FERTIGATION IN SPRINKLER IRRIGATED UPLAND RICE (*Oryza sativa* L.)

By

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(2013-11-180)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FERTIGATION IN SPRINKLER IRRIGATED UPLAND RICE (*Oryza sativa* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Shahanila P. P.

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ABBREVIATIONS

BPH	- Brown Plant Hopper
CPE	- Cumulative Pan Evaporation
DAS	- Days After Sowing
Ep	- Pan Evaporation
Etc	- Crop Evapotranspiration
FAI	- Fertilizer Association of India
FWUE	- Field Water Use Efficiency
FYM	- FarmYard Manure
GM	- Gall Midge
HI	- Harvest Index
HP	- Horse Power
IW	- Irrigation Water
KAU	- Kerala Agricultural University
PE	- Pan Evaporation
PFP	- Partial Factor Productivity
POP	- Package of Practices
PVC	- PolyVinyl-Chloride
RDF	- Recommended Dose of Fertilizers
USWB	- United States Weather Bureau
WCE	- Weed Control Efficiency
WMO	- World Meteorological Organization
WUE	- Water Use Efficiency

INTRODUCTION

1. INTRODUCTION

Rice is a profligate user of water, consuming about half of all the developed fresh water resources of the world (Castaneda *et al.*, 2002). Because of continuous presence of ponded water, there is a huge loss of water through evaporation, seepage and percolation. Indian farmers are using as much as 15,000 liters of water to produce one kilogram of rice while the maximum requirement is only 4,000 liters (Kannony, 2001). The increasing scarcity of fresh water threatens the sustainability of the irrigated rice ecosystems.

By 2025, 17 million ha of irrigated rice areas may experience "physical water scarcity" and 22 million ha may have "economic water scarcity" in Asia (Tuong and Bouman, 2003). Therefore, efficient use of water is needed in rice production. According to Bouman *et al.* (2002), we may have to change the way rice is produced in the future and a new theme "Grow more rice with less water" is gaining attention in all the rice growing regions. To safeguard food security and preserve precious water resources, ways must be explored to grow rice using less water (Belder *et al.*, 2002). A fundamental approach to reduce water use in rice production is to grow it like an irrigated upland crop, such as wheat or maize.

Cultivation of high yielding varieties with good management practices for maximum water and nutrient use efficiency can help to increase the productivity of rice. For upland rice production, inadequate water supply is the primary constraint to yield, followed by nitrogen when water is sufficient (Yoshida, 1975). Aerobic rice with micro irrigation practices is said to be a suitable technology to address water scarcity. The water use of aerobic rice is about 60 per cent less than that of flooded rice and can be highly mechanized than lowland rice (Wang *et al.*, 2002).

Fertigation is a relatively new technology adopted in crop production. Through fertigation nutrients are applied directly into the wetted volume of soil immediately below the emitter where root activity is concentrated or over the leaves. It helps to achieve higher fertilizer and water use efficiency apart from improving quality and quantity of crop yields than conventional practices.

Sprinkler and drip irrigation methods have the potential to increase irrigation water use efficiency by providing water to match crop requirements, reducing runoff and deep drainage losses, and generally keeping top soil drier reducing soil evaporation and increasing the capacity to capture rainfall. Sprinkler irrigation has been recognized as an efficient irrigation method with the application efficiency up to 90 per cent (Martin *et al.,* 1991). McCauley (1990) indicated micro sprinkler irrigation as an alternative irrigation method and can contribute substantially to lower water consumption in rice. It may be an option for farmers where water has become too scarce or expensive to grow flooded rice, and in rainfed areas where rainfall is insufficient for flooded rice production but sufficient for upland crops.

Recent research works in micro irrigation in rice have shown that sprinkler irrigation can be a water saving alternative to conventional flood irrigation. Taking all these into account the present study was planned with the objective, to standardize irrigation and nutrient requirement of sprinkler irrigated high yielding rice variety grown in upland.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Improper management of water and nutirents has contributed extensively to the current water scarcity and pollution. Micro irrigation has emerged as an appropriate technology even under water scarce, undulated, sandy and hilly areas. It is adopted primarily to save labour and water. Apart from this, considerable increase in yield is reported in many crops under micro irrigation. Literature on yield response of rice to micro irrigation, micro irrigation scheduling in rice, fertigation, uptake of nutrients under fertigation, weed management etc. are reviewed under this chapter.

2.1 SCHEDULING IRRIGATION TO CEREALS BY PAN EVAPORATION METHOD

Water is the primary factor influencing the efficient use of applied nutrients as it is directly involved in their solubilization, absorption and translocation to plant parts. Water management has significant influence on the yield and yield attributes of rice. Aragon and De Datta (1982) found a linear relationship between dry matter production of rice and water applied. Irrigation interval, amount and its uniform distribution greatly affect the water use efficiency and yield of rice and wheat crops. Considerable water saving upto 50 per cent was possible with micro irrigation (Patel *et al.*, 2006).

Majority of researchers have been investigating plant water requirement and evapotranspiration so as to determine an optimal irrigation schedule which would secure an optimum soil moisture condition and produce maximum yield. The World Meteorological Organization (WMO) has recommended that the evaporation pan can be adopted as the standard instrument for crop water use determination and irrigation scheduling.

According to Doorenbos and Pruitt (1977), the positive relationship between water loss from an evaporimeter and potential evapotranspiration makes this approach more attractive for irrigation scheduling, as the evaporation is easy to monitor and the necessary equipment is simple and easy to maintain. Vamadevan (1980) indicated that evaporation values measured from a standard USWB class A open pan evaporimeter are extensively used for scheduling irrigation. An evaporation pan is an open pan with water that is subject to the same climatic conditions with that of a growing crop, and from which water is evaporated as a result of the climatic conditions experienced (Smajstrla *et al.*, 2000).

Crop evapotranspiration is an important component used in the planning, design, construction, operation, and maintenance of irrigation systems (Gungor, 1990). Jensen *et al.* (1990) suggested that pan evaporation method usually gives reliable results if its calibration is made for different climatic regions.

Irrigation scheduling in aerobic rice plays a major role in obtaining higher yields. Application of irrigation water with sprinklers has improved on-farm irrigation efficiencies up to 80 per cent under the prevailing climatic conditions in the Indian sub-continent (Sharma, 1984).

Average yield of corn was increased by 47 per cent when irrigated at 41 per cent (low irrigation amount) of average pan evaporation and by 52 per cent when irrigated at 62 per cent (high irrigation amount) of average pan evaporation (Powell and Wright, 1993). Mohamed (1994) reported that irrigation at 60 per cent irrigation requirement gave the highest grain yield and harvest index in wheat, while water use efficiency was highest with 85 per cent irrigation requirements.

According to Zaman *et al.* (2001) irrigation scheduling for crops under pressurized irrigation methods (sprinkler and drip) and improved water management practices are very important in water saving. Reduction in water consumption due to drip method of irrigation over the surface method of irrigation varies from 30 to 70 per cent (Postal *et al.,* 2001) and productivity gain is in the range of 20 to 90 per cent for different crops.

Proper scheduling of irrigation is critical for efficient water management in crop production; particularly under water scarcity conditions (Zeng *et al.*, 2009). Ramulu *et al.* (2010) observed higher grain yield (7.46 t/ha) and straw yield (12.89 t/ha) of maize in fertigation scheduled at 100 per cent Ep supplied with 100 per cent recommended dose of fertilizer. Murthy *et al.* (2012) found that highest grain yield and yield attributes were obtained when irrigation was scheduled at IW/CPE ratio of 1.2.

Adoption of micro irrigation might help in increasing productivity of crop and water use efficiency (Bhalerao *et al.,* 2011). In irrigation cum weed management trial in aerobic rice, Shekara *et al.* (2011) observed that irrigation at IW/CPE ratio of 2.5 recorded higher plant height (89.29 cm), dry matter accumulation (104.55 g/hill), productive tillers/hill (25.74), filled spikelets/panicle (129.17), panicle weight (3.30 g) and grain yield (6.40 t/ha) in rice.

Narolia *et al.* (2014) also reported that irrigation schedules have significant influence on grain and straw yield of rice and recorded maximum grain and straw yield under irrigation at 150 per cent CPE (Cumulative Pan Evaporation). Application of irrigation at 100 per cent CPE increased rice grain and straw yields by 10.2 and 10.3 per cent over the irrigation applied at 75 per cent CPE.

Studies in aerobic rice by Vanitha and Mohandass (2014) revealed that higher grain yield of 5643 kg/ha was with the drip fertigation practice at 125 per cent Ep with 100 per cent recommended dose of fertilizer level. The performance of aerobic rice grown with drip fertigation scheduled at 125 per cent Ep with 100 per cent recommended dose of fertilizer level was found to be superior for most of the source sink characters and grain yield.

Mallareddy and Padmaja (2014) reported that drip irrigation at 75 per cent Ep produced the highest dry matter production, kernel and stover yield in maize than 50 per cent Ep. They also reported highest water use efficiency with drip irrigation at 50 per cent Ep. The highest grain yield (8.0 t/ha) of maize was obtained under irrigation at 1.2 of ETc with fertigation (Ouda *et al.,* 2015).

2.2 FERTIGATION

Fertigation is defined as the application of solid or liquid mineral fertilizers through pressurized irrigation systems along with water (Magen, 1995). It is a common practice in modern irrigated agriculture because it improves the fertilizer use efficiency and allows flexibility in timing of fertilizer application in relation to crop demand. Proper fertilizer application has shown to directly increase water use efficiency and production. This method facilitates easy supply of nutrients as they are available to the plant roots more quickly than solid fertilizers applied to the soil. Fertigation is a suitable technology in intensive agriculture, as it can increase efficiency of fertilizers, increase yield, protect environment and sustain irrigated agriculture.

According to FAI (1995), fertigation enjoys various advantages like (a) higher use efficiency of water and fertilizers, (b) minimum losses of nutrients due to prevention of leaching, (c) optimization of nutrient balance by supplying nutrient directly to root zone in available form, (d) control of nutrient concentration in soil solution to effect proper supply, (e) saving in application cost and (f) improvement of soil physical and biological condition due to proper maintenance of soil moisture levels.

Alternate wetting and drying of soil in the conventional method of flood irrigation leads to greater denitrification loss which is practically absent with fertigation (Greeff, 1975). Drip irrigation is ideally suited for controlling the placement and supply rate of water soluble fertilizers (Goldberg *et al.*, 1976). Nitrogen, the plant nutrient most commonly deficient for crop production is often supplied through drip irrigation system.

Scheduling fertigation once in six days coinciding with the nutrient demand of the crop resulted in more uptake and accumulation of nutrients. Bar-Yosef (1977) and Papadopoulos (1995) reported higher uptake of nutrients when provided through sprinkler irrigation system than broadcasting.

Increase in crop yield, quality and minimization of leaching loss of nutrients could be achieved by managing fertilizer concentrations in irrigation water using drip irrigation (Hagin and Lowengart, 1996). Continuous application of soluble nutrients, particularly in sandy soils, resulted in more uniform distribution of added nutrients and other chemicals around plant roots and enhanced the rate of nutrient uptake by the plants (Keeney 1982; Ritter and Chirnside 1987).

Studies of phosphorous and potassium microfertigation showed improved crop response to these elements. Bar-Yosef (1989) found that phosphorous fertigated sweet corn gave a significantly higher yield than drip irrigated sweet corn received preplant phosphorous fertilizer application.

Stiles (1994) reported that enhanced yield, higher nitrogen use efficiency and control of weeds with nitrogen fertigation in some cereal and vegetable crops.

Papadopoulos (1994) found that in calcareous soil having high pH, fertigation was superior to conventional soil phosphorous application. Application of phosphorous at the rate of 22 kg/ha and nitrogen at the rate of 100 kg/ha through fertigation led 50 per cent more agronomic efficiency as compared to full dose of phosphorous at the rate of 33 kg/ha and nitrogen at the rate of 150 kg/ha applied by broadcast method.

Stone *et al.* (1999) studied the most suitable rate of nitrogen for sprinkler irrigated modern rice cultivars and concluded that rice response to nitrogen fertilizer application is the result of fertilizer effect on the numbers of panicles/m^2 and grains/panicle, and the maximum economic nitrogen rate for upland rice, sown in rows was 87.3 kg/ha.

Application of single super phosphate through fertigation at the rate of 33 kg/ha gave significantly higher grain yield, phosphorous uptake and phosphorous use efficiency in wheat and maize as compared to that obtained with the same dose applied by broadcast method (Iqbal *et al.*, 2003). Hebbar *et al.* (2004) reported that fertigation with normal fertilizer gave significantly lower yield compared to fertigation with water soluble fertilizers.

The amount of fertilizer lost through leaching can be as low as 10 per cent in fertigation whereas it is 50 per cent in the traditional system (Solaimalai *et al.*, 2005). Vishandas *et al.* (2006) mentioned that fertigation increased plant height (7.7%), spike length (4.6%), grains/spike (3.2%), spike/plant (30.2%), straw yield (5.4%) and grain yield (9.3%) of wheat.

It is well documented that split and band application of fertilizers increases the use efficiency of applied fertilizers. According to Dua *et al.* (2007), Partial Factor Productivity (PFP) decreased with increasing rates of fertigation.

Sampathkumar and Pandian (2010) observed that scheduling of drip fertigation with 150 per cent of recommended dose of fertilizer supplied once in six days produced taller (66.5 cm) plants and higher grain yield (8957 kg/ha) than 100 per cent of recommended dose of fertilizer (7915 kg/ha) in maize. Ouda *et al.* (2010) stated that fertigation for wheat grown under sprinkler irrigation enhanced wheat yield by 24 per cent compared with broadcasting of fertilizers.

In fertigation, nutrient use efficiency could be as high as 90 per cent compared to 40 to 60 per cent in conventional methods. Sayed and Bedaiwy (2011) reported that both nitrogen and potassium use efficiency were higher for fertigation treatment than for traditional application method. Drip fertigation once in three days at 100 per cent recommended dose of fertilizer could enhance the productivity of maize and save water upto 43 per cent compared to surface irrigation (Fanish *et al.*, 2011).

The yield attributes of maize crop were higher under drip fertigation with 125 per cent recommended dose of fertilizer as water soluble fertilizers (Krishnasamy *et al.*, 2012)

Negi *et al.* (2013) observed maximum values of growth parameters, grain and straw yield in rice at 120 kg N/ha. Pasha *et al.* (2013) observed that application of 180 kg N/ha resulted in higher dry matter production than 120 and 150 kg N/ha. Fertigation with normal fertilizer increased the yield of maize upto 18 kg per kg of nutrient applied, whereas water soluble fertilizer increased the yield upto 25 kg per kg of nutrient applied (Fanish, 2013).

Iqbal *et al.* (2013) found that the grain yield from fertigated plots was 12 to 18 per cent greater than broadcasted application and 32 to 39 per cent greater than control treatment. After fertigation the higher nitrogen concentration was in the soil layer of 15 to 30 cm depth at a distance of 20 cm from the emitter and the highest potassium concentration was in 0 to 15 cm soil layer (Fansih and Muthukrishnan, 2013).

2.3 MICRO IRRIGATION AND GROWTH AND YIELD OF RICE

Micro sprinkler irrigation is an alternative irrigation method in rice and can contribute substantially to lower water consumption. Hasegawa and Nakayama, (1959) recorded a grain yield of 5 t/ha in aerobic rice with sprinkler irrigation which was comparable to the productivity in flooded culture. Guidice *et al.* (1974) reported decrease in seed weight under sprinkler irrigated rice system.

Studies conducted by McCauley (1990) in USA and Australia revealed that relatively high yields under aerobic conditions were achieved with sprinkler irrigation once to twice a week on relatively wet and clayey soils with soil water tensions below 10 to 30 kPa. He also reported 20 per cent yield reduction in direct seeded rice cultivars under sprinkler irrigation.

The use of drip irrigation and fertigation saved water and fertilizer and gave better yield and quality (Papadopoulos, 1992). Increased milling yields for various cultivars under sprinkler irrigation were also reported by Arf *et al.* (2002). Hafez *et al.* (2001) reported that drip irrigation method increased field and crop water use efficiency by 35 and 9.52 per cent respectively as compared to furrow irrigation in maize.

Irrigation through drip saved water to the tune of 17 to 50 per cent compared to surface irrigation (Jadhav *et al.*, 2002). Studies carried out on drip irrigation in Gujarat indicated water saving of 30 to 73 per cent in various field crops (Malavi and Devidayal, 2002).

Lafitte and Courtosis (2002) reported a decline in chlorophyll content under micro irrigation. Growth parameters like plant height, root volume, crop growth rate and productive tillers of aerobic rice increased under micro sprinkler irrigation at IW/CPE ratio 1.2 followed by 1.0 and 0.8 IW/CPE ratio (Maheswari *et al.*, 2007). Kahlown *et al.* (2007) observed that sprinkler irrigation at 150% ET_c (Crop evapotanspiration) produced higher grain yield of 3359 kg/ha but the crop water productivity (0.38 kg/m^3) was lower than that of 100% ET_c (0.55 kg/m^3) and 125% ET_c (0.45kg/m^3) by 10 and 3 per cent.

Crusciol *et al.* (2008) in Brazil indicated that sprinkler irrigation provided higher milling yields and head rice yield in two upland cultivars namely; IAC 201 and Carajas. Vijayalaksmi *et al.* (2008) reported that the grain yield of rice reduced significantly under micro sprinkler treatments (3000 kg/ha) than drip irrigation (3422 kg/ha) at 100% pan evaporation.

Patel *et al.* (2010) reported that flood irrigation had significantly higher values of yield attributes and yield compared to aerobic treatment except panicle number/m^2, ripening ratio, 1000 grain weight and harvest index, which were least influenced by water management practices.

