47	177	4270
$I_3F_1S_2$	17.40	449	4310
$I_3F_2S_1$	17.00	261	4830
$I_3F_2S_2$	18.20	456	4590
$I_3F_3S_1$	16.77	358	5800
$I_3F_3S_2$	17.60	523	4390
F(4, 34)	20.7**	1.461	0.382
CD	0.888	-	-

* Significant at 5 per cent ** Significant at 1 per cent

interaction effect of various treatment combinations failed to influence the HI values.

4.3 Physiological and chemical estimations

4.3.1 Relative leaf water content (RLWC)

The mean values of RLWC of plants at 60 DAS as influenced by different levels of I, F and S and its combinations are given in Tables 4.3.1.a and 4.3.1.b. The data revealed that only irrigation treatment had significant influence on RLWC. The treatment at I_1 recorded the highest RLWC of 84.46 per cent which was on par with I_2 (78.42 per cent) and was significantly superior than I_1 (61.20 per cent). The I x F and I x F x S interactions failed to influence the RLWC.

4.3.2 Proline content

The data on mean values of proline content of the plant leaves are presented in Tables 4.3.1.a and 4.3.1.b. It is seen from the table that irrigation and nutrient levels had profound influence on leaf proline content. The rainfed treatment recorded the highest value of proline content in the leaf which was significantly superior than I_1 and I_2. Among the NPK levels, F_3 recorded the highest proline content and was significantly superior than F_1 and F_2.

4.3.3 Protein content of grains

The data on protein content of grains as influenced by the treatments are summarised in Tables 4.3.1.a and 4.3.1.b. The data showed that all the treatments except seed priming exerted remarkable influence on the protein

4.3.1.a Effect of irrigation, nutrients and seed priming on relative leaf water content (RLWC), proline content ($\mu g\ g^{-1}$) and grain protein content (%)

Treatment	RLWC (%)	Proline content ($\mu g\ g^{-1}$)	Grain protein (%)
Irrigation			
I_1	84.46	0.80	4.64
I_2	78.42	0.75	4.30
I_3	61.20	1.12	3.74
$F_{(2, 4)}$	44.30**	63.49**	427.6**
CD	7.14	0.096	0.087
Nutrients			
F_1	73.39	0.864	3.94
F_2	76.61	0.843	3.84
F_3	74.01	0.971	4.90
$F_{(2, 16)}$	1.051	4.723*	249.8**
CD	-	0.095	0.111
Seed priming			
S_1	75.11	0.901	4.227
S_2	74.23	0.884	4.227
$F_{(1, 34)}$	0.249	0.225	6.005
CD	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.3.1.b Interaction effect of irrigation, nutrients and seed priming on RLWC (%), proline content ($\mu g\ g^{-1}$) and grain protein content (%)

Treatment	RLWC (%)	Proline content ($\mu g\ g^{-1}$)	Grain protein(%)
$I_1 F_1$	84.93	0.691	4.20
$I_1 F_2$	85.95	0.701	3.96
$I_1 F_3$	82.50	1.02	4.75
$I_2 F_1$	76.78	0.67	4.025
$I_2 F_2$	76.82	0.76	4.30
$I_2 F_3$	81.67	0.84	5.60
$I_3 F_1$	58.48	1.225	3.59
$I_3 F_2$	67.06	1.07	3.27
$I_3 F_3$	57.86	1.055	4.35
F(4, 16)	1.729	6.07	18.8**
CD	-	-	0.192
$I_1F_1S_1$	80.67	0.673	4.90
$I_1F_1S_2$	89.20	0.71	3.50
$I_1F_2S_1$	87.36	0.653	4.02
$I_1F_2S_2$	84.54	0.75	3.90
$I_1 F_3S_1$	85	1.14	4.60
$I_1F_3S_2$	80	0.89	4.90
$I_2F_1S_1$	76.78	0.75	4.90
$I_2F_1S_2$	76.78	0.60	3.15
$I_2F_2S_1$	77.70	0.77	4.90
$I_2F_2S_2$	75.90	0.75	3.70
$I_2F_3S_1$	73.33	0.89	5.60
$I_2F_3S_2$	90.00	0.78	5.60
$I_3F_1S_1$	63.63	1.07	2.98
$I_3F_1S_2$	52.33	1.38	4.20
$I_3F_2S_1$	73.30	1.10	2.34
$I_3F_2S_2$	60.79	1.04	4.20
$I_3F_3S_1$	58.15	1.06	3.80
$I_3F_3S_2$	57.59	1.05	4.90
F(4, 34)	2.364	2.102	22.174**
CD	-	-	0.265

* Significant at 5 per cent ** Significant at 1 per cent

content of grains. Irrigation at I_1 level recorded the highest value and was significantly superior than I_2 and I_3. Among the NPK levels, F_3 registered the highest value of grain protein and was superior than F_1 and F_2 which were on par with each other.

The interactions I x F and I x F x S also had influence on protein content of grains. The treatment combination I_2 F_3 gave the highest value and was significantly superior than all other combinations. Among the three factor interactions I_2 F_3 S_1 and I_2 F_3 S_2 showed more protein content than all other combinations.

4.3.4 Partitioning of biomass

Partitioning of biomass at harvest stage as influenced by different levels of I, F and S is given in Table 4.3.2. From the table it is clear that total dry weight increased progressively with increasing levels of irrigation and nutrition. Both the irrigation treatments I_1 and I_2 showed higher DMP and partitioning efficiency than I_3 and were on par with each other. The effect of nutrient levels on partitioning of photosynthates was not significant except for shoot dry weight. The seed priming treatment failed to exert significant influence on partitioning of biomass.

4.3.5 Nutrient uptake studies

The nutrient uptake by rice plants as influenced by levels of irrigation, nutrients and seed priming and its interaction are summarised in Tables 4.3.3.a and 4.3.3.b.

Table 4.3.2 Effect of irrigation, nutrients and seed priming on partitioning of biomass at harvest

Treatments	Shoot dry weight (g)	Panicle dry weight (g)	Root dry weight (g)	Total DMP (g)
Irrigation				
I_1	44.38	2.33	6.06	52.77
I_2	39.12	2.03	4.47	45.62
I_3	22.96	0.89	2.105	25.96
$F_{(2, 4)}$	234.9**	36.5**	141.3**	44.4*
CD	3.054	0.493	0.657	2.503
Nutrients				
F_1	27.35	1.585	4.15	33.05
F_2	32.09	1.94	4.23	38.16
F_3	47.05	1.82	4.26	53.13
$F_{(2, 16)}$	145.9*	2.14	0.12	2.425
CD	2.57	-	-	-
Seed priming				
S_1	36.07	1.78	4.17	42.08
S_2	35.40	1.72	4.25	41.37
$F_{(1, 34)}$	0.016	0.219	0.174	0.775
CD	-	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.3.5.1 Nitrogen uptake

The data showed that all the treatment effects were significant in influencing the uptake of N. Nitrogen uptake increased with increasing levels of irrigation and nutrient application and highest values were registered with irrigation treatment I_1 and NPK level F_3 and were significantly superior than lower levels. Seed priming treatment S_1 recorded the highest N uptake at 60 DAS and at harvest. The two factor interaction I x F and three factor interaction I x F x S also influenced the N uptake favourably. Among the two factor interactions, the treatment combination I_2 F_3 recorded highest N uptake at 60 DAS while at harvest more uptake was noticed in I_1 F_3. The three factor combination I_2 F_3 S_1 recorded highest uptake of N both at 60 DAS and at harvest.

4.3.5.2 Phosphorus uptake

Phosphorus uptake was also significantly influenced by all the treatments (I, F and S) and its combinations. The treatment levels I_1, F_3 and S_1 recorded highest values of P uptake and were significantly superior than other levels. Among the I x F interactions, I_1 F_3 recorded the highest uptake of P at 60 DAS. However at the time of harvest more P uptake was noticed with I_2 F_3. Among the higher order interactions of I x F x S, I_1 F_3 S_2 and I_2 F_3 S_1 recorded highest P uptake at 60 DAS and at harvest respectively.