Sritharan *et al.* (2010) revealed that in the case of drip irrigation, decline in yield was observed, but the higher level of drip irrigation (200% PE) recorded better yield of 4067 kg/ha which was close to the yield (4089 kg/ha) under flooded irrigation (one day after disappearance of ponded water) and superior to the sprinkler irrigation treatments (3310 kg/ha).

Crusciol *et al.* (2012) reported that levels of water varying from 0.5 to 1.5 times the rice crop coefficient, supplied through sprinkler irrigation system produced seeds with higher physiological quality in upland cultivars. Drip irrigation at 150 per cent Ep with 100 per cent RDF, azophosmet and humic acid registered significantly higher plant height (103 cm) and number of tillers per hill (32) in aerobic rice at maturity stage (Govindan and Grace, 2012).

The highest water use efficiency of 16.86 kg/mm was observed in wheat when irrigation was applied at 0.8 of Crop Evapotranspiration (Abdelraouf *et al.*, 2013). They observed that reduction in the irrigation water from100 to 50 per cent significantly decreased the plant height from 118.44 to 114.78 cm, dry weight of plant from 5.29 to 4.20g and total chlorophyll from 36.96 to 31.96 mg/g respectively.

Abdrabbo *et al.* (2013) stated that the highest water productivity for maize grown under drip irrigation was obtained when maize was irrigated with 1.0 of ETc. Mehanna *et al.* (2013) stated that irrigating maize with 0.8 of ETc gave the highest water productivity under drip irrigation.

Karim *et al.* (2014) suggested that sprinkler systems, such as portable rain gun can be used to apply a desired depth of water during pre sowing and subsequent irrigations. They also reported that grain yield was 7.62 per cent higher in sprinkler irrigation and 4.72 per cent higher in alternate wetting and drying method over flood irrigation.

2.5 NUTRIENT UPTAKE UNDER FERTIGATION

The method of fertilizer application is very important in obtaining optimal use of fertilizer. This will influence the amount of fertilizer used by the plant and the amount lost through leaching. Applying plant nutrients by dissolving them in irrigation water particularly with the micro irrigation system is the most efficient way of nutrient application. Fertigation allows an accurate and uniform application of nutrients to the wetted area where most active roots are concentrated. Therefore, it is possible to dispense adequate quantity of nutrients at appropriate concentration to meet the crop demand during growth period (Ram *et al.*, 2011).

Nitrogen is an important plant nutrient which has a pivotal role in absorption of water and nutrients from the soil. Yoshida (1972) reported that nitrogen functions to establish yield capacity and maintains photosynthetic activity during grain filling. Adequate supply or balance of potassium with other nutrients determines response of crop plants to nitrogen and phosphorus. Potassium along with nitrogen improves photosynthetic activity of rice leaves (Xiaoe *et al.*, 1997). Potassium content in shoot and grain was positively associated with grain yield.

Latif *et al.* (2001) reported that lower dose of nitrogen along with full dose of phosphorous when applied through fertigation gave equal phosphorous uptake to that by full dose of nitrogen and same dose of phosphorous.

Plant nitrogen uptake is mainly affected by the spatial distribution of water and fertilizer applied through sprinkler system. The total nitrogen in plant stem increased with the uniformity of fertilizer applied. Frequent fertigation improved the uptake of nutrients (Silber *et al.*, 2002).

Belder *et al.* (2005) registered relatively low uptake of nitrogen as well as low nitrogen use efficiency under aerobic conditions compared to flooded conditions. Crusciol *et al.* (2008) reported that sulphur and copper levels were higher for grains obtained from sprinkler irrigated systems.

Sampathkumar and Pandian (2011) reported that application of nutrients through fertigation once in six days with 150 per cent recommended dose of fertilizer gave more uptake rate for all nutrients throughout the cropping period.

Iqbal *et al.* (2013) observed that phosphorous fertigation resulted in an increase of 17, 65 and 90 per cent in mean phosphorous uptake, agronomic efficiency and phosphorous use efficiency respectively over broadcast method.

Fanish (2013) reported that drip fertigation with 50 per cent recommended dose of fertilizer resulted in higher nitrogen use efficiency (80.90 kg/kg nitrogen) and phosphorous use efficiency (161.80 kg/kg phosphorous) than that of surface irrigation with soil application of fertilizesr.

Mallareddy and Padmaja (2014) reported that the mean uptake of nitrogen by kernel and stover was higher with the irrigation regime of 75 per cent Ep due to higher dry matter production of maize. Danso and Mickson (2015) revealed that plant nitrogen uptake is mainly affected by the spatial distributions of water and fertilizer applied through sprinkler system.

2.6 WEED COMPETITION IN UPLAND RICE

Weed management is a fundamental practice, failure of which may result in severe losses in terms of yield and economic return. Weeds are dynamic in nature and a shift in their abundance and dominance is likely with changes in management practices. Weeds are perceived to be the most severe constraint in upland and aerobic rice production than the conventional production systems. Weeds rank second to moisture stress in reducing upland rice grain yield and quality (Sankaran and De Datta, 1985). Weed infestation depending upon the situation moderately to severely limit production of upland direct seeded rice. The extent of weed menace is more serious in upland rice than lowland rice mainly due to variations in hydrology and reduction in rice grain yield ranged from 5 to 100 per cent (Singh *et al.*, 2002). They reported that density of weeds emerging between 15 DAS and 30 DAS was high and could compete with the crop resulting in reduced grain yield. According to Borgohanin and Upadhay (1980), yield loss in upland rice due to weeds was upto 71.83 per cent.

In upland irrigated rice, 15 to 30 DAS was the most critical period for crop-weed competition (Shelke *et al.*, 1986). Singh and Singh (1986) reported 89 per cent grain yield loss of upland rice due to unchecked weed growth. The crop is very sensitive to weeds during tillering stage to just before heading stage (Singh *et al.*, 1989).

Sarma (1987) found that grasses and sedges comprised 75.3 per cent and dicot 24.7 per cent of the total weed flora in upland rice field. Bayan (1990) reported that unchecked weed growth reduced the grain yield by 85 per cent in high yielding varieties.

In dry seeded rice ecosystems, rice and weeds emerge simultaneously and weeds compete with rice plant for light, nutrients and moisture resulting in reduction of grain yield upto 80 per cet (Babu *et al.*, 1992). Besides, dry tillage practices and aerobic soil conditions are highly conducive for germination and growth of weeds (Balasubramanian and Hill 2002). Weeds usually appear in several flushes during the growing season of rice in uplands.

Competition from weeds during the first 15 DAS had no significant effect on the grain yield but competition beyond 15 DAS cause drastic reduction in grain yield of rice. The critical period of crop-weed competition for upland direct seeded rice was upto 40 DAS (Varshney, 1991). Ladu and Singh (2006) reported that initial stages of crop are most critical period for weed control in upland rice.

The increase in upland rice grain yield by increasing Weed Control Efficiency (WCE) has been reported by Singh and Singh (2006). Weed pressure is highest in direct seeded aerobic rice among the rice ecosystems and hence, effective weed management is crucial for higher yield under aerobic conditions (Rao *et al.*, 2007).

According to Gowda *et al.* (2009), weed menace continues to be a severe problem in aerobic rice systems resulting in up to 90 per cent reduction in grain yield. In aerobic rice cultivation, weed free condition during the initial crop growth period (upto 35 DAS) is critical (Rajakumar *et al.*, 2010). Mahajan *et al.* (2011) found almost double weed density and biomass in aerobic rice field than those of conventional transplanted rice at 35 and 75 days after sowing or transplanting. Anwar *et al.* (2012) observed that on average, unit increase in WCE resulted in an increase in grain yield of 26 kg/ha in aerobic rice.

2.6 ECONOMICS OF MICROIRRIGATION

Narolia *et al.* (2014) reported that maximum net return and Benefit: Cost (B: C) ratio in direct seeded rice was under irrigation applied at 150% CPE (Cumulative Pan Evaporation). Benefit–cost analyses based on water saved indicated that investing in rain-gun system to irrigate rice and wheat is a financially viable option for farmers (Kahlown *et al.*, 2007). Karim *et al.* (2014) highlighted that total return, net profit and benefit cost ratio were higher in sprinkler irrigated boro rice. So, sprinkler irrigation and reduced tillage system may be the potential technology to cut cost of rice production and to achieve higher yield.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment on "Fertigation in sprinkler irrigated upland rice" was conducted during February to June 2014 at Instructional Farm of KAU campus, Vellanikkara, Thrissur. Infrastructure developed as part of state plan project on "Establishment of Nodal Water Technology Centre for Development and Coordination of Water Management Research for Better Water Productivity in Kerala" under the Department of Agricultural Engineering, was utilized. The details of materials used and methodology adopted are described in this chapter.

3.1 GENERAL DETAILS

3.1.1 Location

The farm is located at latitude of 10° 31' and longitude of 76° 13' in central Kerala at an altitude of 40.3 m above Mean Sea Level.

3.1.2 Climate and weather conditions

The experimental site enjoys typical warm humid tropical climate. The maximum and minimum temperature during the cropping period was 34.97 and 24.25°C respectively. The total rainfall during the crop growth period was 384.6 mm and the RH was 70%. The mean monthly averages of important meteorological parameters observed during the experimental period are presented in Fig. 1 and 2.

3.1.3 Soil characters

The texture of the soil was sandy loam. The physico-chemical characteristics of the soil of the experimental field are presented in Table 1.

Table 1. Physico-chemical characteristics of the soil

Particulars	Value	Method used
a. Physical properties		
Bulk density (g/cm^3)		Core method (Blake, 1965)
0-15 cm	1.29	
15-30 cm	1.44	
30-45 cm	1.56	
Particle density (g/cm^3)	2.53	Pycnometer method (Blake, 1965)
Particle size composition		
Sand (%)	66.5	International Pipette Method (Piper, 1966)
Silt (%)	17	
Clay (%)	16.5	
Texture	Sandy loam	
Soil moisture constants		
Field capacity (%)	16.5	Field method
Permanent wilting point (%)	6.6	Field method
b. Chemical properties		
pH	5.48	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1958)
Electrical Conductivity ($dS\ m^{-1}$)	0.057	Soil water suspension of 1:2.5 and read in EC meter (Jackson, 1958)
Organic carbon (%)	1.70	Walkley and Black method (Walkley and Black, 1934)
Available N (kg/ha)	253.50	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	58	Ascorbic acid reduced molybdophosphoric blue colour method (Bray and Kurtz,1945)

Table 1. continued

Particulars	Value	Method used
Available K_2O (kg/ha)	91.5	Neutral normal ammonium acetate extract using Flame photometer (Jackson, 1958)
Available Ca (mg/kg)	884.11	Neutral normal ammonium acetate extract using Atomic Absorption Spectrophotometer
Available Mg (mg/kg)	58.29	Neutral normal ammonium acetate extract using Atomic Absorption Spectrophotometer
Available S (mg/kg)	16.3	$CaCl_2$ extract-turbidimetry method (Chesnin and Yien, 1951)
Available Cu (mg/kg)	3.8	HCl acid extract method using Atomic Absorption Spectrophotometer (Sims and Johnson, 1991)
Available Fe (mg/kg)	42.96	HCl acid extract method using Atomic Absorption Spectrophotometer (Sims and Johnson, 1991)
Available Zn (mg/kg)	1.61	HCl acid extract method using Atomic Absorption Spectrophotometer (Sims and Johnson, 1991)
Available Mn (mg/kg)	94. 98	HCl acid extract method using Atomic Absorption Spectrophotometer (Sims and Johnson, 1991)

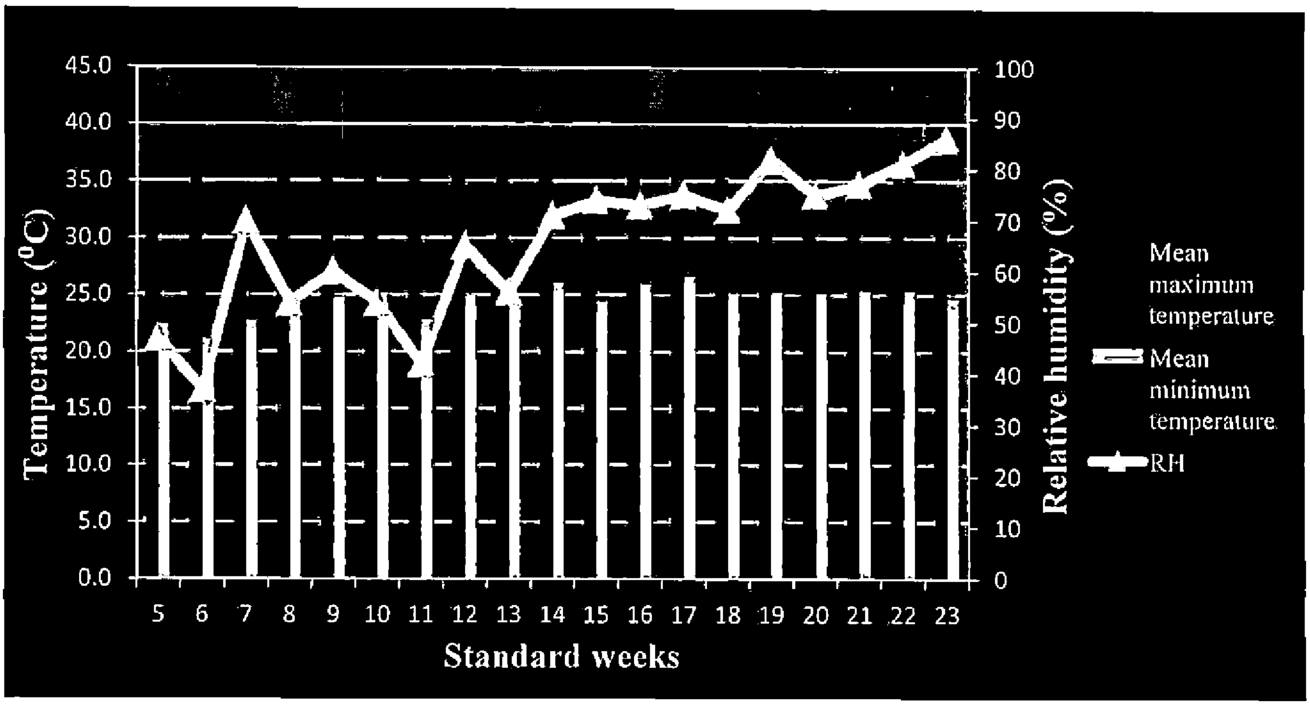

Fig. 1 Mean weekly weather data of atmospheric temperature and relative humidity during crop period

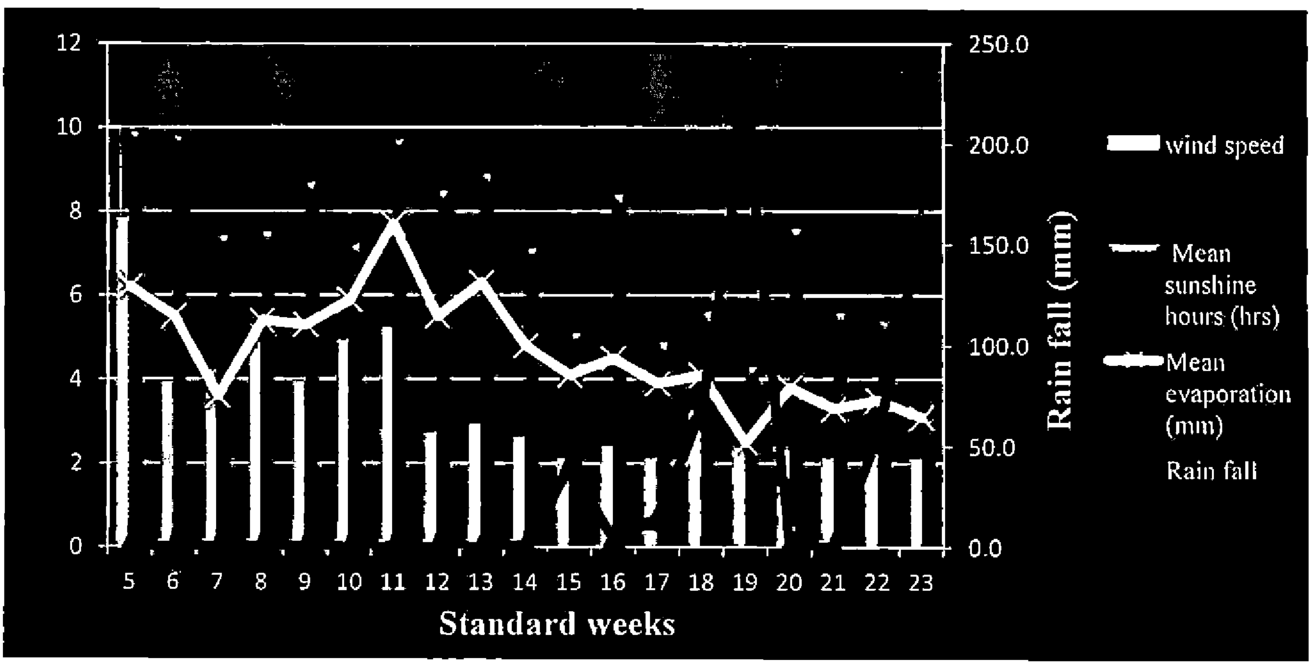

Fig. 2 Mean weekly weather data of wind speed, sunshine hours, evaporation and rain fall during crop period

3.1.4 Season and variety

The crop period was from February to June 2014. The rice variety Uma (MO-16), a red kernelled, medium duration variety of 115 to 120 days duration (Punja) was used for the experiment. The variety is suitable for all the three crop seasons.

It is a non lodging, medium tillering variety resistant to BPH and GM bold Biotype-5 and capable of producing a yield of over 5t/ha under favourable conditions.

3.1.5 Cropping history of the experimental site

The experimental area was a typical upland and it was not under the cultivation for the past years. The area was dominated with cover crops like *Calapogonium mucunoides and Centrosema pubescence* and the grass weed *Panicum maximum.*

3.2 EXPERIMENTAL DETAILS

3.2.1 Lay out

The experiment was laid out in Split Plot design with three replications (Fig 3.)

3.2.2 Treatments

Main plot treatments included four irrigation levels (I_1, I_2, I_3 and I_4) and these were superimposed with three fertilizer levels (F_1, F_2 and F_3) as subplots.

Main plot treatments (Irrigation levels)

1) I_1 : Sprinkler irrigation at 75% Ep (Pan Evaporation)
2) I_2: Sprinkler irrigation at 100% Ep
3) I_3: Sprinkler irrigation at 125% Ep
4) I_4: Life saving irrigations at 5cm depth at required stages

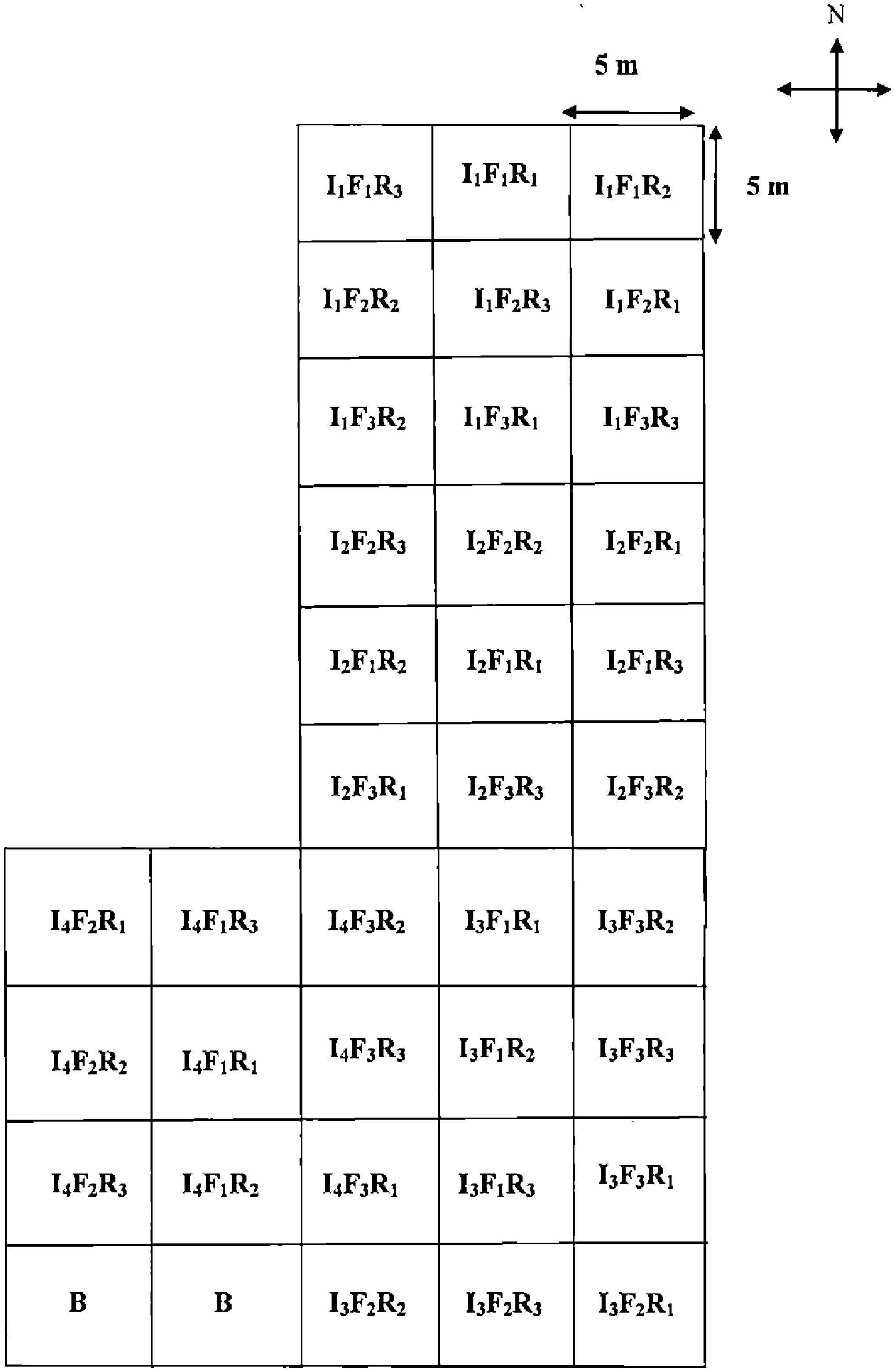

Fig. 3. Lay out of the experimental plot

Sub plot treatments (Fertilizer levels)

1) F_1: 90:45:45 N:P_2O_5:K_2O kg/ha
2) F_2: 70:35:35 N:P_2O_5:K_2O kg/h
3) F_3: 60:30:30 N:P_2O_5:K_2O kg/ha

3.2.3 Cultural practices

Land preparation and sowing

The land was ploughed twice using disc plough attached to a tractor and levelled. Plots of 5m x 5m were made by taking bunds of width 1m on all the four sides. Channels of 1 m width were laid out around all the plots in order to avoid the entry of water from neighbouring plots. FYM at the rate of 5t/ha was applied uniformly to each plot and was incorporated by using a garden tiller. After one week, line sowing was done at a spacing of 20 cm x 10 cm at the rate of 4 to 6 seeds/hill.

Installation of irrigation system and fertilizer injector

The sprinkler irrigation system consisted of main line, sub mains, distributors, riser pipes, valves and pressure gauges. Water was pumped through a 1HP motor and it was conveyed to the main field using 40 mm of PVC pipes after filtering through screen filters. From the main line water was taken to the field through sub mains of 25 mm diameter. From the sub main, a 20 mm riser pipe of 1m height was connected on which the sprinkler heads were fixed. At the head end of each sub main, valves were fixed in order to regulate the irrigation regimes. Each sprinkler head was adjusted at the flow rate of 300 l/hr and the distribution efficiency was 80 per cent.

Fertilizer application

Entire dose of phosphorus as bone meal was applied as basal and incorporated into the soil. Nitrogen and potassium were applied through micro sprinkler with the

Plate 1. View of the experimental field

Plate 2. View of the experimental field at 30 DAS

help of a fertilizer injector in ten split doses at six days interval from 12 DAS to 66 DAS. In the plots receiving life saving irrigation, fertilizers were applied in three split doses (1/3rd N and K as basal, 1/3rd at maximum tillering and 1/3rd at panicle initiation). Urea was used as nitrogen source and muriate of potash as potassium source.

Fertigation schedule followed in the experiment is given below:

Growth stage	Stage of application	Splits
Seedling stage (1/4 dose)	12th, 18th DAS	2
Vegetative stage (1/2 dose)	24th, 30th, 36th, 42nd DAS	4
Upto panicle initiation (1/4 dose)	48th, 54th, 60th, 66th DAS	4

For the life saving irrigation treatment (L_4) fertilizers were applied in three equal splits (one basal and two top dressings as POP recommendation).

Irrigation

From the first day of sowing itself sprinkler system was operated. Irrigation was scheduled based on climatological approach. Daily irrigation based on the evaporation values of the previous day was given to all plots through micro sprinklers except the plots receiving life saving irrigation and the quantity was fixed as per the treatment. Life saving irrigation @ 50mm (life saving irrigations at 5cm depth) was given only when the plants showed wilting symptom of leaf rolling.

The volume of irrigation water required for each treatment was calculated as follows:

Volume (l) = Pan evaporation [Ep (mm)]/1000 x Area (m^2) x 1000

Time of operation of sprinkler system to deliver the required volume of water per plot was computed based on the formula.

Time of application (hr) = Volume of water (l) / Discharge rate of sprinkler (lph)

Distribution uniformity of sprinklers

The distribution efficiency of sprinklers was determined by catch can method (Michael, 1978). Water was collected in catch cans placed at regular grid points from the point of application and measured the quantity of water collected. The distribution efficiency was worked out by the formula,

$$Ed = (1 - y/d) \times 100$$

Where, Ed = Water distribution efficiency (%)

d = average depth of water stored along the run during the irrigation

y = average numerical deviation from'd'

After cultivation

The field was kept weed free by post emergence herbicide application [Bispyribac sodium (Nomineegold 10 SC)] @ 30g *a.i.*/ha followed by hand weeding twice.

Plant protection

Flubendamide (Fame 480 SC) @ 25g *a.i.*/ha and Imidacloprid (Confidor 200 SL) @ 30g *a.i.*/h were applied against leaf folder and stem borer attack. Rice bug attack was noticed during the milky stage and Cypermethrin (Cymbush 25 EC) was applied against it. To control sheath blight, Propiconazole (Tilt 25 EC) @ 125g *a.i.*/ha and Carbendazim (Bavistin 50 WP) @ 125g *a.i.*/ha were applied.

Plate 3. Micro sprinkler head

Plate 4. Estimation of distribution uniformity of sprinkler by catch can method

Harvesting

The crop was harvested during the first week of June after the grains were fully matured. Plants in the two border rows on all sides of each plot were harvested first and removed. Net plots were harvested by cutting the plants at the base. Threshing was done manually and the produce was cleaned, dried and weighed. Weight of grain and straw was expressed as t/ha.

3.3 OBSERVATIONS RECORDED

3.3.1 Biometric observations on crop

Plant height

Height of ten plants was measured in cm from ground level to the tip of the longest leaf at 30 DAS, 60 DAS and at harvest.

Tiller count

The number of tillers per hill was counted from ten different plants randomly selected (at 30 DAS, 60 DAS and at harvest) and the mean was worked out.

Number of panicles per hill

The number of panicles per hill was counted from ten different plants randomly selected and the mean was worked out.

Number of filled grains per panicle

Grains collected from randomly selected ten hills at harvest were separated and counted. The average number of filled grains per panicle was then worked out.

Thousand grain weight

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

Plate 5. View of the experimental field at 60 DAS

Plate 6. View of the experimental field at harvest

Grain yield and straw yield

Harvest from each plot area was threshed, winnowed and weight of grain and straw was recorded separately and expressed in t/ha.

3.3.2 Biometric observations on weeds

Weed count

Species wise weed count was taken using a 75cm x 75cm (0.56 m^2) quadrat. The quadrat was placed at random and samples were taken from each plot at 30 DAS, 60 DAS and at harvest and were reported as number/m^2.

Dry weight

The weeds uprooted from the quadrat were cleaned, air dried and then oven dried at 80 ± 5°C and dry weight was recorded in kg/ha at 30 DAS, 60 DAS and at harvest.

3.3.3 Chemical analysis

Soil analysis

Initial status of major nutrients in soil was estimated. Soil samples were collected before land preparation and soil analysis was done for analyzing the physico-chemical characteristic of the soil using the standard procedures as shown in Table 1.

Plant analysis

For plant analysis, plant samples were collected at 30 DAS, 60 DAS and at harvest. After cleaning, the samples were dried in a hot air oven at 80 ± 5°C and powdered well. The N, P and K content of rice at 30 DAS, 60 DAS and at harvest were analyzed by standard procedures. Total N content of plant samples was determined by Microkjeldal digestion and distillation method (Jackson, 1958). Plant samples were digested in diacid mixture and the P content was determined by Vanadomolybdophosphoric yellow colour method (Piper, 1966). Intensity of colour was read using Spectrophotometer at 430 nm. Potassium content in the diacid digest was estimated using Flame photometer (Piper, 1966).

Incidence of pests and diseases

Incidence of pests like leaf folder, stem borer and rice bug and diseases like sheath blight were observed and timely control measures were adopted.

3.4 MOISTURE CONTENT OF SOIL AT CRITICAL GROWTH STAGES OF RICE

Soil moisture determination was done using gravimetric method. Soil samples were drawn with the help of auger from 0-15, 15-30 and 30-45 cm soil depth during the morning hours just before irrigation.

3. 5 FIELD WATER USE EFFICIENCY

The economic yield per unit of water used is referred to as field water use efficiency and was calculated by using the formula

$$\text{FWUE (kg ha}^{-1}\text{ mm}^{-1}) = \text{Grain yield (kg ha}^{-1})/\text{Water used (mm)}$$

3.6 ECONOMICS OF CULTIVATION

The prevailing labour charge, costs of inputs and extra treatment costs were taken together and gross expenditure was computed and expressed in Rupees per hectare. The price of paddy and that of straw at current local market were taken as total receipts for computing gross return and expressed in Rupees per hectare. Benefit cost ratio was worked out by dividing the gross return with total expenditure per hectare.

3.7 DATA ANALYSIS

The data were subjected to analysis of variance using the statistical package 'MSTAT-C' (Freed, 1986).

RESULTS

4. RESULTS

The results of the experiment on "Fertigation in sprinkler irrigated upland rice" conducted during the third crop season (February to June 2014) are furnished here.

4.1 CROP GROWTH PARAMETERS

4.1.1 Plant height

Data regarding the effect of various treatments on height of rice plants at 30 DAS, 60 DAS and at harvest are given in Table 2.

Levels of irrigation significantly influenced the height of rice plant. Throughout the growth stages, shorter plants were observed under life saving irrigation and the taller plants under 125% Ep (I_3) irrigation. Higher plant height of 37.66 cm at 30 DAS, 59.97 cm at 60 DAS and 85.46 cm at harvest was observed when irrigation was given at 125% E_p (I_3) and was superior to all other irrigation levels. At 30DAS, 100% E_p (I_2) and 125% E_p (I_3) irrigation recorded statistically comparable values of plant height (35.47 and 37.66 cm).

The trend in plant height was almost same at 60 DAS with shorter plants (40.84 cm) under life saving irrigation (I_4) and taller plants in 125% E_p (I_3) irrigation level and all the irrigation levels differed significantly from each other.

At harvest, irrigation at 125% E_p (I_3) continued to register the higher value with respect to plant height (85.46 cm) and was superior to all other irrigation levels. Irrigation levels of 75% (I_1) and 100% E_p (I_2) recorded next higher values and were comparable. The shorter plants (66.24 cm) were observed under (I_4) life saving irrigation.

In the case of subplot treatments *ie.*, fertilizer levels, no significant effect could be observed at 30 DAS. However at 60 DAS and at harvest, significant difference was observed (Table 2). At 60 DAS, the higher value of 55.25 cm was recorded in fertilizer level, 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) which was on par with 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) which in turn was on par with the lower fertilizer level, 60:30:30 N, P_2O_5, K_2O kg/ha (F_3). Similar trend was noticed at harvest also.

Though higher levels of irrigation and fertilizer applied favoured plant height positively, the interaction between irrigation and fertilizer levels was not significant with respect to plant height of rice at all stages of crop growth.

Table 2. Influence of irrigation and fertilizer levels on plant height of rice

Treatment	Plant height (cm)		
	At 30 DAS	At 60 DAS	At harvest
Irrigation			
I_1 (75% Ep)	34.06	53.09	72.64
I_2 (100% Ep)	35.47	57.70	77.87
I_3 (125% Ep)	37.66	59.97	85.46
I_4 (Life saving irrigation)	24.22	40.84	66.24
SEm±	1.208	0.868	2.672
CD (0.05)	2.95	2.12	6.52
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	33.63	55.25	76.94
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	32.41	52.67	76.07
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	32.53	50.80	73.65
SEm±	0.726	1.297	1.389
CD (0.05)	NS	2.75	3.01
Interaction (I x F)	NS	NS	NS

4.1.2 Number of tillers/hill

The data furnished in Table 3. indicate that at 30 DAS, number of tillers/hill was not significantly influenced by irrigation levels. On the contrary, irrigation levels significantly affected tiller number/hill at 60 DAS and at harvest. Throughout the growth stages, irrigation scheduled at 125% E_p (I_3) registered higher number of tillers/hill and the lower number under life saving irrigation (I_4).

At 60 DAS, irrigation at 125% E_p (I_3) recorded higher number of 27.22 tillers/hill which statistically differed from other irrigation levels. 100% E_p (I_2) registered the next higher value which was on par with 75% E_p (I_1). The lower number of tillers/hill was observed in life saving irrigation (I_4).

Almost similar trend was noticed at harvest also, however all irrigation levels differed significantly from each other. The sprinkler irrigation given at 125% E_p (I_3) registered significantly higher number of tillers/hill (30.89), while the lower number of tillers/hill (8.22) were produced under life saving irrigation (I_4). A wide variation in tiller number between I_3 and I_2 was observed at harvest stage. Tiller number in I_2 being 50 per cent lower than that in I_3.

With regard to subplot treatments *ie.*, fertilizer levels, no significant influence could be observed at 30 DAS and at harvest. However at 60 DAS, significant influence could be observed. Higher number of tillers/hill (22.91) was recorded with the fertilizer level 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) which was on par with F_2 (70:35:35 N, P_2O_5, K_2O kg/ha) which in turn was comparable to F_3 (60:30:30 N, P_2O_5, K_2O kg/ha).

The interaction effect between the irrigation and fertilizer levels was not significant throughout the growth stages with respect to number of tillers/hill.

Table 3. Influence of irrigation and fertilizer levels on tiller number of rice

Treatment	Tiller number per hill		
	At 30 DAS	At 60 DAS	At harvest
Irrigation			
I_1 (75% Ep)	18.32	23.21	12.11
I_2 (100% Ep)	18.44	24.10	14.78
I_3 (125% Ep)	19.65	27.22	30.89
I_4 (Life saving irrigation)	16.11	19.78	08.22
SEm±	1.627	0.768	0.721
CD (0.05)	NS	1.88	1.76
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	19.41	22.91	17.00
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	19.25	20.83	16.08
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	18.00	19.58	16.42
SEm±	1.559	1.314	0.720
CD (0.05)	NS	2.78	NS
Interaction (I x F)	NS	NS	NS

4.2 YIELD ATTRIBUTES

4.2.1 Number of productive tillers/hill

The effect of various treatments on yield attributes of rice is given in Table 4. Irrigation levels significantly affected number of panicles/hill. Higher number of panicles/hill (18.23) was noticed under irrigation scheduled at 125% E_p (I_3) and this was closely followed by irrigation at 75% and 100% E_p (11.66 and 13.55). Plants under life saving irrigation (I_4) registered statistically lower number for panicles/hill.