4.3.5.3 Potassium uptake

Unlike N and P uptake, the K uptake was influenced by the irrigation and seed priming treatments. Irrigating the crop at an IW /CPE ratio of 1.5

Table.4.3.3.a Effect of irrigation, nutrients and seed priming on nutrient uptake (kg ha^{-1})

Treatment	N uptake		P uptake		K uptake	
	60DAS	Harvest	60DAS	Harvest	60DAS	Harvest
Irrigation						
I_1	29.91	96.73	10.30	68.25	82.24	255.08
I_2	28.56	80.82	10.04	62.96	95.61	226.16
I_3	18.03	68.89	6.16	27.48	61.85	150.7
$F_{(2, 4)}$	98.40**	22.70**	23.20**	19.30**	24.30**	19.20**
CD	0.257	0.116	0.025	0.082	5.89	6.19
Nutrients						
F_1	19.84	60.46	8.01	41.43	72.99	176.8
F_2	26.15	71.43	8.68	45.34	80.89	226.73
F_3	30.51	114.55	9.80	71.92	91.8	228.39
$F_{(2, 16)}$	89.70**	20.20*	86.30**	24.60**	3.604	1.982
CD	0.17	0.083	0.017	0.044	-	-
Seed priming						
S_1	27.99	86.96	9.164	56.35	90.41	217.49
S_2	23.01	77.33	8.50	49.45	73.38	203.8
$F_{(1, 34)}$	25.40**	19.40**	20.40**	19.80**	11.76**	0.457
CD	0.135	0.044	0.011	0.049	10.08	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

Table 4.3.3.b Interaction effect of irrigation, nutrients and seed priming on nutrient uptake (kg ha^{-1})

Treatment	N uptake		P uptake		K uptake	
	60DAS	Harvest	60DAS	Harvest	60DAS	Harvest
$I_1 F_1$	21.32	73.65	10.23	60.165	71.76	214.8
$I_1 F_2$	29.97	86.49	7.73	64.36	76.37	293.5
$I_1 F_3$	34.39	130.06	12.94	80.23	116.58	256.9
$I_2 F_1$	25.06	48.13	9.754	41.58	88.17	189.8
$I_2 F_2$	28.34	84.85	11.48	51.06	97.63	229.9
$I_2 F_3$	36.31	109.47	8.875	96.22	101.03	259.02
$I_3 F_1$	13.13	59.59	4.04	22.23	59.05	125.77
$I_3 F_2$	20.145	42.95	6.815	20.60	68.69	157.09
$I_3 F_3$	20.835	104.14	7.625	39.30	57.82	169.25
F(4, 16)	48.80**	21.65**	59.40**	18.70**	2.826	0.262
CD	0.296	0.143	0.029	0.073	-	-
$I_1F_1S_1$	30.03	70.87	14.51	49.35	97.77	223.04
$I_1F_1S_2$	12.60	76.45	5.96	70.98	45.75	206.56
$I_1F_2S_1$	39.27	99.45	7.70	58.38	54.70	268.36
$I_1F_2S_2$	20.67	73.53	7.76	70.35	98.04	318.65
$I_1 F_3S_1$	34.07	100.8	11.14	61.80	117.04	236.83
$I_1F_3S_2$	34.72	159.3	14.75	98.59	116.12	277.02
$I_2F_1S_1$	20.11	41.61	8.13	22.50	88.62	181.21
$I_2F_1S_2$	30.02	54.65	11.38	60.67	87.73	198.53
$I_2F_2S_1$	26.22	116.03	14.04	64.75	113.44	273.4
$I_2F_2S_2$	36.47	53.68	8.92	37.38	81.81	185.76
$I_2F_3S_1$	45.73	160.60	7.87	109.56	121.26	279.24
$I_2F_3S_2$	26.88	79.34	9.88	82.89	80.8	238.79
$I_3F_1S_1$	13.23	45.82	4.36	20.45	59.11	90.95
$I_3F_1S_2$	13.03	73.36	3.72	24.62	58.98	160.58
$I_3F_2S_1$	14.63	28.46	6.76	12.70	75.62	150.68
$I_3F_2S_2$	25.66	57.45	6.87	28.50	61.76	163.51
$I_3F_3S_1$	28.61	98.03	7.96	45.46	86.14	253.71
$I_3F_3S_2$	13.06	68.25	7.29	33.15	29.48	84.77
F(4, 34)	5478.3 **	65.05**	55.98**	50.97**	6.331**	1.996
CD	0.405	0.133	0.032	0.147	30.24	-

* Significant at 5 per cent ** Significant at 1 per cent

and 1.0 (I_1 and I_2) registered more K uptake at 60 DAS and at harvest. The influence of seed priming was noticed at 60 DAS only and S_1 recorded the highest potassium uptake. Among the interactions, I x F x S was significant at 60 DAS and I_2 F_3 S_1 recorded the highest potassium uptake value..

4.4 Root Studies

Root characters as influenced by different levels of I, F and S are presented in Table 4.4.1. The data relating to root length, root volume, root weight and root spread revealed that the irrigation levels alone exerted appreciable differences. Irrigation at IW/CPE ratio of 1.5 (I_1) invariably produced better root characters and all the treatments failed to exert significant influence on root shoot ratio.

4.5 Water use efficiency (kg ha^{-1} cm^{-1})

The mean values of WUE as influenced by different levels of I, F and S are given in Tables 4.5.1 a and 4.5.1 b. The levels of I, F and S recorded significant influence on WUE. The unirrigated treatment (I_3) showed higher WUE while between I_1 and I_2 the latter gave better WUE. nutrient treatment at F_3 and seed priming at S_1 recorded better WUE. Among the treatment combinations I_3 F_3 and I_3 F_3 S_1 registered highest values of WUE.

4.6 Benefit cost ratio (BCR)

The data on BCR as influenced by different levels of I, F and S and its combinations are presented in Tables 4.5.1 a and 4.5.1 b. The data revealed that all the treatment factors and its combinations had significant influence on

BCR. Among the irrigation levels, the highest BCR was recorded by I_1 (1.4) and was significantly superior than I_2 and I_3. An increase in NPK levels also registered a progressive increase in BCR. Higher levels of NPK (F_3) recorded the highest BC ratio which was significantly higher than F_1 and F_2. The BC ratio was also influenced by seed priming, S_1 recorded the highest value and was on par with S_2. The interaction effect of treatments *viz.*, I x F and I x F x S also exerted a remarkable influence on BCR. Among the combinations I_1 F_3 (1.62) and I_1 F_3 S_1 (1.67) recorded the highest values.

Table 4.4.1 Effect of irrigation, nutrients and seed priming on root parameters

Treatment	Root length (cm)	Root volume (cm^3 $hill^{-1}$)	Root weight (g $hill^{-1}$)	Root spread (cm)	Root shoot ratio
Irrigation					
I_1	11.43	7.58	6.06	3.17	0.132
I_2	8.77	6.13	4.47	2.38	0.125
I_3	7.48	3.30	2.105	2.19	0.376
$F_{(2, 4)}$	503.39**	423.4**	141.3**	19.84**	0.803
CD	0.352	0.415	0.657	0.479	-
Nutrients					
F_1	9.09	5.54	4.15	2.38	0.141
F_2	9.41	5.77	4.23	2.63	0.111
F_3	9.17	5.69	4.26	2.73	0.381
$F_{(2, 16)}$	0.54	0.426	0.12	1.171	0.84
CD	-	-	-	-	-
Seed priming					
S_1	9.28	5.7	4.17	2.53	0.12
S_2	9.17	5.63	4.25	2.63	0.301
$F_{(1, 34)}$	0.205	0.152	0.174	0.452	0.946
CD	-	-	-	-	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

Table 4.5.1. a Effect of irrigation, nutrients and seed priming on water use efficiency (WUE) and benefit : cost ratio (BCR)

Treatments	WUE	BCR
Irrigation		
I_1	40.92	1.4
I_2	41.86	1.28
I_3	55.79	0.71
$F_{(2, 4)}$	159**	440**
CD	0.082	0.007
Nutrients		
F_1	38.25	0.97
F_2	39.27	1.145
F_3	61.05	1.28
$F_{(2, 16)}$	873**	455**
CD	0.041	0.007
Seed priming		
S_1	46.32	1.17
S_2	46.06	1.09
$F_{(1, 34)}$	314.5**	0.53
CD	0.029	-

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Irrigation levels (3)
I_1 : Irrigating the crop at an IW/CPE ratio of 1.5
I_2 : Irrigating the crop at an IW/CPE ratio of 1.0
I_3 : Rain fed

Nutrition levels (3)
F_1: 20 : 10 : 15 kg ha^{-1} NPK
F_2: 40 : 20 : 30 kg ha^{-1} NPK
F_3: 60 : 30 : 45 kg ha^{-1} NPK

Seed priming (2)
S_1 : 1.0 per cent KCl for 15 hours
S_2 : 2.5 per cent KCl for 15 hours

4.5.1.b Interaction effect of irrigation, nutrients and seed priming on water use efficiency (WUE) and benefit : cost ratio (BCR)

Treatments	WUE	BCR
$I_1 F_1$	35.4	121
$I_1 F_2$	37.6	1.37
$I_1 F_3$	49.7	1.62
$I_2 F_1$	29.5	1.04
$I_2 F_2$	41.61	1.34
$I_2 F_3$	54.45	1.45
$I_3 F_1$	49.76	0.66
$I_3 F_2$	38.59	0.72
$I_3 F_3$	79.003	0.76
F(4, 16)	134**	624**
CD	0.072	0.012
$I_1F_1S_1$	29.07	1.07
$I_1F_1S_2$	41.81	1.36
$I_1F_2S_1$	40.73	1.26
$I_1F_2S_2$	34.47	1.48
$I_1 F_3S_1$	41.35	1.67
$I_1F_3S_2$	58.07	1.58
$I_2F_1S_1$	23.37	0.83
$I_2F_1S_2$	35.71	1.24
$I_2F_2S_1$	56.87	1.46
$I_2F_2S_2$	26.37	1.23
$I_2F_3S_1$	57.08	1.46
$I_2F_3S_2$	51.81	1.45
$I_3F_1S_1$	38.27	0.63
$I_3F_1S_2$	61.26	0.68
$I_3F_2S_1$	23.81	0.71
$I_3F_2S_2$	53.38	0.72
$I_3F_3S_1$	106.33	0.84
$I_3F_3S_2$	51.67	0.68
F(4, 34)	572**	345.7**
CD	0.087	0.018

* Significant at 5 per cent ** Significant at 1 per cent

DISCUSSION

5. DISCUSSION

The present investigation was undertaken with the objective of assessing the response of irrigation, nutrient management and seed priming on growth and yield of upland rice. The results of the experiment presented in the previous chapter are discussed here.

5.1 Growth and growth characters

Results of the study indicated a significant positive influence of irrigation, nutrient and seed priming levels on the growth characters of upland rice. All the growth characters studied *viz.*, plant height, tiller count and LAI were profoundly influenced by irrigation and nutrient levels. Seed priming levels also showed a marked variation in plant height and LAI. The interaction effect of the treatments was noticed only in the case of LAI.

The plant height, tiller count and LAI showed an increasing trend with increasing levels of irrigation and maximum value for these growth characters were registered with the treatment I_1 (IW/CPE - 1.5). Chandramohan (1965) stated that rice requires more water than any other crop of similar field duration and that the requirement varies with soil texture, climate, cultural practices and growth duration. Moisture stress being the most important constraint under upland situation, both the irrigation treatments I_1 and I_2 recorded significantly higher expression of growth as noticed by the growth characters (Table 4.1). The rainfed control treatment recorded less vigour even though a rainfall of 214 mm was received during the crop period. The plant availability of major nutrients by mass flow and diffusion decreases as the moisture content of soil decreases (Parish, 1971). Thus the low moisture content of upland soils reduces the steady supply of nutrients to the roots. The positive influence of irrigation might be also due to the continuous and uniform availability of soil moisture which in turn increases the turgidity of cells favouring cell enlargement and cell division (Begg and Turner, 1976). A similar increase in growth characters by irrigation was observed by Sahu and Rao (1974) and they reported that moisture stress during vegetative phase of the crop resulted in reduced plant height, tiller number and leaf area and this might be due to the coincidence of maximum physiological activity and morphological advancement of plant during this period. Similar observations were also reported by O'Toole and Baldia (1982) and Sheela (1993).

An increasing trend in growth characters was noticed with the application of higher levels of NPK. The increasing trend in growth characters as observed might be due to the increased uptake of major nutrients with adequate supply of these nutrients through fertilizers (Table 4.3.3. a). Vaijayanthi (1986) reported that the positive influence of N,P and K in plant height may be due to their combined influence in cell division and cell elongation. An adequate supply of N was reported to increase plant height and deficiency resulted in stunted growth of rice plant (Roy *et al.*, 1980). Increase in plant height due to increased application of P (Choudhury *et al.*, 1979) and K (Vijayan and Sreedharan, 1972) was also reported. According to De Datta (1981) N increased height and tiller number, P encouraged tillering and root development and K increased P response and favoured tillering in rice. Deshmukh *et al.* (1988) also observed similar increase in plant height and tiller number for early duration rainfed rice when the NPK level was increased from 20 : 15 : 10 to 80 : 60 : 40 kg ha^{-1}. Increase in plant height and tiller number might have contributed to a corresponding increase in the number of leaves which in turn might have influenced LAI.

Among the growth characters, plant height at 30 DAS and LAI at 60 DAS were significantly influenced by seed priming. In the present study seed priming with one per cent KCl was found to be superior than that with 2.5 per cent KCl. Seed priming enhances the capacity to maintain turgour and turgour mediated processes in the seeds resulting in better survival and growth of seedlings (Cutler *et al.*, 1980). Increased rate of elongation of radicle and plumule by seed hardening was reported by Dakshinamoorthy and Sivaprakasam (1989). Basu *et al.* (1974) reported that seed hardening increased vigour of upland rice in the early stages. Similar observations were also reported by Singh and Chatterjee (1981), Peeran and Natanasabapathy (1980) and Sheela (1993).

Interaction effects I x F and I x F x S showed a significant influence on LAI. The treatment combinations I_1 F_3 and I_1 F_3 S_1 recorded the highest value of LAI. It might be due to the better uptake of nutrients at higher levels of soil moisture or might be due to the drought resistance induced by the seed priming process. Sheela (1993) reported that increased moisture level enhanced the root growth and solubility of nutrients which in turn improved nutrient uptake in drought tolerant rice varieties under rainfed conditions.

5.1.2 Dry matter production (Fig. 3)

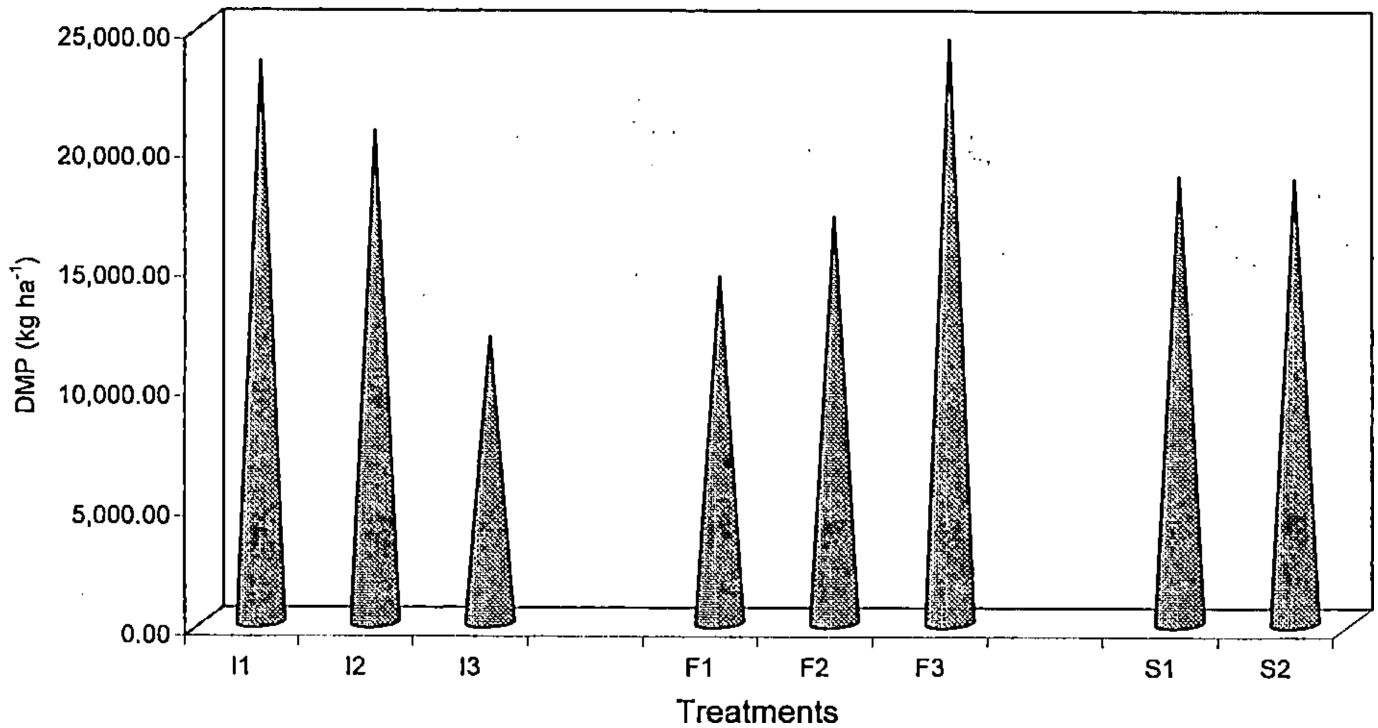
Dry matter production showed a progressive increase throughout the crop growth and was significantly influenced by all the three factors viz., irrigation, nutrition and seed priming.

The impact of irrigation treatment was noticed at 30 DAS and at harvest. Irrigating the crop at an IW/CPE ratio of 1.5 and 1.0 produced taller plants with more number of tillers and more leaf area resulting in higher DMP. Drastic reduction in vegetative characters was noticed in plants under rainfed condition, which in turn reduced the DMP. Similar reduction in DMP due to moisture stress was reported by Agarwal *et al.* (1985), Sheela (1993) and Deka and Baruah (1998).