In the case of fertilizer levels, statistically significant differences could not be observed. Higher number of panicles/hill was recorded with 90:45:45 N, P_2O_5, K_2O

kg/ha (F_1) which was on par with other two treatments, values being in the range of 12.67 to 13.16.

4.2.2 Number of grains per panicle

Data presented in Table 4 show that increase in irrigation level from 75% to 125% E_p significantly increased the number of grains/panicle. Irrigation scheduled at 125% E_p (I_3) recorded higher number of grains/panicle (78.89). Whereas life saving irrigation (I_4) recorded lower number of grains/panicle (56.22). Irrigation at 100% E_p recorded next higher value which was on par with 75% E_p irrigation which inturn made statistically comparable values with life saving irrigation treatment (I_4).

Number of grains/panicle was not significantly influenced by fertilizer levels. Fertilizer level 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) registered higher number of grains/panicle (68.25) which was on par with the other two fertilizer levels.

The interaction between irrigation and fertilizer levels was also not significant.

4.2.3 Chaff percentage

The percentage of unfilled grains was very high and it ranged from 24.22 to 29.33 per cent (Table 4). The higher chaff percentage was recorded in the higher irrigation level (125% Ep, I_3) which was comparable to that recorded under life saving irrigation (I_4). The fertilizer levels failed to show any significant change in chaff percentage.

4.2.4 Thousand grain weight (Test weight)

Thousand grain weight was not significantly affected by various irrigation levels (Table 4). Higher test weight of 21.67g was observed when irrigation given at

125% E_p (I_3) and it was on par with scheduling of irrigation at 75% E_p (I_1), 100% E_p (I_2) and life saving irrigation.

Fertilizer levels also failed to show any significant effect on the test weight of sprinkler irrigated upland rice and the average test weight was 21.46g.

Table 4. Influence of irrigation and fertilizer levels on yield attributes of rice

Treatment	Number of panicles per hill	Number of grains per panicle	Chaff (%)	1000 grain weight (g)
Irrigation				
I_1 (75% Ep)	11.66	62.22	24.22	21.61
I_2 (100% Ep)	13.55	68.67	26.67	21.34
I_3 (125% Ep)	18.23	78.89	29.78	21.67
I_4 (Life saving irrigation)	08.12	56.22	29.33	21.21
SEm±	0.382	3.969	0.887	0.359
CD (0.05)	0.93	9.71	2.17	NS
Fertilizer				
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	13.16	68.25	26.25	21.58
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	12.83	66.17	27.67	21.31
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	12.67	65.08	28.58	21.48
SEm±	0.250	1.880	0.936	0.373
CD (0.05)	NS	NS	NS	NS
Interaction (I x F)	NS	NS	NS	NS

4.3 YIELD

4.3.1 Grain yield

The data furnished in Table 5 indicate that there was significant improvement in grain yield of rice with increase in irrigation level. Irrigation given at 125 % E_p (I_3)

resulted in higher grain yield of 3.2 t/ha and was superior to all other irrigation levels. The irrigation levels, 75% E_p (I_1) and 100% E_p (I_2) recorded next higher values (2.78 and 2.84 t/ha) and also were statistically different from each other. The lower grain yield of 2.04 t/ha was recorded in plots which received life saving irrigation (I_4).

With regard to subplot treatments, fertilizer levels could not bring significant variation in grain yield. Among the various fertilizer levels, higher grain yield (2.73 t/ha) was obtained with the higher fertilizer level of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1). However, it remained statistically at par with other two fertilizer levels; 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) and 70:35:35 N, P_2O_5, K_2O kg/ha (F_2).

Interaction between irrigation and fertilizer levels was found to be non-significant.

4.3.2 Straw yield

The data pertaining to straw yield of rice is shown in Table 5. and the trend was exactly same as in the case of grain yield. Straw yield varied significantly amongst different irrigation levels. The higher straw yield of 4.74 t/ha was registered when irrigation given at 125% E_p (I_3) which was superior to all other irrigation levels.

The different fertilizer levels did not significantly influence the straw yield of rice. However, as in the case of grain yield it was found that the straw yield was higher (3.62 t/ha) in fertigation level of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) which was statistically at par with other two fertigation levels.

In case of straw yield also, the interaction between irrigation and fertilizer levels was not significant.

4.3.3 Harvest index

The effect of various treatments on harvest index is shown in Table 5. The data revealed that irrigation levels had significant influence on harvest index of rice which gradually decreased with increase in irrigation level. Significantly higher harvest index of 0.47 was recorded in life saving irrigation and the lower harvest index of 0.40 was recorded under the higher irrigation level (125% Ep).

Fertilizer levels was found to be non significant with regard to harvest index. However, the higher harvest index of 0.43 was recorded under lower fertilizer levels.

The interaction between irrigation and fertilizer levels also failed to produce any significant influence on harvest index of rice.

Table 5. Influence of irrigation and fertilizer levels on grain and straw yield of rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index
Irrigation			
I_1 (75% Ep)	2.78	3.39	0.45
I_2 (100% Ep)	2.84	3.97	0.42
I_3 (125% Ep)	3.20	4.74	0.40
I_4 (Life saving irrigation)	2.04	2.25	0.47
SEm±	0.025	0.044	0.00
CD (0.05)	0.04	0.11	0.01
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	2.73	3.62	0.42
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	2.72	3.59	0.43
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	2.70	3.57	0.43
SEm±	0.018	0.036	0.00
CD (0.05)	NS	NS	NS
Interaction (I x F)	NS	NS	NS

4.4 NUTRIENT CONTENT OF RICE

Data on nutrient content of rice at 30 and 60 DAS and at harvest are furnished in Table 6.

4.4.1 Nitrogen content of rice

At 30 DAS, nitrogen content of rice plant was not significantly influenced by irrigation level. However, higher N content of 2.72 per cent was observed under the irrigation schedule of 125% Ep (I_3) which was on par with other three irrigation levels.

As the growth progressed, N content showed a declining trend and was significantly influenced by irrigation level. At 60 DAS, N content varied from 1.69 per cent at 125% Ep (I_3) irrigation to 2.23 at 75% Ep (I_1) irrigation which was superior to all other irrigation levels. Irrigation at 100% Ep (I_2) and life saving irrigation (I_4) recorded comparable values of 1.96 and 1.93 per cent nitrogen respectively.

With regard to subplot treatments *ie*., fertilizer levels, no significant influence on N content of rice could be observed at 30 and 60 DAS. However lower fertilizer level; 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) recorded higher N content of 2.76 and 1.98 per cent at 30 and 60 DAS respectively which were on par with other fertilizer levels.

Interaction between irrigation and fertilizer level was found to be non significant with regard to N content of rice at 30 and 60 DAS.

4.4.2 Phosphorus content of rice

Levels of irrigation showed significant effect on P content of rice at 30 DAS. Significantly higher P content of 0.3 per cent was noticed under the irrigation schedule of 125% Ep (I_3) which was superior to all other irrigation levels and the lower P content of 0.16 per cent was recorded in the irrigation schedule of 75% Ep (I_1).

At 60 DAS also, P content of rice plant was found to be significantly influenced by irrigation levels. Higher P content of 0.29 per cent was registered by irrigation at 125% Ep which was on par with irrigation scheduled at 100% Ep.

With regard to fertilizer levels, significant influence on P content of rice could be observed at 30 and 60 DAS. Higher P content of 0.29 per cent at 30 DAS was obtained with the higher fertilizer level, 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and other treatments were on par. At 60 DAS, significantly higher P content of 0.27 per cent was observed under the fertilizer levels; 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) and 70:35:35 N, P_2O_5, K_2O kg/ha (F_2).

It could be seen that interaction effect of irrigation and fertilizer was not significant with regard to P content of grain and straw.

4.4.3 Potassium content of rice

Irrigation levels failed to show any significant effect on K content of rice at 30 and 60 DAS. However, irrigation at100% Ep (I_2) at 30 DAS and 75% Ep at 60 DAS registered higher K content of 2.59 and 2.25 per cent respectively.

It was found that K content of rice at 30 DAS was not significantly influenced by fertilizer levels. However higher fertilizer level (90:45:45 N, P_2O_5, K_2O kg/ha) recorded higher K content of 2.54 per cent which was on par with other treatments. By 60 DAS, the K content of rice plant decreased and it varied from 2.03 to 2.19 per cent. Significantly higher value of 2.19 per cent was recorded under 70:35:35 N, P_2O_5, K_2O kg/ha fertilizer level which was on par with 90:45:45 N, P_2O_5, K_2O kg/ha and the lower K content of 2.03 per cent was recorded by 60:30:30 N, P_2O_5, K_2O kg/ha fertilizer level.

Interaction between irrigation and fertilizer level was not significant with respect to K content of rice at 30 and 60 DAS.

Table 6. Influence of irrigation and fertilizer levels on nutrient content of rice at 30 and 60 DAS

Treatment	N content (%)		P content (%)		K content (%)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Irrigation						
I_1 (75% Ep)	2.66	2.23	0.16	0.20	2.24	2.25
I_2 (100% Ep)	2.59	1.96	0.28	0.26	2.59	2.01
I_3 (125% Ep)	2.72	1.69	0.30	0.29	2.56	2.23
I_4 (Life saving irrigation)	2.71	1.93	0.24	0.22	2.56	2.04
SEm±	0.157	0.063	0.014	0.012	0.127	0.104
CD (0.05)	NS	0.15	0.04	0.03	NS	NS
Fertilizer						
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	2.69	1.97	0.29	0.24	2.54	2.18
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	2.56	1.91	0.26	0.27	2.41	2.19
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	2.76	1.98	0.25	0.27	2.51	2.03
SEm±	0.143	0.084	0.012	0.009	0.158	0.051
CD (0.05)	NS	NS	0.03	0.02	NS	0.11
Interaction (I x F)	NS	NS	NS	NS	NS	NS

4.4.4 Nutrient content of grain and straw of rice

Nitrogen content of grain and straw

Data pertaining to nutrient content of rice grain and straw (Table 7) indicate that N content in grain was significantly influenced by irrigation level. Significantly higher N content of 1.32 per cent was registered under life saving irrigation and the lower content was registered by 125% Ep irrigation level. 75 and 100% Ep irrigation levels were on par which in turn was on par with 125% Ep irrigation level.

Contradictory to this, N content in straw was not significantly influenced by irrigation level. However, higher N content of 0.86 per cent was recorded under 125% Ep irrigation level.

In case of fertilizer level, no significant effect on N content of grain could be observed. However, it showed significant effect on N content of straw which increased with increase in fertilizer level. 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) recorded higher N content of 0.91 per cent which was superior to all other fertilizer levels. Fertilizer level, 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) recorded next higher value (0.75 per cent) which was on par with the fertilizer level of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3).

Interaction effect of irrigation and fertilizer level was found to be significant for N content of grain and straw. Among the treatment combinations, life saving irrigation (I_4) along with 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) recorded superior value (1.40 per cent) of N content in grain which was on par with life saving irrigation along with 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) and 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) fertilizer levels. Lower N content of 0.64 per cent was recorded in the treatment combination of 100% Ep (I_2) and 90:45:45 N, P_2O_5, K_2O kg/ha (F_1). In the case of straw, higher N content (0.97 per cent) was recorded in irrigation at 75% Ep (I_1) along with 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) which was on par with the treatment combinations, life saving irrigation (I_4) along with 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and 125% Ep irrigation along with 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) or 90:45:45 N, P_2O_5, K_2O kg/ha.

Phosphorus content of grain and straw

At harvest stage, P content of grain as well as straw was significantly influenced by irrigation levels. It varied from 0.20 to 0.26 per cent in grain and 0.14 to 0.23 per cent in straw respectively. Significantly higher P content of 0.26 per cent in grain was registered by higher irrigation level (125% Ep) which was superior to all other irrigation levels. Other irrigation levels were on par with each other. In the case of straw, irrigation at 100% Ep (I_2) recorded higher P content (0.23 per cent) while the lower value of 0.14 per cent was observed under the irrigation schedule of 75% Ep.

Effect of fertilizer levels on P content of grain as well as straw was found to be non significant. However higher P content of 0.23 per cent in grain and 0.2 per cent in straw was recorded under the fertilizer level of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) respectively.

Interaction between irrigation and fertilizer level was not significant with regard to P content of grain as well as straw.

Potassium content of grain and straw

Potassium content of rice grain and straw under various treatments is furnished in Table 7 which revealed that K content in grain was not significantly affected by irrigation level. As in the case of K content at 30 DAS, irrigation at100% Ep (I_2) recorded higher value (0.51 per cent) in grain also. Significant variation was noticed between levels of irrigation with respect to K content in straw. Higher K content of 1.77 per cent was recorded under life saving irrigation (I_4) and the lower K content of 1.29 per cent was noticed at 75% Ep irrigation.

Potassium content of grain and straw was not significantly influenced by fertilizer levels. It was in the range of 0.49 to 0.51 per cent in grain and 1.44 to 1.54 per cent in straw respectively.

Potassium content of grain was not significantly affected by the interaction of irrigation and fertilizer level. However, in the case of straw, interaction effect of irrigation and fertilizer level was significant for K content and it varied from 1.23 per cent in irrigation at 100% Ep and 90:45:45 N, P_2O_5, K_2O kg/ha to 2.18 per cent under life saving irrigation and 60:30:30 N, P_2O_5, K_2O kg/ha.

Table 7. Influence of irrigation and fertilizer levels on nutrient content of grain and straw of rice

Treatment	N content (%)		P content (%)		K content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Irrigation						
I_1 (75% Ep)	0.93	0.76	0.22	0.14	0.50	1.29
I_2 (100% Ep)	0.79	0.79	0.20	0.23	0.51	1.31
I_3 (125% Ep)	0.72	0.86	0.26	0.17	0.50	1.54
I_4 (Life saving irrigation)	1.32	0.73	0.21	0.20	0.49	1.77
CD (0.05)	0.15	NS	0.02	0.02	NS	0.22
Fertilizer						
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	1.04	0.91	0.23	0.18	0.49	1.46
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	1.06	0.75	0.22	0.18	0.50	1.44
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	1.07	0.70	0.21	0.20	0.51	1.54
CD (0.05)	NS	0.08	NS	NS	NS	NS
Interaction (I x F)	0.23	0.16	NS	0.03	NS	0.25

Table 7(a). Interaction of irrigation and fertilizer levels on N content of grain at harvest

Treatments	F_1	F_2	F_3
I_1	1.04	0.98	0.77
I_2	0.64	0.73	0.98
I_3	1.28	1.17	1.11
I_4	1.23	1.34	1.40

Table 7(b). Interaction of irrigation and fertilizer levels on N content of straw at harvest

Treatments	F_1	F_2	F_3
I_1	0.97	0.77	0.57
I_2	0.83	0.77	0.77
I_3	0.89	0.92	0.77
I_4	0.93	0.57	0.70

Table 7(c). Interaction of irrigation and fertilizer levels on K content of straw at harvest

Treatments	F_1	F_2	F_3
I_1	1.38	1.25	1.24
I_2	1.23	1.45	1.27
I_3	1.51	1.65	1.47
I_4	1.71	1.43	2.18

4.5 DRY MATTER PRODUCTION OF RICE

Data regarding the effect of irrigation levels on dry matter production of rice at harvest are given in Table 9. There were significant differences in dry matter production by irrigation level and the higher dry matter production of 5.69 t/ha was observed under the higher irrigation level (125% Ep). Next higher values were recorded in irrigation at 75 and 100% Ep and the lower dry matter production of 2.93 t/ha were observed under life saving irrigation.

Fertilizer levels also significantly influenced the dry matter production of rice. Higher dry matter production was observed in the fertilizer level of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) which was comparable with 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) and the lower value was in the fertilizer level, 60:30:30 N, P_2O_5, K_2O kg/ha (F_3).

Interaction of irrigation and fertilizer level also showed significant effect on dry matter production of rice. Of the different treatment combinations, higher irrigation level (125% Ep) along with lower fertilizer level (60:30:30 N, P_2O_5, K_2O kg/ha; F_3) recorded higher dry matter production which was on par with higher irrigation (125% Ep) and fertilizer level (90:45:45 N, P_2O_5, K_2O kg/ha; F_1). Life saving irrigation along with lower fertilizer level registered lower dry matter production.

4.6 NUTRIENT UPTAKE BY RICE AT HARVEST

Data on total N, P and K uptake by rice at harvest are given in Table 8. Data indicate that the uptake of N, P and K by rice is influenced by the moisture regime. Total nutrient uptake varied from 31.52 to 57.62, 6.05 to 11.91 and 29.56 to 60.72 kg N, P and K per hectare respectively. The higher N, P and K uptake was recorded under irrigation scheduled at 125% Ep while the lower uptake was recorded under life saving irrigation. 75% Ep (I_1) and 100% Ep irrigation levels were on par in case of N uptake whereas in case of P and K uptake, all the irrigation levels differed significantly from each other.

N uptake by rice at harvest stage was found to be significantly influenced by quantity of fertilizer supplied. However, various fertilizer levels failed to show any significant effect on P and K uptake. In case of N uptake, the higher fertilizer level 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) recorded higher uptake of 43.8 kg/ha which was on par with the fertilizer level 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) which in turn was on par with the lower fertilizer level, 60:30:30 N, P_2O_5, K_2O kg/ha (F_3).

Interaction between irrigation and fertilizer levels was found to be significant with regard to N and P uptake. Among the various treatment combinations, the higher irrigation level (125% Ep, I_3) with the higher fertilizer level (90:45:45 N, P_2O_5, K_2O kg/ha; F_1) recorded higher N uptake (61.04 kg/ha). The lower values of N uptake were noticed in the combination of 75% Ep (I_2) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) followed by life saving irrigation (I_4) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3). In case of P uptake, higher value of 12.53 kg/ha was registered in 125% Ep (I_3) and 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) combination followed by irrigation at 125% Ep (I_3) along with 90:45:45 N, P_2O_5, K_2O kg/ha (12.19 kg/ha) and these were on par with each other. The lower value (5.08 kg/ha) of P uptake was recorded under life saving irrigation (I_4) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3).

Table 8. Influence of irrigation and fertilizer levels on nutrient uptake by rice at harvest

Treatment	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Irrigation			
I_1 (75% Ep)	37.35	07.93	38.28
I_2 (100% Ep)	37.80	10.58	47.46
I_3 (125% Ep)	57.62	11.91	60.72
I_4 (Life saving irrigation)	31.52	06.05	29.56
SEm±	2.724	0.362	1.858
CD (0.05)	6.67	0.89	4.55
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	43.80	9.10	44.53
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	41.03	9.19	44.09
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	38.39	8.97	43.40
SEm±	1.579	0.264	2.285
CD (0.05)	3.34	NS	NS
Interaction (I x F)	6.69	1.12	NS

Table 8(a). Interaction of irrigation and fertilizer levels on N and P uptake by rice at harvest

N uptake			
Treatments	F_1	F_2	F_3
I_1	44.59	38.16	29.31
I_2	35.81	35.73	41.85
I_3	61.04	59.06	52.76
I_4	33.75	31.16	29.65
P uptake			
Treatments	F_1	F_2	F_3
I_1	8.15	7.56	8.09
I_2	9.42	10.26	11.70
I_3	12.19	12.53	11.01
I_4	6.63	6.43	5.08

4.7 FIELD WATER USE EFFICIENCY OF RICE

The data pertaining to field water use efficiency and total water used are given in Table 9. Levels of irrigation significantly influenced the field water use efficiency. Field water use efficiency showed an increasing trend with increase in total water applied. The quantity of water applied in the irrigation schedule of 75% Ep (I_1) was 305 mm which recorded higher water use efficiency of 9.11 kg ha^{-1} mm^{-1} and was superior to all other irrigation levels. In life saving irrigation treatment, the quantity of water applied was 600 mm which registered the lower field water use efficiency of 3.39 kg ha^{-1} mm^{-1}. Total water applied in the irrigation levels of 100% and 125% Ep was 391.8 mm and 516.13 mm respectively which recorded intermediary values of field water use efficiency of 7.25 and 6.20 kg ha^{-1} mm^{-1} respectively.

Field water use efficiency was not significantly influenced by fertilizer levels. However, the higher fertilizer level F_1 (90:45:45 N, P_2O_5, K_2O kg/ha) registered higher field water use efficiency of 6.52 kg ha^{-1} mm^{-1} which was on par with the other two fertilizer levels.

The interaction between irrigation and fertilizer levels was also not significant.

Table 9. Influence of irrigation and fertilizer levels on dry matter production and field water use efficiency of upland rice

Treatment	DMP of rice (t/ha)	Total water applied (mm)	Field water use efficiency (kg ha^{-1} mm^{-1})
Irrigation			
I_1 (75% Ep)	4.39	305.00	9.11
I_2 (100% Ep)	4.80	391.80	7.25
I_3 (125% Ep)	5.69	516.13	6.20
I_4 (Life saving irrigation)	2.93	600.00	3.39
SEm±	0.036	-	0.059
CD (0.05)	0.09	-	0.15
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	4.51	-	6.52
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	4.49	-	6.48
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	4.36	-	6.47
SEm±	0.036	-	0.046
CD (0.05)	0.08	-	NS
Interaction (I x F)	0.15	-	NS

Table 9(a). Interaction of irrigation and fertilizer levels on dry matter production of rice at harvest

Treatments	F_1	F_2	F_3
I_1	4.44	4.36	4.37
I_2	4.84	4.77	4.79
I_3	5.67	5.07	5.68
I_4	3.07	3.13	2.58

4.8 SOIL MOISTURE CONTENT AT CRITICAL GROWTH STAGES OF RICE

The gravimetric soil moisture content estimated at panicle initiation, flowering and milk stage of rice from three depths 0-15 cm, 15-30 cm and 30-45 cm are shown in Table 10. At all the three critical growth stages, soil moisture content increased with increase in irrigation level in all the three soil layers.

The gravimetric soil moisture content varied from 10.18 to 17.36% at panicle initiation stage, 9.35 to 14.28 % at flowering and 10.27 to 15.16 % at milk stage in 0-15 cm soil layer.

Throughout the growth period, irrigation at 125% Ep (I_3) registered maximum soil moisture content while the lower moisture content was noticed under life saving irrigation (I_4) in all the three soil layers. At panicle initiation stage, maximum moisture content was observed in 15-30 cm soil layer followed by 30-45 and 0-15 cm. At flowering and milk stage, higher soil moisture content was observed in 30-45 cm layer and lower in 15-30 cm soil layer and the moisture use from 0-15cm layer was high as that of 15-30 cm soil layer.

The volumetric moisture content up to a depth of 45 cm was also estimated. It was found that the total moisture content varied from 6.44 to 11.6 cm over the different stages.

Table 10. Soil moisture content (% w/w) at critical growth stages of rice under sprinkler irrigation

Treatments	Panicle initiation stage					Flowering stage					Milk stage				
	Soil depth (cm)														
	0-15	15-30	30-45	Average	Soil moisture up to 45 cm depth	0-15	15-30	30-45	Average	Soil moisture up to 45 cm depth	0-15	15-30	30-45	Average	Soil moisture up to 45 cm depth
I_1 (75% Ep)	13.22	15.32	12.62	13.72	08.82	13.22	11.8	16.58	13.87	8.99	12.13	11.65	13.36	12.38	7.99
I_2 (100% Ep)	15.20	15.58	15.11	15.29	09.84	13.57	13.28	16.20	14.35	9.29	12.37	12.45	13.92	12.91	9.69
I_3 (125% Ep)	16.36	17.88	17.67	17.30	11.16	14.28	13.63	16.66	14.86	9.61	15.16	14.57	16.11	15.28	9.85
I_4 (life saving irrigation)	10.18	14.38	11.59	12.05	07.90	10.35	09.25	10.43	10.01	6.44	10.27	11.43	11.47	11.06	7.14

4.9 STUDIES ON WEEDS

The observations related to weed spectrum, species wise weed count and weed dry matter production at 30 and 60 DAS and at harvest are furnished below.

4.9.1 Weed spectrum

Major graminaceous weed found in experimental plot was *Panicum maximum* (Guinea grass). No other graminaceous weeds were present. *Borreria hispida, Melochia corchorifolia, Centrosema pubescens, Calopogonium mucunoides and Cleome* spp. were the dominant broad leaved species.

4.9.2 Weed density

Species wise weed count was taken at 30 and 60 DAS and at harvest which is given in Table 11, 12 and 13.

It was found that irrigation levels significantly influenced the density of *Panicum maximum* when observations were recorded at 30 DAS. The higher density of 314.48/m^2 was registered in the higher level of irrigation which was superior to other levels of irrigation. The weed density in all other irrigation levels including life saving irrigation was on par.

Borreria hispida, Melochia corchorifolia, Centrosema pubescens etc. were dominant among the dicots present. There was significant variation in their density with respect to irrigation regime. Density of *Borreria hispida* was the maximum and it varied from 48.41/m^2 in irrigation schedule of 125% Ep (I_3) to 17.17/m^2 in I_2 (100% Ep). It was observed that the lower density of all the dicot weeds was in plots which received life saving irrigation and the maximum density was in plots with 75% Ep irrigation.

No variation in weed density could be observed with increase in fertilizer level. With regard to weed density, the interaction between irrigation and fertilizer levels was also not significant.

By 60 DAS, the only weed species in the experimental plot was Guinea grass (*Panicum maximum*) and no other weeds could be observed as the plots were kept weed free by manual weeding. The density of *Panicum maximum* was not altered either by irrigation or fertilizer level. Density of other weeds was very low as compared to Guinea grass and was also not altered either by irrigation or fertilizer level.

At harvest stage also, *Panicum maximum* was the only graminaceous weed observed and there was significant variation in its density with regard to irrigation level. The maximum density of 40.28/m^2 was registered in irrigation scheduled as 100% Ep (I_2) and was superior to all other irrigation levels. *Borreria hispida, Melochia corchorifolia* and *Centrosema pubescens* were the major broad leaved weeds found in experimental plot and their density was low as compared to guinea grass. A high count of *Borreria hispida as* compared to other broad leaved weeds was observed in all irrigation levels and it ranged from 3.09 to 12.70 /m^2. In the case of *Melochia corchorifolia*, higher level of irrigation (125% Ep) registered statistically higher weed count (4.77/m^2) which was comparable with the irrigation level, I_1 (75% Ep) and I_4 (life saving irrigation). The higher count (6.35/m^2) of *Centrosema pubescens* was under irrigation scheduled at 75 % Ep (I_1) which was on par with other three irrigation levels. In general, maximum density of broad leaved species was observed in the higher level of irrigation (125% Ep).

Data on species wise weed count at harvest revealed that fertilizer levels had no significant effect on weed count. However the higher values were observed in the lower fertilizer level 60:30:30 N, P_2O_5, K_2O kg/ha (F_3). At harvest stage also, the interaction between irrigation and fertilizer levels was not significant.

Table 11. Influence of irrigation and fertilizer levels on species wise weed count (No./m²) at 30 DAS

Treatments	*Panicum maximum*	*Borreria hispida*	*Melochia corchorifolia*	*Centrosema pubescense*	*Cleome* spp.	*Calopogonium mucunoides*	Total dicots
Irrigation							
I_1 (75% Ep)	12.71 (161.11)	4.99 (24.42)	5.16 (26.19)	6.26 (38.69)	5.83 (33.53)	5.41 (28.77)	12.33 (151.67)
I_2 (100% Ep)	13.79 (189.68)	4.20 (17.17)	4.25 (17.61)	4.94 (24.00)	3.71 (13.29)	5.29 (27.58)	10.00 (99.67)
I_3 (125% Ep)	17.74 (314.48)	6.99 (48.41)	5.05 (25.05)	3.19 (9.72)	3.57 (12.30)	2.72 (6.94)	10.14 (102.43)
I_4 (Life saving irrigation)	12.13 (146.82)	4.66 (21.23)	3.89 (14.68)	2.61 (6.35)	1.51 (1.79)	4.14 (16.67)	7.82 (60.72)
SEm±	0.963	1.776	1.163	0.549	0.912	0.733	1.439
CD (0.05)	2.36	NS	NS	1.34	2.23	1.79	3.52
Fertilizer							
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	12.82 (163.98)	4.25 (17.58)	4.35 (18.49)	4.24 (17.56)	4.28 (17.86)	4.60 (20.68)	9.62 (92.17)
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	14.71 (215.92)	6.46 (41.30)	4.38 (18.77)	5.00 (24.55)	3.97 (15.33)	4.57 (20.39)	10.99 (120.35)
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	15.15 (229.16)	5.00 (24.55)	5.08 (25.39)	4.17 (16.96)	3.60 (12.5)	4.40 (18.90)	9.94 (98.35)
SEm±	1.477	0.973	0.700	0.598	0.550	0.748	0.992
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
Interaction (I x F)	NS	NS	NS	NS	NS	NS	NS

*$\sqrt{x+0.5}$ transformed values, original values in parentheses

Table 12. Influence of irrigation and fertilizer levels on species wise weed count (No./m^2) at 60 DAS

Treatment	*Panicum maximum*	Other weeds
Irrigation		
I_1 (75% Ep)	*3.48 (11.68)	1.54 (1.89)
I_2 (100% Ep)	2.97 (8.33)	1.52 (1.82)
I_3 (125% Ep)	3.79 (13.89)	1.49 (1.73)
I_4 (Life saving irrigation)	3.25 (10.12)	1.50 (1.78)
SEm±	0.704	0.069
CD (0.05)	NS	NS
Fertilizer		
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	3.58 (12.35)	1.47 (1.67)
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	3.16 (9.52)	1.47 (1.67)
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	3.43 (11.31)	1.52 (1.83)
SEm±	0.709	0.151
CD (0.05)	NS	NS
Interaction (I x F)	NS	NS

$*\sqrt{x+0.5}$ transformed values, original values in parentheses

Table 13. Influence of irrigation and fertilizer levels on species wise weed count (No./m^{2}) at harvest

Treatment	*Panicum maximum*	*Borreria hispida*	*Melochia corchorifolia*	*Centrosema pubescense*	Other dicots	Total dicots
Irrigation						
I_1 (75% Ep)	*4.70 (21.62)	3.19 (9.72)	1.63 (2.18)	2.61 (6.35)	1.36 (1.35)	4.53 (20.05)
I_2 (100% Ep)	6.38 (40.27)	3.54 (12.10)	1.51 (1.79)	2.20 (4.37)	1.92 (3.20)	4.72 (21.83)
I_3 (125% Ep)	4.66 (21.23)	3.63 (12.70)	2.29 (4.77)	1.87 (3.00)	2.00 (3.51)	4.99 (24.42)
I_4 (Life saving irrigation)	3.57 (12.30)	1.89 (3.09)	1.75 (2.58)	1.99 (3.48)	1.56 (1.94)	3.48 (11.63)
SEm±	0.585	0.354	0.212	0.311	0.277	0.242
CD (0.05)	1.43	0.86	0.51	NS	NS	0.59
Fertilizer						
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	4.80 (22.62)	2.92 (8.06)	1.82 (2.83)	2.29 (4.76)	1.76 (2.63)	3.99 (15.49)
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	4.71 (21.73)	3.32 (10.57)	1.78 (2.68)	2.07 (3.80)	1.43 (1.56)	4.29 (19.36)
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	5.26 (27.23)	3.61 (12.58)	1.86 (2.98)	2.19 (4.33)	1.95 (3.31)	4.90 (23.60)
SEm±	0.566	0.388	0.282	0.241	0.180	0.288
CD (0.05)	NS	NS	NS	NS	NS	NS
Interaction (I x F)	NS	NS	NS	NS	NS	NS

***$\sqrt{x+0.5}$ transformed values, original values in parentheses**

4.9.3 Weed dry weight

The data on dry weight by weeds at 30 and 60 DAS and at harvest are shown in Table 14. The weed dry weight in higher level of irrigation (125% Ep) was statistically superior to all other irrigation levels at 30 DAS and at harvest. However at 60 DAS, the higher weed dry weight was recorded in plots with 75% Ep (I_1) irrigation.

At 30 DAS, irrigation at 125% Ep (I_1) recorded maximum weed dry weight of 365.28 kg/ha which was superior to all other irrigation levels. Weed dry weight in other irrigation levels was comparable. However lower dry weight (157.94 kg/ha) was noticed under life saving irrigation (I_4).

By 60 DAS, in general weed dry weight decreased in all treatments. Irrigation scheduled at 75% Ep (I_1) recorded significantly higher value of 138.45 kg/ha. Irrigation level I_3 (125% Ep) recorded next higher value which was similar to other two irrigation levels.

An increase in weed dry weight could be observed from 60 DAS to harvest. At harvest, maximum dry weight by weeds was noticed under higher irrigation level I_3 (125% Ep) but was comparable with other two irrigation levels, 75% Ep (I_1) and 100% Ep (I_2) which in turn were comparable to life saving irrigation (I_4).

In case of subplots, statistically significant variation in weed density could not be observed with increase in fertilizer dose.

Interaction between irrigation and fertilizer levels was also not significant with respect to weed dry matter production as in the case of weed density.

Table 14. Influence of irrigation and fertilizer levels on weed dry weight

Treatment	Weed dry weight (kg/ha)		
	30 DAS	60 DAS	At harvest
Irrigation			
I_1 (75% Ep)	*12.83 (164.21)	11.78 (138.45)	12.50 (155.75)
I_2 (100% Ep)	13.52 (182.54)	8.38 (69.84)	12.14 (147.02)
I_3 (125% Ep)	19.12 (365.28)	9.03 (81.15)	13.10 (171.34)
I_4 (Life saving irrigation)	12.58 (157.94)	8.66 (74.54)	10.20 (103.57)
SEm±	0.844	0.914	1.093
CD (0.05)	2.07	2.24	2.68
Fertilizer			
F_1 (90:45:45 N, P_2O_5, K_2O kg/ha)	12.86 (164.88)	9.59 (91.56)	12.06 (145.09)
F_2 (70:35:35 N, P_2O_5, K_2O kg/ha)	16.32 (265.92)	9.10 (82.32)	12.00 (143.60)
F_3 (60:30:30 N, P_2O_5, K_2O kg/ha)	14.91 (221.83)	9.98 (99.11)	12.04 (144.50)
SEm±	0.785	0.869	0.994
CD (0.05)	NS	NS	NS
Interaction (I x F)	NS	NS	NS

***$\sqrt{x+0.5}$ transformed values, original values in parentheses**

4.10 ECONOMICS OF CULTIVATION

The data pertaining to the economics (Rs./ha) of cultivation of upland rice under different irrigation and fertilizer levels are presented in Table 15. The data indicated that gross return, net return and B: C ratios were significantly influenced by irrigation and fertilizer levels.

Higher irrigation level (125% Ep) registered higher total cost, gross return, net return and B: C ratio. Costs of production as well as the net returns were lower in life saving irrigation (I_4). Higher fertilizer level; 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) recorded higher total cost and gross return. Net return and B: C ratio were higher when a lower fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) was supplied.

In the case of all irrigation levels, the B: C ratio increased with decrease in fertilizer level. The lower value for net return as well as B: C ratio was registered for life saving irrigation. However the higher B: C ratio was recorded with a fertilizer dose of 70:35:35 N, P_2O_5, K_2O kg/ha (F_2).

A comparison of B: C ratio under a given fertilizer level shows an increase with increase in irrigation regime from 75% Ep to 125% Ep.