The influence of nutrition levels was also significant in DMP throughout the crop growth. The fertilizer combination of 60 : 30 : 45 kg NPK ha^{-1} (F_3) recorded the highest DMP. Fertilizer application at higher levels might have increased the availability of nutrients which in turn resulted in the improvement of growth characters and thereby higher DMP. Appreciable enhancement in DMP of rice with enhanced NPK levels has been previously reported by Roy *et al.* (1997), Singh *et al.* (1998) and Saha *et al.* (1999).

The impact of seed priming was noticed only at 30 DAS and S_1 recorded the highest DMP. This could be accounted by the well developed root system of the treated plants which might have improved the nutrient uptake by the plant which in turn improved the growth characters and hence

Fig. 3 Effect of irrigation (I), nutrients (F) and seed priming (S) on DMP at harvest (kg ha^{-1})



the DMP. Similar results were also reported by Narayanasamy (1985), Chockalingam (1986), Mathew (1989) and Sheela (1993).

5.2. Yield and yield attributing characters

5.2.1. Yield attributing characters

Results of the study revealed that the levels of irrigation and nutrients exerted significant influence on yield attributes *viz.*, number of productive tillers per hill, length of panicle, weight of panicle, number of spikelets per panicle, number of filled grains per panicle, chaff percentage and test weight. All these characters except length of panicle were profoundly influenced by irrigation treatment. Similarly, levels of nutrition also registered remarkable variation on majority of the characters except on length and weight of the panicle. The interaction effect of the treatment combination I x F was significant on number of spikelets per panicle, number of filled grains per panicle, chaff percentage and thousand grain weight whereas that of I x F x S was significant on number of filled grains per panicle, chaff percentage and test weight.

Irrigating the crop at an IW / CPE ratio of 1.5 recorded the highest value for all the yield attributing characters. A drastic reduction in all these characters was observed in plants under rainfed condition. It might be due to the high soil moisture tension experienced throughout the crop growth period especially during critical stages which in turn might have restricted the development of reproductive phase of the crop. Extreme reduction in tiller number and leaf area due to moisture stress could have led to a permanent strain in rice crop as observed by Cruz and O' Toole (1984). Rahman and Yoshida (1985) observed that panicle exertion showed an inhibitory effect due to water stress under moisture stress conditions. Lenka and Garnayak (1991) reported that grain sterility is directly related to stress during flowering to panicle ripening. In the present study panicles produced by the plants subjected to rainfed situation failed to emerge out completely and were sterile. The deliterious effect of water deficit on spikelet opening (Ekanayake *et al.*, 1989) would have resulted in high chaff percentage. Similar observations were also recorded by Prasad *et al.* (1992). Sudhakar *et al.* (1989) reported that soil moisture stress during tillering stage resulted in significant reduction in panicle number while stress during panicle development and ripening reduced the percentage of filled grains of rice.

Among the nutrient levels, F_3 recorded the highest value for all the yield attributes. Under upland condition, the nutrient availability is very less because of the rapid mineralisation of organic matter, loss of N through leaching and denitrification, P fixation and leaching loss of K. Therefore, to ensure sufficient crop growth and yield, fertilizer application at optimum levels is a pre-requirement. Significantly higher number of panicles at F_3 level of nutrients might be due to the increased tiller production which could have resulted from the efficient utilization of nutrients at higher rates of NPK application. Ghose *et al.* (1960) reported that increased absorption of nutrients at panicle initiation stage favoured increased production of grains per panicle as noticed in the present study. Channabasavanna and Setty (1994) also reported increase in grain number per panicle in rice with higher NPK levels.

Roy *et al.* (1980) reported that K stimulated build up and translocation of carbohydrates and grain development which increased the number of filled grains. At higher level of NPK fertilizers, a significant increase in chaff percentage was observed in the present study. With higher fertilizer doses, the vegetative growth was more resulting in high LAI and this might have resulted in mutual shading which affected photosynthesis. The reduced translocation of accumulated starch and decreased photosynthetic activity during the reproductive and ripening stages might have resulted in the production of more number of chaffy grains. It might also be due to the poor partitioning of biomass to panicles at higher levels of fertilizer application (Table 4.3.2). Similar results were also reported by Sudha (1999) and Asif *et al.* (1999). This could be the reason for similar test weight at higher and lower nutritional levels. Deshmukh *et al.* (1988) reported that combined application of major nutrients at higher levels resulted in favourable response of yield attributes in rice.

5.2.2 Yield

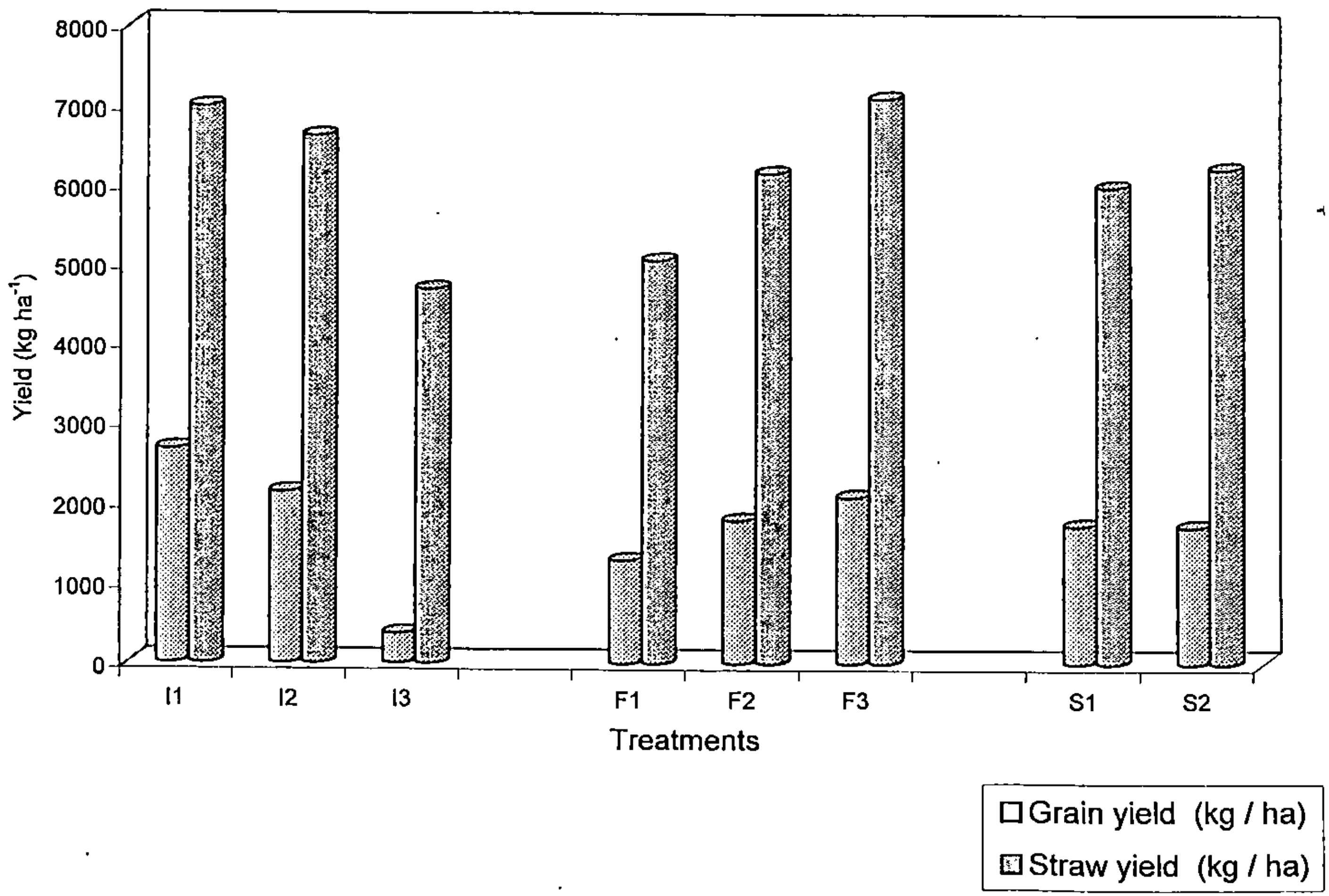
The data pertaining to grain and straw yields are presented in Table 4.2.3 a and Fig. 4. The results clearly indicated that the irrigation treatment significantly influenced both the grain and straw yields. The rainfed treatment (I_3) gave only meagre yield due to the moisture stress experienced at different growth stages especially during the reproductive phase of the crop. The influence of irrigation was very much evident and the maximum yield was obtained when the crop was irrigated at an IW/CPE ratio of 1.5 (I_1). The highest level of irrigation recorded an yield increase of 24.8 per cent in grain yield and 5.4 per cent in straw yield over I_2 (IW/CPE = 1.0). The reduction in crop yield at rainfed and lesser irrigated treatment might be due to the severe and mild moisture stress experienced by the crop. Under the moisture stress situation increased soil mechanical resistance and poor root growth may occur. Phillips (1966) reported that under unsaturated soil moisture environment a vapour gap would be formed around the roots by their turgour pressure under water stress. Such a gap if ever present would reduce the availability of nutrients to the roots probably due to lesser contact between roots and soil particles causing drastic reduction in uptake of nutrients and DMP. This might be the major reason for lower yield of crop with high moisture stress. The increase in grain yield in irrigated plots is due to the concomitant increase of the yield attributes at higher levels of irrigation (Table 4.2.1 a and 4.2.2 b). Lee *et al.* (1985) indicated that soil moisture stress reduced the number of spikelets per panicle and filled grain percentage resulting in yield reduction upto 50 per cent in rice. Similar results were also reported by Fussel *et al.* (1991). It was reported that yield reduction under moisture stress was mainly due to the increased number of unfilled grains per panicle rather than reduction in panicle number per unit area. Similar trend was also observed by Murty (1991) and Sheela (1993). The increased straw yield with increasing levels of irrigation is attributed to the combined effect of plant height, tiller production and DMP, which were favourably influenced by irrigation levels. The stunted growth, poor tiller production coupled with extremely low leaf area might have resulted in reduced straw yield in the control treatment. This finding is in agreement with the studies of Singh and Singh (1993) and Pant *et al.* (1987).