Among the treatment combinations, the higher net return of Rs. 23728 per hectare was obtained for irrigation at 125% Ep (I_3) along with 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) with a B: C ratio of 1.36. The next best treatments were irrigation at 125% Ep (I_3) along with 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) followed by irrigation at 125% Ep (I_3) along with 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and these treatments registered B: C ratio of 1.35 and 1.31 respectively. Life saving irrigation (I_4) along with 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) recorded lower B: C ratio of 0.87.

Table 15. Economics (Rs./ha) of upland rice cultivation under various irrigation and fertilizer levels

Irrigation level	90:45:45 N, P_2O_5, K_2O kg/ha (F_1)				70:35:35 N, P_2O_5, K_2O kg/ha (F_2)				60:30:30 N, P_2O_5, K_2O kg/ha (F_3)			
	Total cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio	Total cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio	Total cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
75% Ep (I_1)	67999	73677	5678	1.08	65966	72857	6890	1.10	65270	73067	7796	1.12
100% Ep (I_2)	68083	78657	10574	1.16	66050	77127	11077	1.17	65354	77780	12426	1.19
125% Ep (I_3)	68164	89343	21179	1.31	66131	89150	23019	1.35	65435	89163	23728	1.36
Life saving irrigation (I_4)	60349	52370	-7979	0.87	58316	53347	-4969	0.92	57620	50897	-67231	0.88

DISCUSSION

5. DISCUSSION

A field experiment on "Fertigation in sprinkler irrigated upland rice" was conducted at Instructional Farm at KAU campus, Vellanikkara, Thrissur. The results obtained from the experiment are discussed below based on available literature.

5.1 CROP GROWTH PARAMETERS

The results of the study reveal that irrigation levels have significant effect on growth parameters of rice plant. Throughout the growth stages, performance of upland rice grown under sprinkler irrigation at 125% Ep was superior for growth parameters like plant height and number of tillers per hill while the least values were noticed under life saving irrigation. Similar results were also reported by Govindan and Grace (2012) in aerobic rice. The increased plant height under irrigation scheduled at 125% Ep might have been due to the continuous availability of sufficient quantity of water and better conductive rhizosphere environment for higher uptake of nutrients which in turn boosted the growth. The lower values of plant height under life saving irrigation might be due to the reduction in soil moisture status due to the increased loss of water through evapotranspiration and percolation and resultant moisture stress experienced by the crop. Chowdhury *et al.* (2004) and Zoinalabedin *et al.* (2008) also reported that plant height decreased with decrease in soil moisture levels. Reduction in growth parameters with increase in severity of water stress is due to anatomical changes in the plant like decrease in cell volume, cell division, cell elongation, intercellular space and thickening of cell wall as reported by Adriano *et al.* (2005). It can be inferred that the plants under 75% and 100% Ep irrigation level (I_2 and I_1) also might have experienced moisture stress as the plant height was in general low in these treatments compared to irrigation at 125% Ep. The average plant height of the variety Uma under wetland condition is 102.8 cm (Devika *et al.*, 2004) whereas in the present study under upland condition average plant height was only 75.5 cm at harvest. From which it can also be inferred that plant

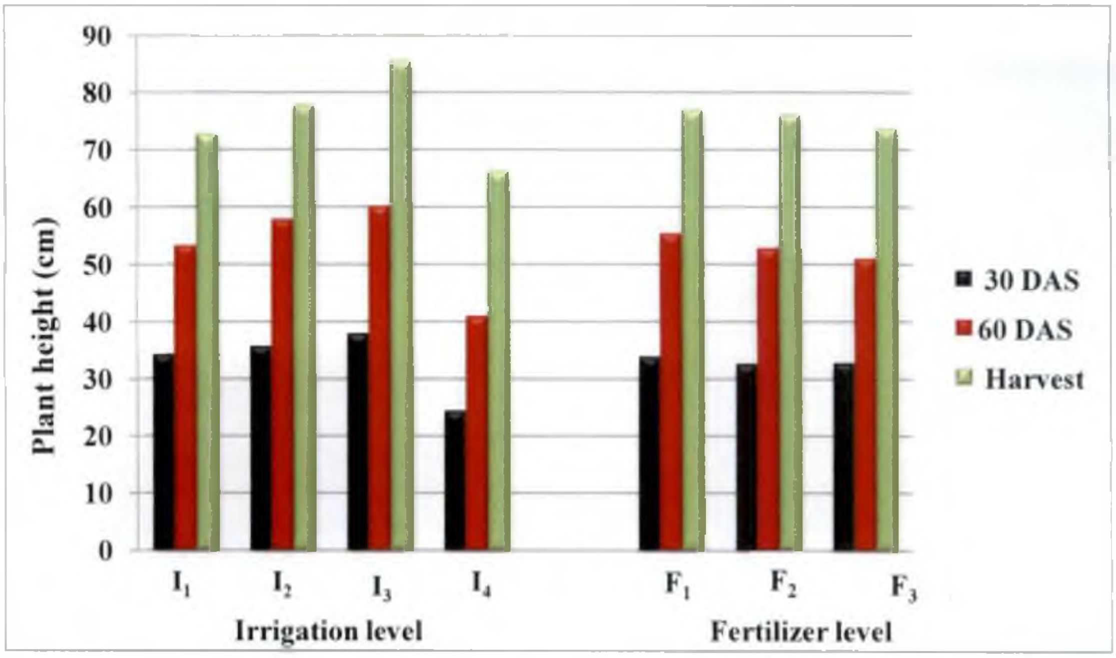

Fig. 4. Plant height of rice at different growth stages as influenced by irrigation and fertilizer levels

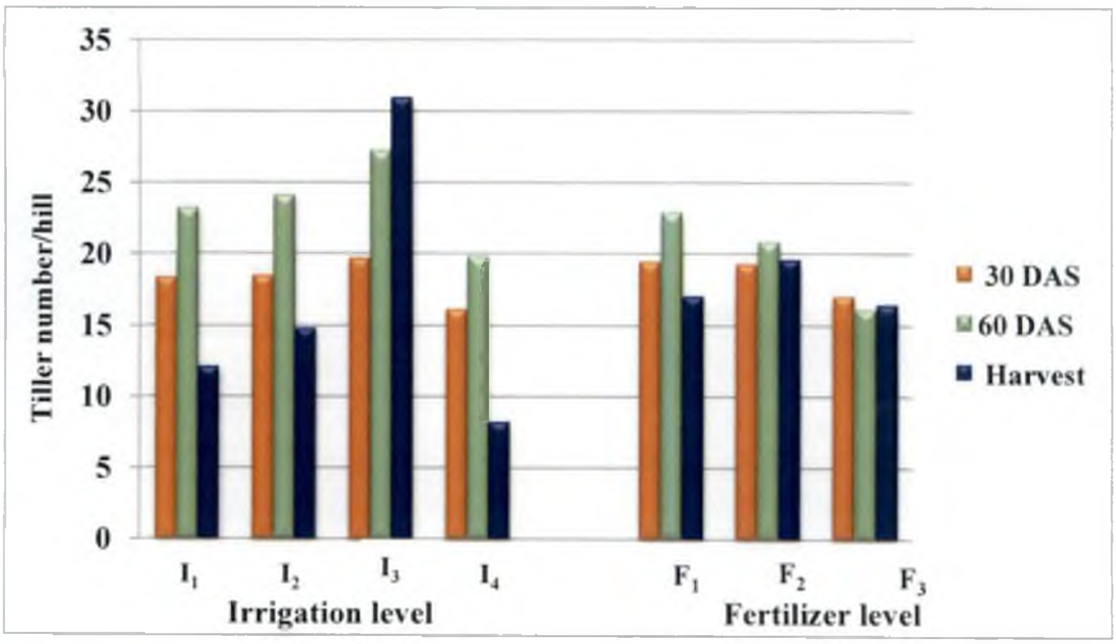

Fig. 5. Number of tillers/hill of rice at different growth stages as influenced by irrigation and fertilizer levels

might have experienced moisture stress even under 125% Ep irrigation compared to flooded or lowland situation.

The trend in plant height was same at all growth stages. At harvest plants in life saving irrigation recorded almost 30 per cent reduction in height over the higher level of irrigation I_3 (125% Ep). Even the supply of 100% Ep irrigation water resulted in 10 per cent reduction in plant height. This shows the influence of moisture availability on plant physiology and growth.

Nutrient supply is another most important factor which influences plant growth. Sampathkumar and Pandian (2010) reported increased plant height with 150% of recommended dose of fertilizer in upland rice under drip fertigation. Vishandas *et al.* (2006), Negi *et al.* (2013) and Pasha *et al.* (2013) also reported taller plants under higher levels of nitrogen. However contradictory to this, in the present study it was found that the various nutrient levels have no influence on plant height at 30 and 60 DAS as well as at harvest stage of rice. A marginal increase in plant height was observed with increase in fertilizer level from 60:30:30 to 90:45:45 N, P_2O_5, K_2O kg/ha. The poor response of upland rice to increased levels of fertilizer is also reported by many scientists. Yoshida (1975) reported that restricted uptake of nutrients other than nitrogen may be a limitation for rice in aerobic soils. Belder *et al.* (2005) found relatively low uptake of nitrogen under aerobic condition compared to flooded conditions, which was reflected by the relatively low fertilizer nitrogen recovery under aerobic conditions. Teo *et al.* (1995) and Sariam (2009) found that total root length and density were significantly lower for rice grown under field capacity condition. Tanguilig *et al.* (1987) and Fageria *et al.* (2014) reported reduced nutrient uptake and eventually reduced growth and grain yield of rice under field capacity conditions. The unfavourable factors like moisture stress might have resulted in low root growth which in turn adversely affected nutrient uptake and plant growth.

As in case of plant height, a positive influence of irrigation on tillering of rice plant was observed. However the tiller number was not much influenced by irrigation levels at 30 DAS. This might be due to the fact that the crop was not in the maximum tillering stage as Uma is a medium duration variety with 120-125 days duration which will reach maximum tillering only by 40 days of sowing. However by 60 DAS, the higher tiller number of 27.22 per hill was recorded in 125% Ep (I_3) irrigation regime. Here also unfavourable effect of moisture stress on tillering of rice plant was observed with reduction in tiller count to the tune of 4 numbers per hill in 75% Ep (I_1) irrigation compared to 125% Ep (I_3) irrigation. Kahlown *et al.* (2007) and Murthy *et al.* (2012) also reported reduction in tiller count of rice with lower irrigation regime.

A drastic reduction in tiller count to the tune of almost 10 numbers per hill from 60 DAS to harvest stage was observed in 75% Ep (I_1) and 100% Ep (I_2) irrigation whereas in I_3 tiller number increased from 27.22/hill to 30.89/hill from 60 DAS to harvest. This data shows that moisture stress have more pronounced effect on tiller count towards the maturity phase of rice probably due to the fact that the water requirement is high as crop growth advances. Though the plants produced almost 24 tillers per hill, most of the tillers were dried as there was no sufficient water to sustain growth and produce panicle. Islam *et al.* (2005), Zubaer *et al.* (2007) and Bakul *et al.* (2009) also reported reduction in tiller number of rice under moisture stress condition. Davatgar *et al.* (2009) reported that the severe water stress at mid tillering reduced plant height and number of panicle per hill and delayed flowering. Moisture stress at tillering reduced the number of tillers and panicles/hill and also increased the mortality of productive tillers (Lu *et al.*, 2002). Data on tiller count at 60 DAS and at harvest under life saving irrigation clearly indicates this fact. Though the tiller count increased from 16.11 to 19.78/hill from 30 to 60 DAS, it declined to 8.22/hill at harvest stage. This also shows that in the initial stage upto 30 DAS, the crop is not very sensitive to moisture stress with respect to tillering probably because the crop water requirement is low in the initial growth stages which might have contributed by soil moisture storage also. Aryal (2012) also reported that crop water requirement was low in initial growth stages and more water required with the increase in days after planting and successive developmental stages of rice

Influence of fertilizer levels on tiller number could be observed only at 60 DAS where maximum tiller number of 22.91/hill was recorded in higher fertilizer 90:45:45 N, P_2O_5, K_2O kg/ha. Comparing different growth stages of rice, it was found that though tiller number increased from 30 to 60 DAS, it declined from 60 DAS to harvest. Similar result was also reported by Anila (2014).

Interaction between irrigation and fertilizer level was not significant on plant growth parameters. Contradictory to this, Vanitha and Mohandass (2014) reported that drip fertigation scheduled at 125% PE with 100% recommended dose of fertilizer was superior for most of the crop growth parameters.

5.2 YIELD ATTRIBUTES

Number of productive tillers/hill is one of the most important yield determinant in rice. It was found that panicle number per hill was significantly influenced by irrigation as evident from 8.12 panicles/hill in moisture stressed plants which received only life saving irrigation to 18.23 panicles/hill in plants which received irrigation at the rate of 125% Ep (I_3). Comparison of three different irrigation levels also shows that panicle number is greatly influenced by levels of irrigation. The increase in irrigation from 75% to 125% Ep resulted in 56 per cent increase in panicle number where as increase in irrigation from 75% to 100% Ep resulted in only 16 per cent increase in panicle number. This clearly shows that crop water requirement was not met even with 100% Ep irrigation.

A comparison of tiller number and panicle number also points to this fact. In I_3 *ie*., 125% Ep, of the 30.89 tillers only 18.23 tillers were productive, probably due to deficit in moisture to meet crop demand towards the last phase of crop growth period. Kumar *et al.* (2006) and Shekara *et al.* (2011) also reported that in rice the productive tiller number is influenced by moisture supply. A close examination of data further shows that at 75% and 100% Ep irrigation levels, there was not much difference between total tiller and productive tillers. This was due to the fact that in these two treatments the crop experienced moisture stress, much earlier which resulted in death of a considerable number of tillers before anthesis and heading stage.

In the present study, the grains per panicle varied from 56.22 to 78.89 and significant influence of irrigation was observed in this parameter also. The plants which received life saving irrigation recorded comparable number of grains per panicle as that of plants which received 75% Ep irrigation regime due to the fact that these two treatments experienced moisture stress. It can be inferred that in rice number of panicles per hill as well as number of grains per panicle is greatly influenced by moisture stress. Similar results were also reported by Maheswari *et al.* (2007). Vanitha and Mohandass (2014) reported that spikelet number per unit area reduced with deficit and excess water availability situations (13.2 and 5.7% in 100 and 150% PE levels respectively as against 125% PE). Rahman *et al.* (2002) reported decrease in number of panicles per hill and filled grains per panicle due to the moisture stress occurred at critical growth stages of booting, flowering and grain filling.

In the case of percentage of unfilled grains, life saving irrigation as well as higher level of irrigation recorded statistically comparable values. Of the total number of grains about 30% was chaff. This again points to severe moisture stress experienced by the crop even under 125% Ep irrigation similar to the crop under life saving irrigation. The chaff percentage increased with increase in levels of irrigation from 75% Ep to 125% Ep, as there was an increase in number of grains per panicle also. However the data indicate that there is slight increase in panicle number per hill as well as grains per panicle with increase in fertilizer level and a decrease in chaff percentage.

Contradictory to the above parameters, the test weight of grain did not show any statistically significant variation with respect to irrigation level. These are in conformity with the findings of Westcott and Vines (1986), Patel *et al.* (2010) and Karim *et al.* (2014). Probably because it is a varietal character determined by genetic makeup and is not much altered by environmental factors. However contradictory to this, Guidice *et al.* (1974), McCauley (1990), Narolia *et al.* (2014), Parthasarathi and Mohandass (2014) and Vanitha and Mohandass (2014) reported that irrigation regime had significant effect on thousand grain weight of rice under microirrigation. However in the present study test weight of variety Uma was on an average 21.46g which is lower than the standard test weight of 25g reported for the variety under wetland condition. This might be due to the moisture stress experienced by the crop as well as other climatic parameters compared to wetland condition. Similar results of reduction in thousand grain weight due to moisture stress were also reported by Nieuwenhuis *et al.* (2002) and Shao *et al.* (2004).

The study indicates that nutrient levels do not influence yield attributes of upland rice. This is probably due to the fact that the crop experienced moisture stress. Soil moisture status is a major deciding factor of nutrient use efficiency of crop and in the present study, the irrigation levels tried were probably not sufficient to meet crop demands and hence no response to applied fertilizers could be observed. Similar results were also reported by Aragon *et al.* (1984).

The interaction between irrigation and fertilizer levels was not significant with respect to all yield attributes due to the fact that fertilizer levels failed to show any significant influence due to moisture stress experienced by the crop throughout the growth phases.

5.3 GRAIN AND STRAW YIELD

The grain and straw yield of sprinkler irrigated upland rice showed an increasing trend with increase in irrigation level. The lower grain and straw yield were recorded in plots which received life saving irrigation. This was 36 per cent lower than yield under 125% Ep (I_3) irrigation. This resulted from the lower values of yield attributes registered in this treatment. The reduction in productive tiller count compared to 125% Ep (I_3) was 10 numbers/hill. Several authors like Kahlown *et al.* (2007), Narolia *et al.* (2014) and Vanitha and Mohandass (2014) reported decrease in grain and straw yield of aerobic rice under lower level of irrigation water supplied through sprinkler or drip. Pirdashti *et al.* (2004) also reported reduction in grain yield of rice by 21, 50 and 21 per cent on an average when moisture stress occurred during vegetative, flowering and grain filling stages respectively in comparison to control.

The severe moisture stress experienced by the crop would have adversely influenced the yield attributes and ultimately the yield. The moisture stress adversely affected growth parameters like plant height and tiller number and this led to reduction in straw yield. The effect of moisture stress on plant vegetative growth is well documented by Islam and Gretzmacher (2001). Supply of 75% Ep (I_1) irrigation water also resulted in considerable reduction in grain and straw yield. The reduction in grain yield was 420 kg/ha and straw yield was 1350 kg/ha over 125% Ep (I_3). It is evident from the data on growth and yield parameters that supply of even 100% Ep (I_2) was insufficient to meet the crop demand. The reduction in grain yield in 100% Ep (I_2) irrigation was 360 kg/ha and straw yield was 770 kg/ha over 125% Ep (I_3) irrigation. It can be seen that even under 125% Ep (I_3), the yield was only 3.2 t/ha which is very low compared to yield potential of high yielding varieties. This resulted from the reduction in yield attributes like number of productive tillers, grains/panicle and chaff percentage as well as test weight of grains. Similar results were also reported by De Datta *et al.* (1973). The unfavourable effect of moisture stress on yield parameters of rice was reported by many scientists. Suriyan *et al.* (2010)

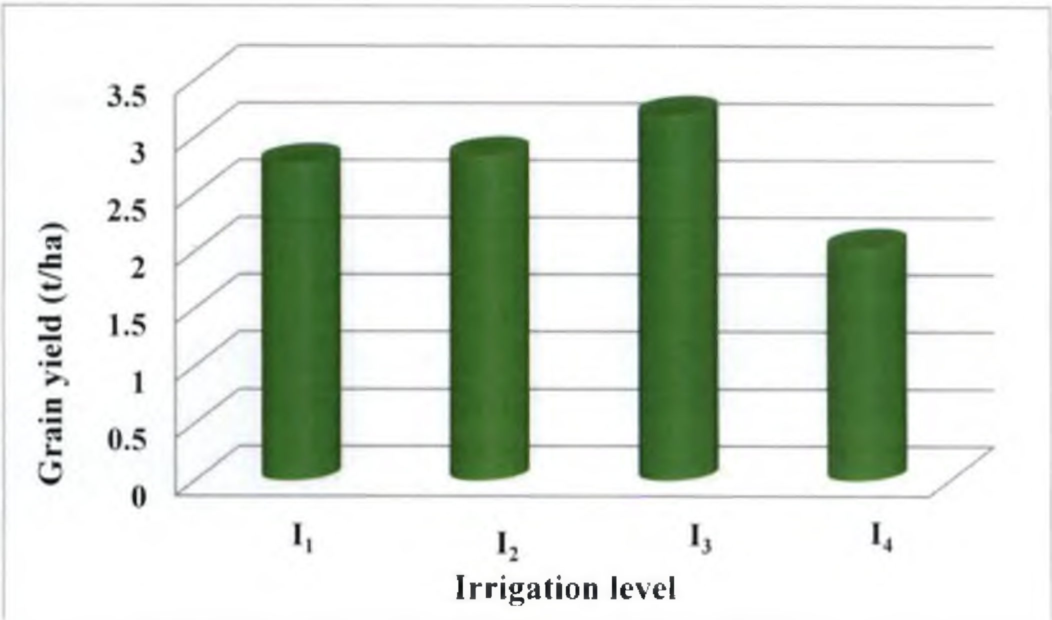

Fig. 6. Grain yield of rice as influenced by irrigation levels

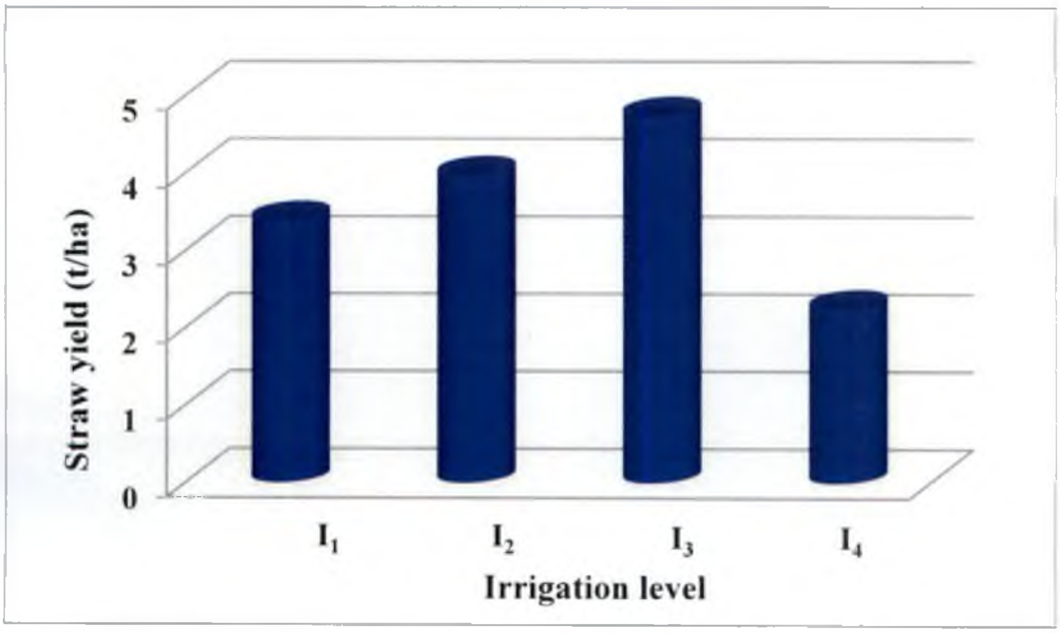

Fig. 7. Straw yield of rice as influenced by irrigation levels

reported that the number of fertile grains, total number of grains and 1000 grain weight significantly decreased when plants were subjected to mild water stress under aerobic condition. According to Jongdee *et al.* (2002), the stress during milk stage can led to increase in unfilled grains which resulted in 40 per cent yield reduction in rice. Reduced photosynthates production because of stomatal closure and early senescence (Singh and Wilkens, 1999) and the biochemical and physiological changes occurred during panicle initiation and grain filling leads to abnormalities in gamete formation (Namuco and OToole, 1986) which ultimately affect grain development processes. Here also an increase in chaff percentage was noticed which can be attributed to unfavourable factors which affected the physiological processes.

The harvest index was 0.40 under 125% Ep which is below the standard value under favourable condition. This resulted from low grain yield compared to straw yield. Hence it can be assumed that the moisture supply was sufficient for vegetative growth and at later phases the plant experienced stress which affected the grain yield. The crop water requirement of rice is low at the seedling stage and increase up to the reproductive stage because plant consumes large quantity of water at this stage and hence moisture stress at this stage increased panicle sterility and adversely affected heading and flowering (Nanda and Agrawal, 2006). The increase in percentage of unfilled grains also indicates the insufficient water supply at grain filling stage. The unfavourable climatic factors like temperature also might have influenced grain filling as the mean temperature during grain filling was 29.5°C at Vellanikkara whereas the optimum temperature for grain filling in rice is 24°C (Subramanyam, 2015).

5.4. NUTRIENT CONTENT OF RICE

The content of major nutrients was estimated at 30 and 60 DAS. The data are presented in Table 10. N and K content in rice were found to be not altered with irrigation levels at 30 DAS. However in the case of P, the higher and statistically

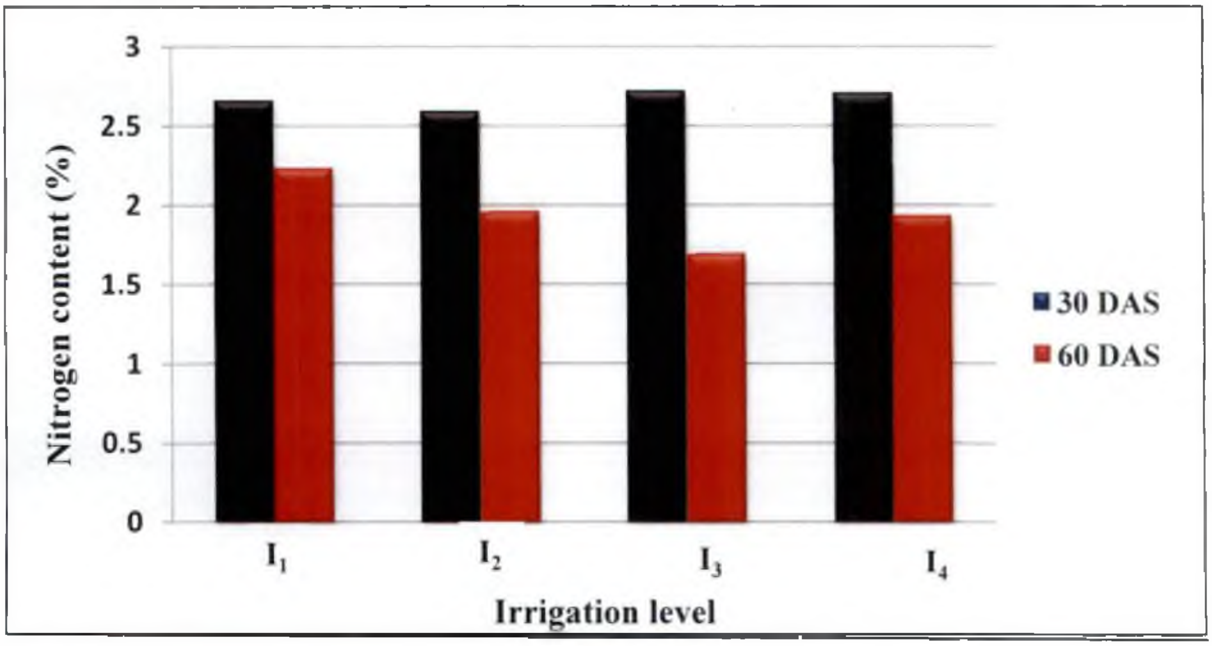

Fig. 8. Nitrogen content of rice at 30 and 60 DAS as influenced by irrigation levels

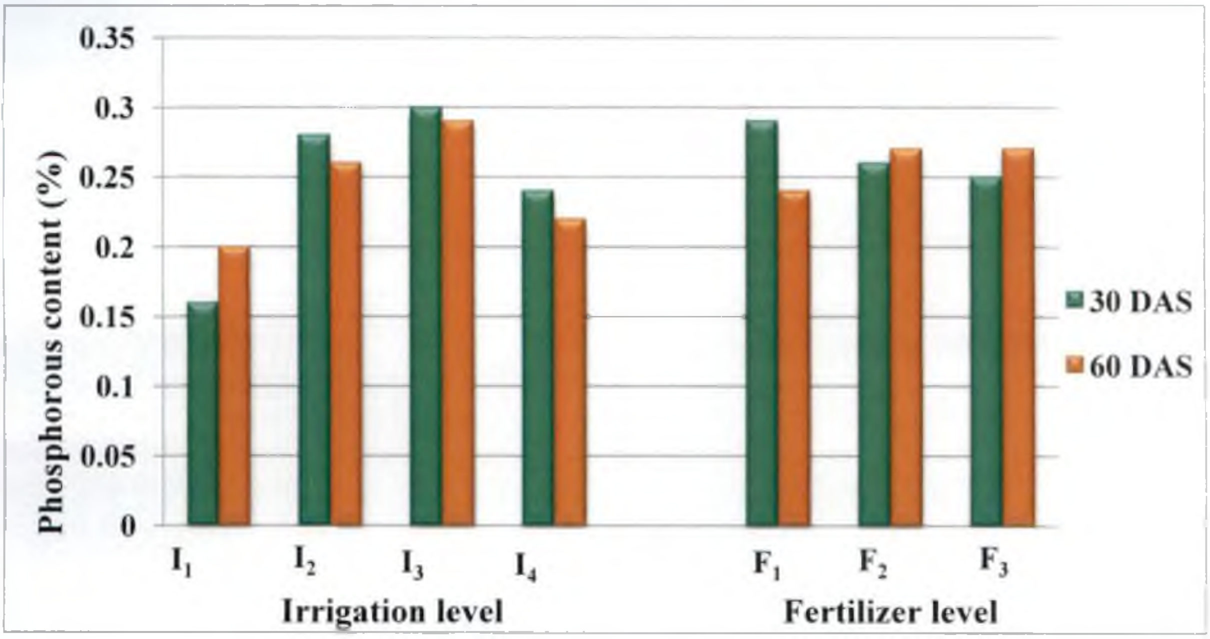

Fig. 9. Phosphorus content of rice at 30 and 60 DAS as influenced by irrigation and fertilizer levels

superior content was registered for 125% Ep irrigation (I_3) and the content showed an increasing trend with increase in irrigation level from 75% Ep to 125% Ep (from 0.16 to 0.30 per cent).

The content of all the three major nutrients in plant tissues showed a declining trend from 30 DAS to 60 DAS. The average N content decreased from 2.49 to 2.13 per cent. However the P content remained more or less the constant. The effect of irrigation level on K content was not significant where N and P content varied with irrigation water supplied. However no definite trend could be observed. In general, nutrient contents was low in 75% Ep (I_1) irrigation probably because of low absorption of nutrients due to moisture stress and resultant poor plant growth as evident from low value of growth parameters like plant height and tiller number. It was found that nutrient content in rice plant was not influenced by levels of fertilizer nitrogen at 30 and 60 DAS though the levels varied from 60 to 90 kg N/ha. This may be probably due low efficiency of applied nutrients under upland condition as reported by Fageria (2001) and Kishor *et al.* (2008). A close examination of data indicates that moisture stress resulted in increased content of N. For example, at 60 DAS higher N contents were observed in 75% Ep (2.23 per cent) and life saving irrigation (1.93 per cent) and the lower in treatment I_3 which received 125% Ep irrigation. A negative correlation between plant N content and moisture availability is also reported by Reddy (2013) in maize.

Data on the P content in rice plant at 30 and 60 DAS shown that at 30 DAS higher P content was in plants which received higher doses of P probably due to the fact that the plant absorption from basally applied P was high during initial stages.

The K content in rice plant at 30 DAS was found to be not altered by fertilizer levels. But as plant growth advanced, higher contents were recorded in plots which received higher doses.

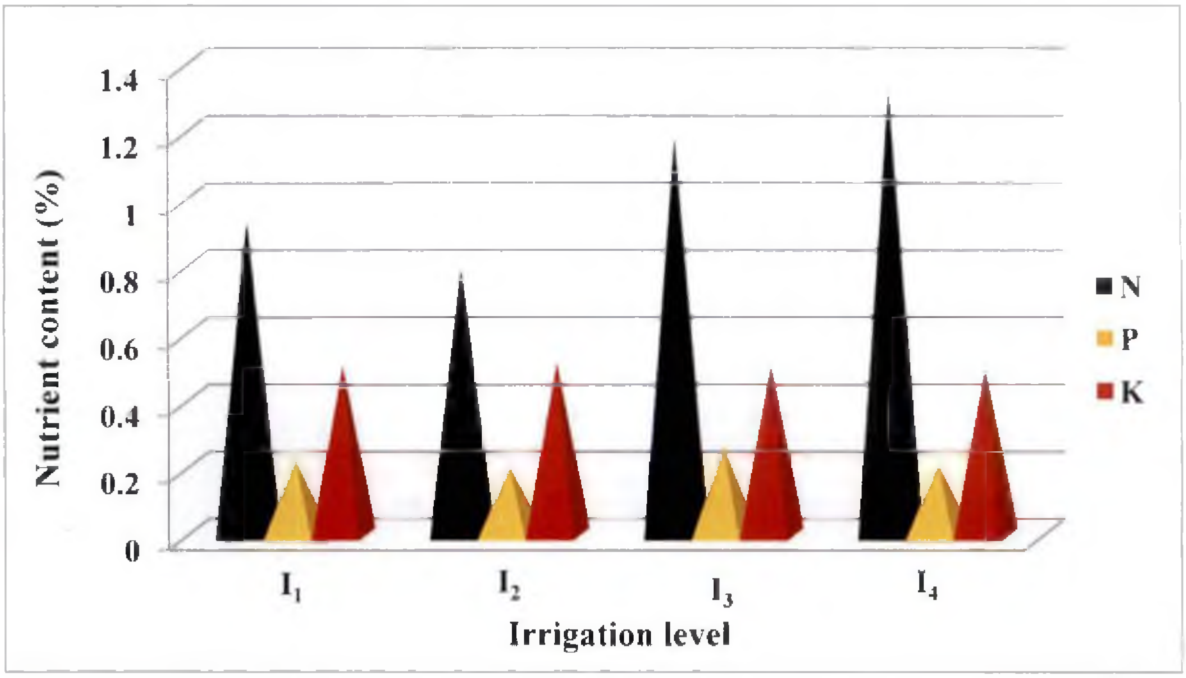

Fig. 10. Nutrient content of grain as influenced by irrigation levels

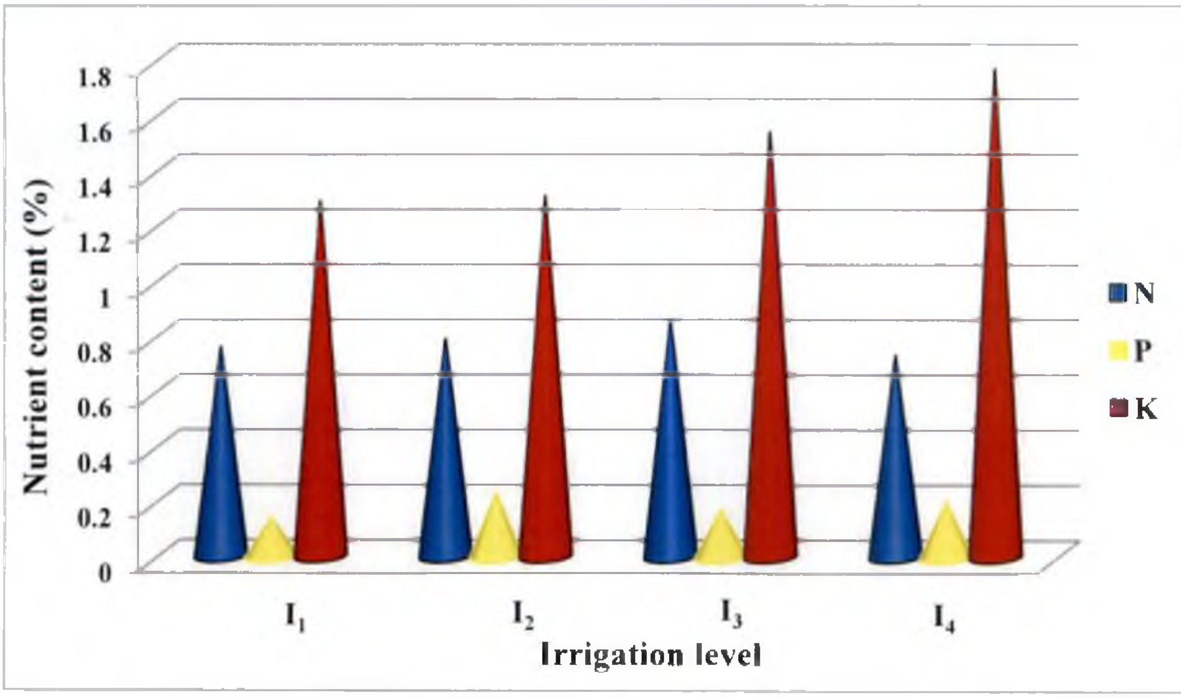

Fig. 11. Nutrient content of straw as influenced by irrigation levels

The N, P and K content in grain was 1.16, 0.22 and 1.48 per cent respectively. The corresponding values for straw were 0.79, 0.19 and 1.48 per cent. It was found that N and P content in rice grain are altered by moisture regime whereas K content is not influenced.