The variation in nutrition also explicitly influenced the grain and straw yields. The NPK level at 60 : 30 : 45 kg ha^{-1} (F_3) produced 16.43 and 15.3 per cent increase in grain yield and straw yield respectively as compared to the Package of Practices (POP) recommended dose of 40 : 20 : 30 kg ha^{-1} (F_2), while the yield increase of F_2 over F_1 (20 : 10 : 15 kg ha^{-1}) was 38.38 per cent in grain yield and 21.89 per cent in straw yield. Higher uptake of major nutrients (Table 4.3.3.a) due to increased application of these nutrients might have contributed to the enhancement of yield attributing characters which in turn improved the grain yield. These findings are in agreement with the studies of Sharma and Choubey (1986) and Sheela (1993). A similar trend was observed in straw yield also. The data presented on growth characters (Table 4.1.1.a, 4.1.2. a and 4.1.3. a) clearly indicated that higher NPK levels had positive influence on plant height, tiller number, LAI and DMP which have a direct bearing on straw yield. These findings are in corroboration with the reports of Singh *et al.* (1998).

The impact of seed priming either alone or in combination with the levels of irrigation or nutrients was not significant on the grain or straw yield.

Among the interaction effects, I x F alone was significant on grain yield and the treatment combination I_1 F_3 produced maximum grain yield and was significantly superior than all other treatment combinations. The yield increase recorded by I_1 F_3 was 21.62 per cent over I_1 F_2 and 23.16 per cent over I_2 F_3. This indicates that under higher levels of NPK application crop needs frequent irrigation. The better expression of higher levels of nutrition with high level of irrigation was well documented in all major field crops. It is also evident from the result that under situations of lesser irrigation (I_2) the

Fig. 4 Effect of irrigation (I), nutrients (F) and seed priming (S) on yield (kg ha^{-1}) of rice



present POP recommendation is optimum. At rainfed treatment the grain and straw yields were on par with each other at lower and higher levels of NPK.

5.2.3 Harvest index (HI)

Results indicated that effects of irrigation and nutritional levels had profound influence on HI. Irrigating the crop at an IW / CPE ratio of 1.5 registered the highest value of HI and it might be due to the better growth and partitioning of biomass at higher levels of irrigation. Higher HI was recorded for treatments which received medium dose of NPK (F_2). Under high input situations the vegetative growth was more and this might be the reason for reduced HI. It might be also due to the poor partitioning of biomass to economic part at higher levels of fertilizer application (Table 4.3.2). Reduction in HI with enhanced fertilizer application was reported by Surendran (1985) and Babu (1996).

5.3 Physico-chemical properties

5.3.1 Relative leaf water content (RLWC)

The results revealed that irrigation treatments alone had significant influence on RLWC and the irrigation treatment I_1 recorded the highest RLWC. It might be due to the better development of root system and uniform availability of moisture which favoured greater water absorption and better water potential in the plant. Ramakrishnayya and Murty (1991) and Sheela (1993) also reported a decrease in RLWC with increase in moisture stress.

5.3.2 Proline content

The rainfed treatment recorded the highest value of leaf proline content than the other two irrigation treatments. The main reason for proline accumulation in stressed plants is the synthesis of free proline from glutamic acid (Stewart *et al.* 1977). Rajagopal *et al.* (1977) pointed out that under stressed conditions, proline accumulation could provide quick mechanism for maintaining the osmoticum of cells and tissues. This can be a plant adaptation to stress situation as observed from the experiment. Similar results were also reported by Sheela (1993) and Deka and Baruah (1998).

Fertilizer application at higher levels was also significant in its effect on proline content. The highest proline content at F_3 level might be due to the significant influence of K on the proline accumulation as reported by Umar *et al.* (1991). Krishnasatry (1985) also reported that K increased proline content in finger millet under stress conditions as a result of proline biosynthesis via K mediated arginase activity. Similar reports on K induced proline accumulation is also available in maize leaf (Mukherjee, 1974).

5.3.3 Protein content of grains

The protein content of the grain was influenced by both irrigation and nutrient levels. The irrigation treatment at I_1 and NPK level at F_3 recorded more protein content. The favourable influence might be due to the increased N uptake by the frequently irrigated plants with higher levels of fertilizer application. It is well established that N is the important constituent of protein. Even though, the kind of protein formed is largely influenced by genetic factors, the amount of protein is governed by environmental factors, especially N supply. (Tisdale *et al.*, 1985). Similar increase in grain protein content with increasing levels of irrigation and fertilizer application was previously reported by Sheela (1993).

5.3.4 Partitioning of biomass

A close scrutiny of the data presented in Table 4.3.2 clearly indicates significant increase in translocation of photosynthates to the storage organ as evident from a high panicle dry weight at I_1 (IW/CPE – 1.5) level of irrigation. However, lesser levels of irrigation had considerably reduced the effect and the panicle dry weight was very low under rainfed situation. Total DMP also was higher in the first level of irrigation. The beneficial effect accrued from the effect of irrigation might be attributed to the increased absorption and translocation of nutrients and water to the shoot and subsequent utilization in the physiological and biochemical processes of the plant. I_2 and I_3 levels of irrigation could only sustain a lower level of nutrient and water utilization from the soil matrix, thus reducing the photosynthetic activity and the translocation efficiency considerably in the plant. The general decline in the dry matter content of various plant parts analysed with decreasing levels of irrigation is thus well explained. It is quite obvious from the data that the translocation efficiency of photosynthates with irrigation is maximum for I_1, recording the highest conversion of dry matter to grains. This level of irrigation clearly established its superiority in all the four parameters investigated. Hence the redistribution of photosynthates to various parts of the plant, including the storage organ is considerably influenced by irrigation levels.

The effect of nutrient levels on the partitioning efficiency of photosynthates was not significant except for shoot dry weight. Thus it is clear from the data that irrespective of the NPK levels, translocation efficiency to different plant parts remains more or less the same and is mostly determined by the genetic make up of the plant. This finding is in agreement with the reports of Devi and Nair (1984). The result obtained for shoot dry weight consequent to fertilizer application could be attributed to an increase in the vegetative growth resulting in a significant increase in total DMP. Thus NPK levels could not impart a significant influence in the translocation of photosynthates from the source to the sink.

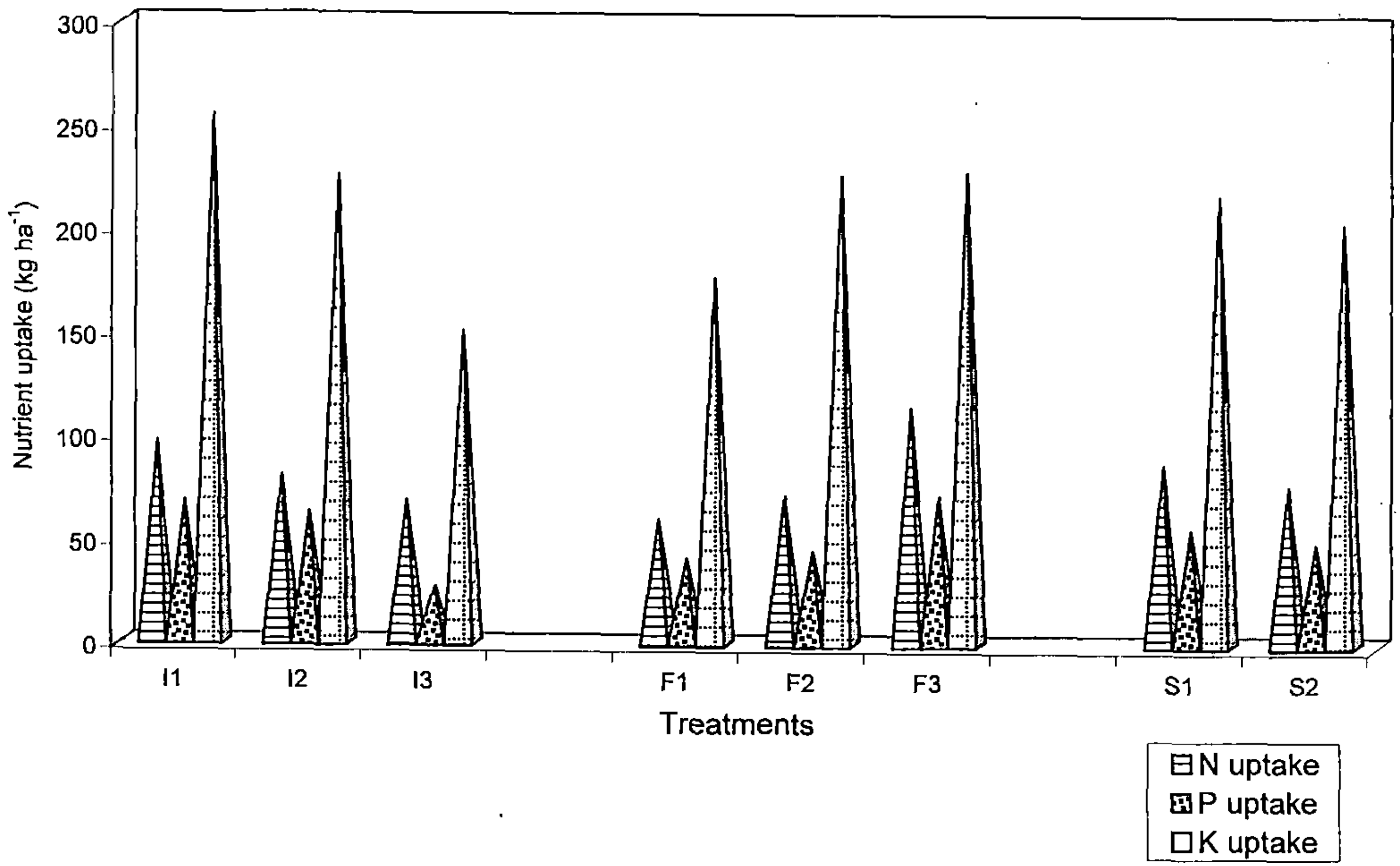
Seed priming had no effect on either the total DMP or the other parameters investigated with respect to partitioning of biomass. The observed non-significant result might be due to the closely parallel levels selected without much difference.

5.3.5 Nutrient uptake

The results of the nutrient uptake studies revealed that both N and P uptake were influenced by effect of irrigation, nutrition and seed priming whereas K uptake was influenced by irrigation and seed priming treatments only.

Irrigating the crop at an IW/CPE ratio of 1.5 recorded the highest uptake of N, P and K. This increasing trend in N and K uptake might be due to exploitation of larger volume of soil by virtue of more root length and volume at higher levels of irrigation. Better uptake of P is due to the

Fig. 5 Effect of irrigation (I), nutrients (F) and seed priming (S) on nutrient uptake at harvest (kg ha^{-1})



increased root surface area due to high order branching as its uptake is related to root surface area. Reduction in NPK uptake of rice due to moisture stress was reported by Reddy and Kuladaivelu (1992) and Sheela (1993).

Among the nutrient levels studied, F_3 recorded the highest uptake of NPK. This could be attributed to the combined effect of higher content of these elements in plant parts and the increase in DMP by enhanced availability of fertilizer elements at all stages of crop growth. Moreover, increased nutrient levels resulted in increased root growth and consequently better absorption of nutrients. Similar results were also reported by Roy *et al.* (1997) and Choubey *et al.* (1999).

The influence of seed priming on nutrient uptake was also significant and the treatment S_1 recorded higher nutrient uptake than S_2. The positive influence of seed priming might be due to the better development of root system which in turn increased the water and nutrient absorption. Similar increase in nutrient uptake by seed treatment was previously reported by Chockalingam (1986) and Mathew (1989).

5.4 Root studies

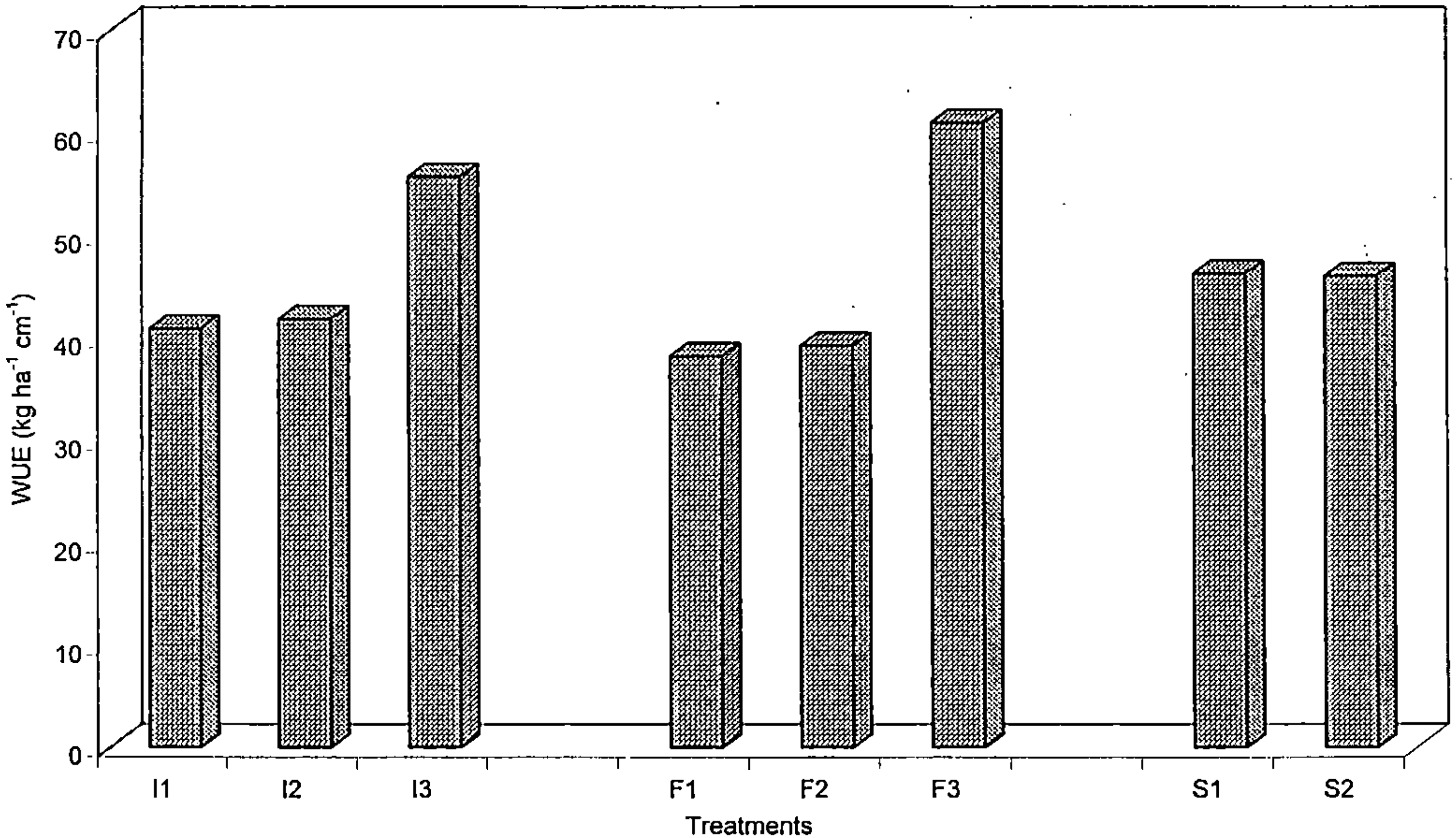
The results indicated that root morphology was substantially altered by moisture regimes. Irrigation at an IW/CPE ratio of 1.5 recorded better root characters *viz.*, root length, root weight, root volume and root spread. The drastic reduction in root characters under moisture stress might be due to more mechanical resistance to root proliferation which might have restricted root growth to the surface layers (Klepper, 1991). Moreover stress could have led to several physiological and biochemical changes which are directly or indirectly related to root generation. Similar observations were also reported by Reddy and Kuladaivelu (1992) and Sheela (1993).

5.5 Water use efficiency (WUE)

The water use efficiency of the crop was appreciably influenced by the irrigation treatments. The rainfed treatment (I_3) recorded the highest WUE. Usually there is an increase in WUE with a decrease in soil moisture supply. Lower leaf number and leaf area might be responsible for the lower rate of transpiration from the less irrigated treatment and this might have reflected in higher WUE in I_3, though the yield was less in this treatment. The lower WUE associated with higher irrigation treatment can be attributed to proportionately higher consumptive use of water. Kulandaivelu (1990) reported that scheduling irrigation to rice at 1.5 IW/CPE was proved to be inferior in terms of WUE compared to those at IW/CPE ratios of 1.0 and 0.5. In the present study due to the poor performance of the crop WUE of I_3 cannot be compared to I_1 and I_2. In terms of WUE, I_2 (IW/CPE – 1.0) is considered as optimum.

The nutrition and seed priming treatments also influenced the WUE of the crop. The maximum WUE was registered at F_3 level of NPK and S_1 level of seed priming. It might be due to the higher uptake of nutrients due to better root development and nutrient availability at higher levels of fertilizer application and seed priming.

Fig. 6 Effect of irrigation (I), nutrients (F) and seed priming (S) on water use efficiency (WUE) (kg ha^{-1} cm^{-1})

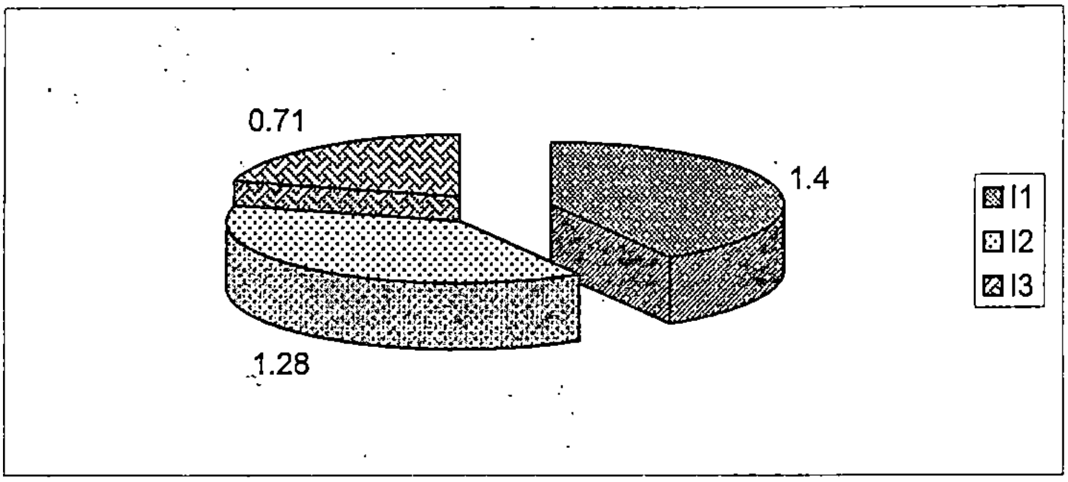


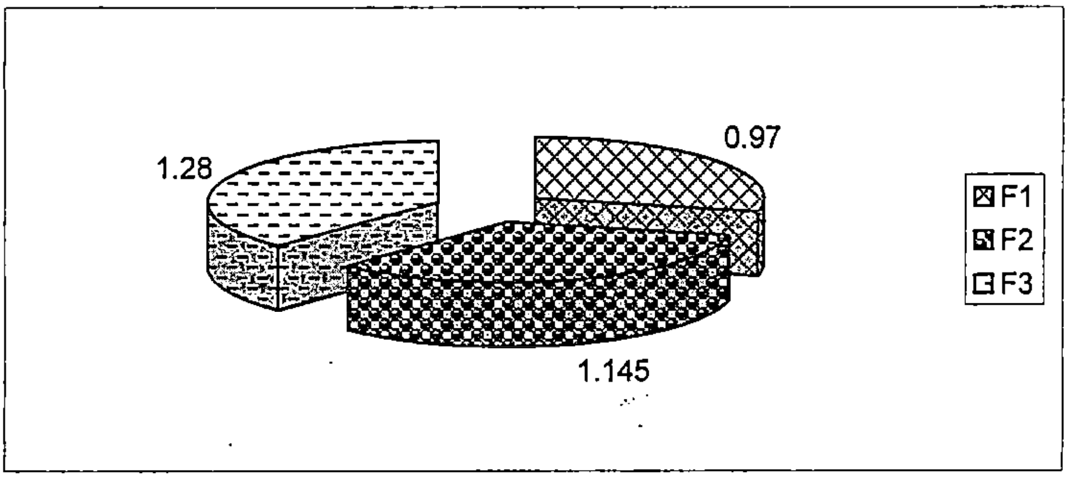
5.6 Benefit cost ratio (BCR)

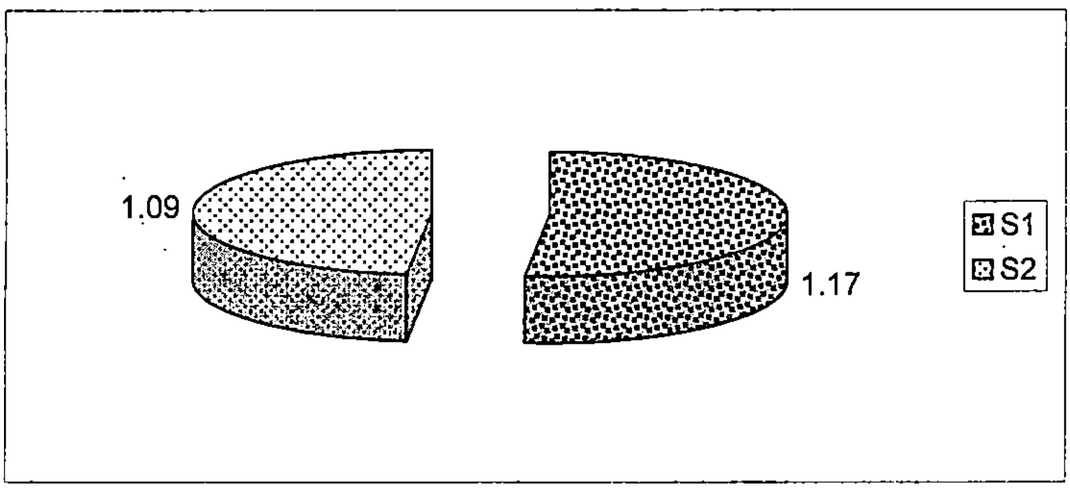
All the treatment factors studied in the present experiment (I, F, S) exerted significant variation on BC ratio. Maximum BC ratio of 1.4 was attained in I_1 and was significantly superior than I_2 (1.28) and I_3 (0.71). From the data it is clear that a reduction of South West monsoon during the crop period resulted in crop failure and poor economic returns in rainfed treatment. Similarly NPK levels at F_3 (60 : 30 : 45 kg ha^{-1}) recorded the highest BC ratio of 1.24 while F_1 and F_2 gave a low BC ratio of 0.97 and 1.15 respectively. This indicates that the present POP recommendation or higher levels of fertilizers is required for getting economic returns in upland rice.

Among the treatment combinations, I_1 F_3 produced the highest BC ratio of 1.62 and was significantly superior than all other combinations which indicates that the frequent application of irrigation at an NPK dose of 60 : 30 : 45 kg ha^{-1} is necessary for getting maximum economic returns. Unlike the grain yield BC ratio was more at I_2 F_3 than at I_2 F_2. Under the rainfed condition fertilizer levels invariably registered less than one rupee per rupee invested. It could be inferred that the BC ratio was appreciably enhanced by double the dose of present NPK recommendations in the package of practices. Higher order interaction I x F x S also exerted significant influence on BC ratio and the treatment combination of I_1 F_3 S_1 recorded more BC ratio (1.67). This indicates that seed priming at one per cent KCl with higher levels of irrigation (I_1) and nutrition (F_3) fetch maximum returns in upland rice cultivation.

Fig. 7 Effect of irrigation (I), nutrients (F) and seed priming (S) on B : C ratio







SUMMARY

6. SUMMARY

A field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during the late first crop season of 1999 to study the response of upland rice to nutrient management and seed priming under varying levels of irrigation. The soil of the experimental field was sandy clay loam in texture, acidic in reaction, low in available N and medium in available P and K. The experiment was laid out in split split plot design with three levels of irrigation (I_1- Irrigating the crop at an IW/CPE ratio of 1.5, I_2 - Irrigating the crop at an IW/CPE ratio of 1.0, and I_3- Rainfed) in the main plots, three nutrition levels (F_1-20 : 10 : 15, F_2- 40 : 20 : 30 and F_3-60 : 30 : 45 kg ha^{-1} NPK) in the sub plots and two levels of seed priming (S_1- one per cent KCl and S_2 -2.5 per cent KCl) in the sub sub plots with three replications. Observations on biometric and yield attributing characters, yield, RLWC, root characters, nutrient uptake, WUE and economics of the treatments were collected, statistically analysed and the results of the study are summarised below.

There was a progressive increase in plant height in all the treatments at different stages of crop growth. The irrigation treatment at I_1, nutrition at F_3 and seed priming level of S_1 recorded an appreciable increase in plant height over other levels.

Increased tiller count was observed with increasing levels of nutrient application, maximum tiller count was recorded with NPK rate of 60 : 30 : 45 kg ha^{-1} throughout the crop growth. Though, the effect of irrigation was not significant at earlier stages, appreciable difference in tiller count was observed towards the later stages of growth. The irrigation treatment at I_1 recorded the maximum number of tillers and was on par with I_2 and rainfed.

Higher levels of irrigation and nutrient application recorded higher LAI. The irrigation level I_1, nutrient level F_3 and seed priming level S_1 registered appreciable increase in LAI over other levels. The interactions I x F and I x F x S also influenced the LAI. Treatment combinations I_1 F_3 and I_1 F_3 S_1 registered the highest values of LAI.

The total DMP increased with increase in plant growth. Both the irrigation treatments I_1 and I_2 recorded significantly higher values of DMP at 30 DAS and at harvest. Fertilizer application @ 60 : 30 : 45 kg ha^{-1} NPK gave the highest DMP throughout the crop growth. Impact of seed priming was evident at 30 DAS only and S_1 recorded the highest DMP. The treatment combinations I_1F_3 and $I_1F_3S_1$ registered the maximum DMP.

The maximum panicle number was observed at I_1 level of irrigation and at F_3 level of nutrient application. The seed priming treatments and interaction effect of treatment combinations failed to influence number of panicles per hill.

Though not significant, an increase in length of panicle was noticed with increase in irrigation and nutrient levels. Significantly higher panicle weight was noticed with irrigation at an IW/CPE ratio of 1.5 and 1.0 than at rainfed.

Number of spikelets per panicle and number of filled grains per panicle were significantly influenced by irrigation and nutrient treatments. Irrigation treatments at I_1 and I_2 and nutrition management at F_2 and F_3 registered higher number of spikelets per panicle and filled grains per panicle.

A reduction in chaff percentage was observed with increase in irrigation levels and decrease in NPK dose. Rainfed control and NPK level at 60 : 30 : 45 kg ha^{-1} recorded the highest chaff percentage. Seed priming treatment also exerted a significant influence on chaff percentage and higher values was noticed at S_1.

Irrigating the crop at an IW/CPE ratio of 1.5 produced significantly higher test weight over I_2 and I_3. The enhanced NPK doses could also register higher test weight as compared to the lower dose.

Irrigation at an IW/CPE ratio of 1.5 and fertilizer application @ 60 : 30 : 45 kg NPK ha^{-1} recorded the highest grain yields and were significantly superior than lower levels. Among the treatment combinations, the highest grain yield was observed with I_1F_3, which could produce 3223 kg ha^{-1} of rice grain.

Straw yield was found to be high for the irrigation treatment I_1 (7004 kg ha^{-1}) and nutrient level at F_3 (7120 kg ha^{-1}).

Harvest index showed an increasing trend with increasing levels of irrigation and was highest at I_1. Among the nutrient levels F_2 (40:20: 30 kg ha^{-1}) recorded higher HI than other two levels.

Relative leaf water content and partitioning of biomass were influenced by irrigation treatments alone and I_1 recorded the highest values for both the characters.

The differential levels of irrigation and nutrients had profoundly influenced the leaf proline content at 60 DAS and grain protein content. The irrigation treatment I_3 (rainfed) recorded the highest leaf proline content while I_1 produced the highest grain protein content. Fertilizer application @ 60 : 30 : 45 kg NPK ha^{-1} registered the highest values of proline content in the leaf and protein in the grains.

Nitrogen uptake was favourably influenced by all the three factors studied. Irrigation treatment at I_1, nutrient application at F_3 and seed priming at S_1 recorded highest N uptake. Similar trend was obtained in the case of P uptake also. While K uptake was influenced by irrigation and seed priming treatments only. Among the irrigation levels highest K uptake was observed at I_1 and was on par with I_2. The influence of seed priming on K uptake was observed at 60 DAS only and greater values were noticed at S_1 level.

Among the treatment factors, irrigation levels alone registered a significant influence on root characters and irrigation treatment I_1 recorded more spread, length, weight and volume of crop roots.

Though the yield was very low and uneconomic, higher WUE was noticed with rainfed treatment. Between the irrigation levels, I_2 recorded greater WUE than I_1. Nutrition and seed priming levels also exerted significant influence on WUE. The NPK level F_3 and seed priming level S_1 produced higher WUE than other levels.

It is evident from the study that the crop respond to an irrigation level of IW/CPE ratio of 1.5 with an NPK level of 60 : 30 : 45 kg ha^{-1} with seed priming at one per cent KCl for 15 hours to attain maximum yield and highest economic returns (B : C ratio).

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* Original not seen

APPENDICES

APPENDIX – I

Data on weather parameters during cropping period
(June 20 to October 10, 1999)

Standard week	Relative humidity (%)	Temperature (^{0}C)		Evaporation (mm/day)	Rainfall (mm) (Weekly total)
		Maximum	Minimum		
25	80.6	31.0	24.24	3.9	24.4
26	77.5	30.8	24.00	4.4	7.4
27	84.5	28.3	23.30	2.0	25.8
28	88.1	28.9	23.6	3.0	75.6
29	83.0	28.4	23.34	2.8	22.2
30	85.0	28.9	23.10	3.3	37.2
31	85.4	29.5	23.50	3.4	31.0
32	80.5	30.3	24.32	4.0	1.2
33	82.5	29.7	23.70	4.5	67.6
34	82.8	29.6	23.50	3.6	4.6
35	80.4	29.6	23.30	3.6	2.9
36	79.6	30.5	23.70	4.4	2.5
37	76.2	31.2	23.90	4.6	0.8
38	76.0	32.2	24.40	5.3	-
39	84.5	30.15	23.60	2.9	12.2
40	86.7	28.9	23.20	2.3	106.8

APPENDIX – II

Total quantity of water received by each irrigation treatment during the cropping period (mm)

Treatment	Irrigation (mm)	Effective rainfall (mm)	Total (mm)
I_1	400	144	544
I_2	250	205.5	455.5
I_3	-	214	214

I_1 – Irrigating the crop at an IW/CPE ratio of 1.5

I_2 – Irrigating the crop at an IW/CPE ratio of 1.0

I_3 – Rainfed

RESPONSE OF SEED PRIMING, NUTRIENT MANAGEMENT AND IRRIGATION ON UPLAND RICE (*Oryza sativa* L.)

By

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ABSTRACT OF THE THESIS
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THIRUVANANTHAPURAM

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ABSTRACT

A field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during the late first crop season of 1999 to study the effect of nutrient management and seed priming on upland rice under varying levels of irrigation.

The experiment was laid out in split split plot design with three replications. The treatments included three levels of irrigation (IW/CPE ratio of 1.5, 1.0 and no irrigation) in the main plots, three levels of NPK (20 : 10 : 15, 40 : 20 : 30 and 60 : 30 : 45 kg ha^{-1}) in the sub plots and two levels of seed priming (1 per cent KCl and 2.5 per cent KCl immersed for 15 hours) in the sub sub plots.

Results of the experiment revealed that effect of both irrigation and nutrients and their combinations had significant influence on most of the biometric and yield attributing characters of upland rice. Irrigation at an IW/CPE ratio of 1.5 and fertilizer dose of 60 : 30 : 45 kg ha^{-1} NPK were found significantly superior to lower levels. Eventhough, the effect of seed priming was significant on almost all the growth characters, the effect was not visible on the yield attributing characters and yield of the crop.

Irrigation and fertilizer treatments exerted a remarkable influence on the proline content of leaves and grain protein content while irrigation alone exerted significant influence on RLWC and partitioning of biomass.

The uptake of nutrients was profoundly influenced by the treatments. N and P uptake was influenced by irrigation and NPK levels whereas that of K was influenced by nutrient and seed priming levels.

The root morphology was substantially altered by irrigation treatments and I_1 recorded the highest value for all the characters studied. Though WUE was highest at the no irrigation treatment (I_3) it was very inferior and uneconomic in grain and straw yields. Hence, I_2 level of irrigation is considered as the best treatment for attaining higher WUE. Among the fertilizer levels, F_3 (60 : 30 : 45 kg ha^{-1} NPK) registered the highest WUE. Impact of seed priming also was significant and S_1 recorded the highest WUE.

The results of economic analysis revealed that BC ratio was maximum when the irrigation was scheduled at an IW/CPE ratio of 1.5. The nutrient dose at F_3 (60 : 30 : 45 kg NPK ha^{-1}) and seed priming at S_1 (1 per cent KCl) was also found to be profitable.