Regarding N, P and K content of straw, it can be inferred that N content is not influenced by moisture regime, probably due to translocation of N to grains towards maturity phase and resultant low content in straw. An opposite trend was seen with respect to P and K content in straw which varied with irrigation levels. The higher K content of 1.77 per cent was registered in plants which received life saving irrigation. These are corroborated with the findings of Singh (1975) who reported higher levels of K in plant under moisture stress. The poor fertilizer response of rice under upland condition is reported by many workers and this may be the reason for comparable nutrient content in rice plant at various fertilizer levels at different growth stages.

5.5 DRY MATTER PRODUCTION OF RICE

The results of the study reveal that irrigation regime have significant influence on dry matter production of rice. It could be seen that there exist a linear relationship between irrigation levels and dry matter production which increased up to the irrigation level of 125% Ep. The increase in irrigation from 75 to 125% Ep resulted in 23 per cent increase in dry matter production whereas increase in irrigation from 75 to 100% Ep resulted in only 8.5 per cent increase. Low dry matter production under life saving irrigation might be due to the severe moisture stress experienced by the crop. Higher dry matter production of rice under higher levels of irrigation might be due to the availability of sufficient quantity of water which in turn resulted in higher nutrient uptake and growth rate. High dry matter production of aerobic ice under high levels of irrigation is also reported by Aragon and De Datta (1982) and Shekara *et al.* (2011).

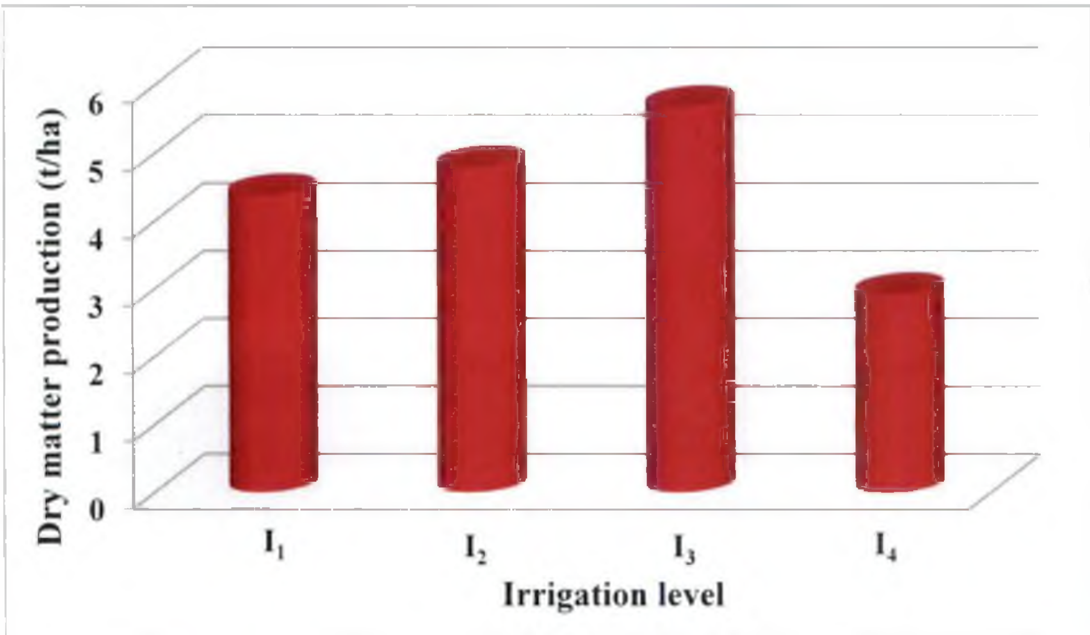

Fig. 12. Dry matter production of rice at harvest as influenced by irrigation levels

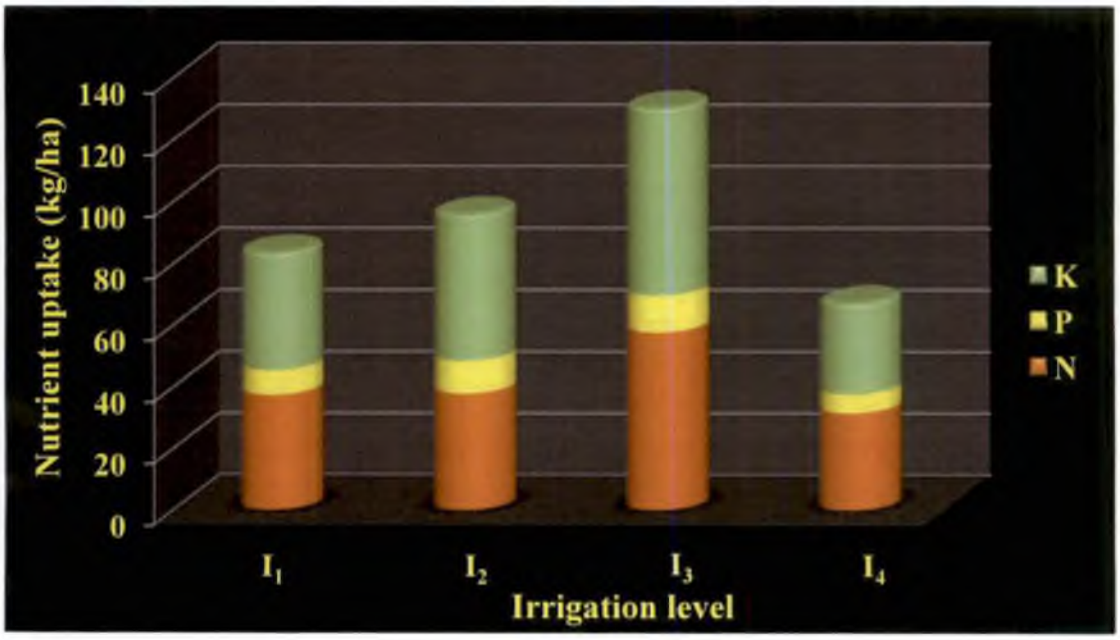

Fig. 13. Nutrient uptake by rice at harvest as influenced by irrigation levels

The effect of fertilizer levels on dry matter production of rice was also found to be significant. Higher dry matter production of rice under higher fertilizer level might be due to the higher uptake of nutrients. The fertilizer dose of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) recorded comparable dry matter production probably due to the fact that the fertilizer response of upland rice is poor. Though the variety tried was Uma which is a medium duration variety with yield of 5 to 6 t/ha under wetland condition (Devika *et al.*, 2004), in the present trail under upland condition the maximum yield registered was only 3.2 t/ha. This itself indicate that the conditions were not favourable for expression of maximum or even average production potential. It can be seen that the dry matter production recorded under 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) were comparable under the irrigation level of 125% Ep which also points to poor fertilizer response of variety even under the higher irrigation regime tried.

Regarding the partitioning of dry matter it was observed that high moisture level favored vegetative growth as evident from low Harvest Index (HI) of 0.40 recorded under 125% Ep followed by 0.42 in 100% Ep. The higher HI of 0.47 under life saving irrigation even with the lower dry matter production of 2.93 t/ha was due to low straw yield as well as grain yield. Regarding partitioning of photosynthates, it can be inferred that moisture stress favoured translocation of photosynthates to grain. Howell and Hiler (1975) and Boyer and McPherson (1976) also reported higher yield of various cereals under reproductive period stress when a prior stress occurred during the vegetative period. As in the case of life saving irrigation, plants under irrigation at 75% Ep of pan evaporation also experienced moisture stress and in this case also the HI was high (0.45), which again points to partitioning of photosynthates favouring grain yield under moisture stress condition.

5.6. NUTRIENT UPTAKE

The plant uptake of nutrients is influenced by all the factors which influence the growth of plant. In the present study significant influence of irrigation regime on NPK uptake by rice was observed. The N uptake increased by 35 per cent by increasing irrigation level from 75 to 125% Ep. The corresponding values for P and K were 33 and 37 per cent respectively. It can be seen that there is an increase in plant dry matter production to the tune of 23 per cent due to increase in irrigation level from 75 to 125% Ep. Hence the increased uptake of nutrients under higher moisture regimes can be attributed to increased dry matter production together with more absorption of nutrients by plants due to favourable growth conditions and availability of nutrients. Higher dry matter production under higher moisture regime in maize is also reported Mallareddy and Padmaja (2014) and many other workers.

The higher uptake values of N at higher fertilizer level of 90:45:45 kg N, P_2O_5 and K_2O per hectare and higher irrigation level of 125% Ep can be attributed to higher plant dry matter production of 5.6 t/ha and higher N content under this treatment. Similar results were also reported by Brown *et al.* (1960), Mahajan *et al.* (2011) and Kaur and Mahal (2014). The plants under life saving irrigation as well as 75% Ep irrigation recorded least uptake values of N due to low plant dry matter production due to low availability of water and nutrients and resultant poor growth. Data on plant height and number of tillers also show that these plants were at a disadvantage.

The effect of irrigation level on P uptake was significant. The entire dose of P was supplied as bone meal as basal dose and favourable moisture condition in soil might have influenced its degradation and availability to plants. The per cent P content in plant tissue shows an increasing trend with increase in moisture regime. Comparable P uptake under P dose of 45 kg/ha and 35 kg/ha was probably due to poor P response of rice due to high P status of soil of the experimental plot (58 kg/ha). Low response to applied P in soils having high P status is reported by many workers.

Though there was no significant difference with respect to content of K in rice plant with varying irrigation or fertilizer levels, uptake varied with levels of irrigation. This is due to high dry matter production recorded at higher levels of irrigation.

The various levels of fertilizer K applied *ie.*, 45, 35 and 30 kg K_2O/ha failed to record any significant difference in K uptake by rice. It was seen that the K content in grain or straw is not influenced by levels of fertilizer K applied, though K is a nutrient which show luxury consumption. This may be due to poor fertilizer response of rice under aerobic situation together with other unfavourable conditions like moisture stress experienced by the crop during growth (Fageria and Baligar, 2005).

5.7 FIELD WATER USE EFFICIENCY

The field water use efficiency (FWUE) was the higher for irrigation at 75% Ep. The lower field water use efficiency of 3.39 kg $ha^{-1}mm^{-1}$ was registered for crop grown under life saving irrigation. The higher water use efficiency in 75% Ep is as a result of lower quantity of irrigation water applied. Decreasing WUE with increase in levels of irrigation is also reported by Toung *et al.* (2004), Belder *et al.* (2005) and Kahlown *et al.* (2007). A comparison of total quantity of water supplied revealed that 75% Ep received the lower quantity of 305 mm. As the entire quantity was supplied through sprinkler, the wastage was less and the efficiency was high. However the yield was not high. The total quantity of water applied in 100% Ep and 125% Ep irrigation levels was 391.8mm and 516.13 mm repectively. The treatment I_2 which received 100% Ep registered efficiency of 7.25 kg $ha^{-1}mm^{-1}$ and 125% Ep registered still lower efficiency of 6.2 kg $ha^{-1}mm^{-1}$. In I_4 (life saving irrigation), quantity of irrigation water applied was 600 mm and registered the lower field water use

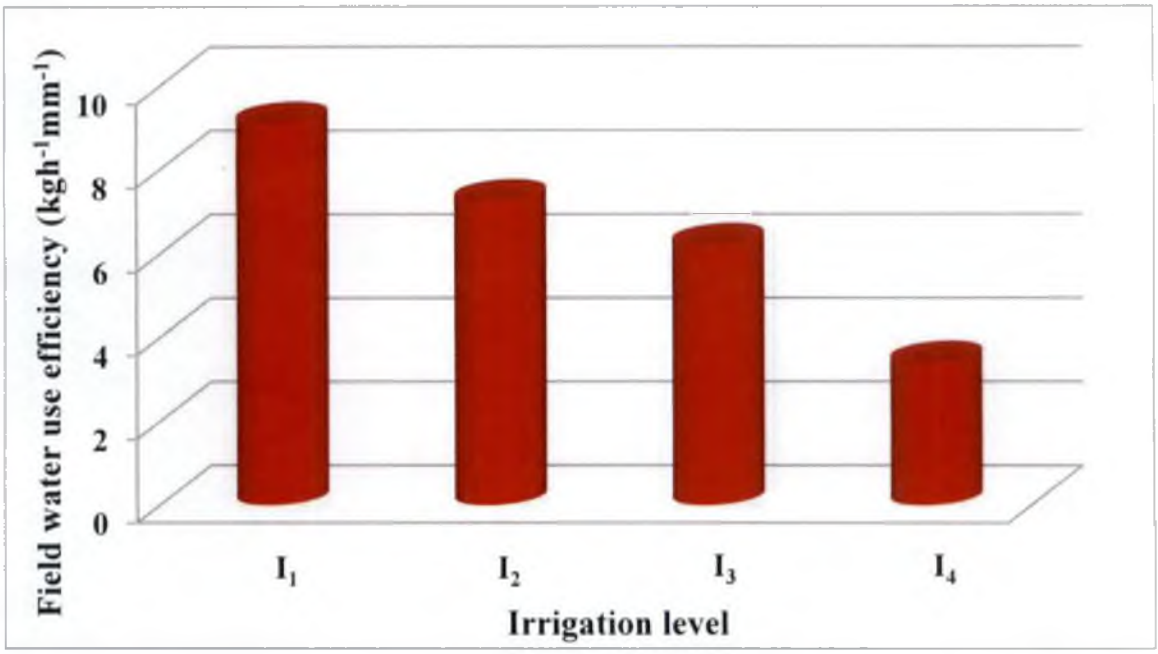

Fig. 14. Field water use efficiency of upland rice as influenced by irrigation levels

efficiency resulted from low yield as well as wastage of water by different means. As the irrigation level increased, the FWUE decreased probably due to mere evaporation losses as the crop was raised in peak summer month. The crop might have experienced temperature stress also apart from moisture stress. The microclimate of the crop field was altered due to sprinkling of water and it favoured fungal diseases on leaf sheath. Severe incidence of disease on leaf sheath also adversely affected the yield of crop and resultant low water use efficiency.

The FWUE was not significantly influenced by fertilizer levels and average FWUE was 6 kg/ha. This resulted from the lack of response to applied fertilizer in the case of upland rice.

5.8 SOIL MOISTURE CONTENT AT CRITICAL GROWTH STAGES

The data indicate that 0-15 cm soil layer was below field capacity at all stages of crop growth. This is due to the fact that soil moisture was estimated immediately before irrigation and part of available moisture was extracted by the crop during the 24hr period preceding irrigation. There was evaporation loss also. It can also be inferred that the available water was not fully depleted from the soil during the 24hr period. Even in life saving irrigation a moisture contribution of about 10% was observed which means about 50% of available water was present in soil.

The soil moisture content estimated at various stages of growth indicated that the moisture content varied with growth stages of crop. Though the variation was not very wide, the maximum moisture extraction was in milk stage probably due to the crop demand during this stage is maximum. The moisture content was lower in the surface 0-15 cm layer due to the maximum crop removal from this layer especially in early phases of growth combined with evaporative losses.

A comparison of moisture content in 15-30 cm layer at panicle initiation and milk stage also indicates the fact that at seedling stage moisture extraction is maximum from surface layer, however at milk stage there is moisture extraction from the second layer of soil also.

A comparison of average moisture percentage in different irrigation levels (*ie.*, 75% Ep to 125% Ep) shows that the moisture content was maximum in soils which received 125% Ep irrigation at all growth stages due to more quantity of irrigation water supplied. Lower soil moisture content was observed in life saving irrigation treatment which received 600mm. However in this treatment, the wastage of water was probably high due to more evaporation and percolation loss compared to sprinkler irrigation.

It can be inferred that in 125% Ep irrigation level all the soil layers were always at or above field capacity at panicle initiation stage, whereas at flowering stage moisture content was low in 0-15 cm and 15-30 cm layers due to crop removal from these two layers. Almost the same trend was seen at milk stage also in 125% Ep irrigation level.

5.9 STUDIES ON WEEDS

5.9.1 Weed density

The experimental plot was an uncultivated area occupied by seasonal upland weeds. The major plant species was the fodder grass Guinea which attained the status of weed due to its self sowing nature. However when the area was cleared for cultivation, apart from Guinea grass some dicot weeds also germinated which included *Borreria hispida, Cleome* sp., *Melochia corchorifolia* and the green manure legumes *Centrosema pubescens* and *Calopogonium mucunoides.* The presence of cover crops like *Centrosema pubescens* and *Calopogonium mucunoides* as weed is due to the fact that the area was under rubber cultivation previously. It can be seen that of the total weed flora 66 per cent was *Panicum maximum* and rest 34 per cent included various dicot weeds at 30 DAS.

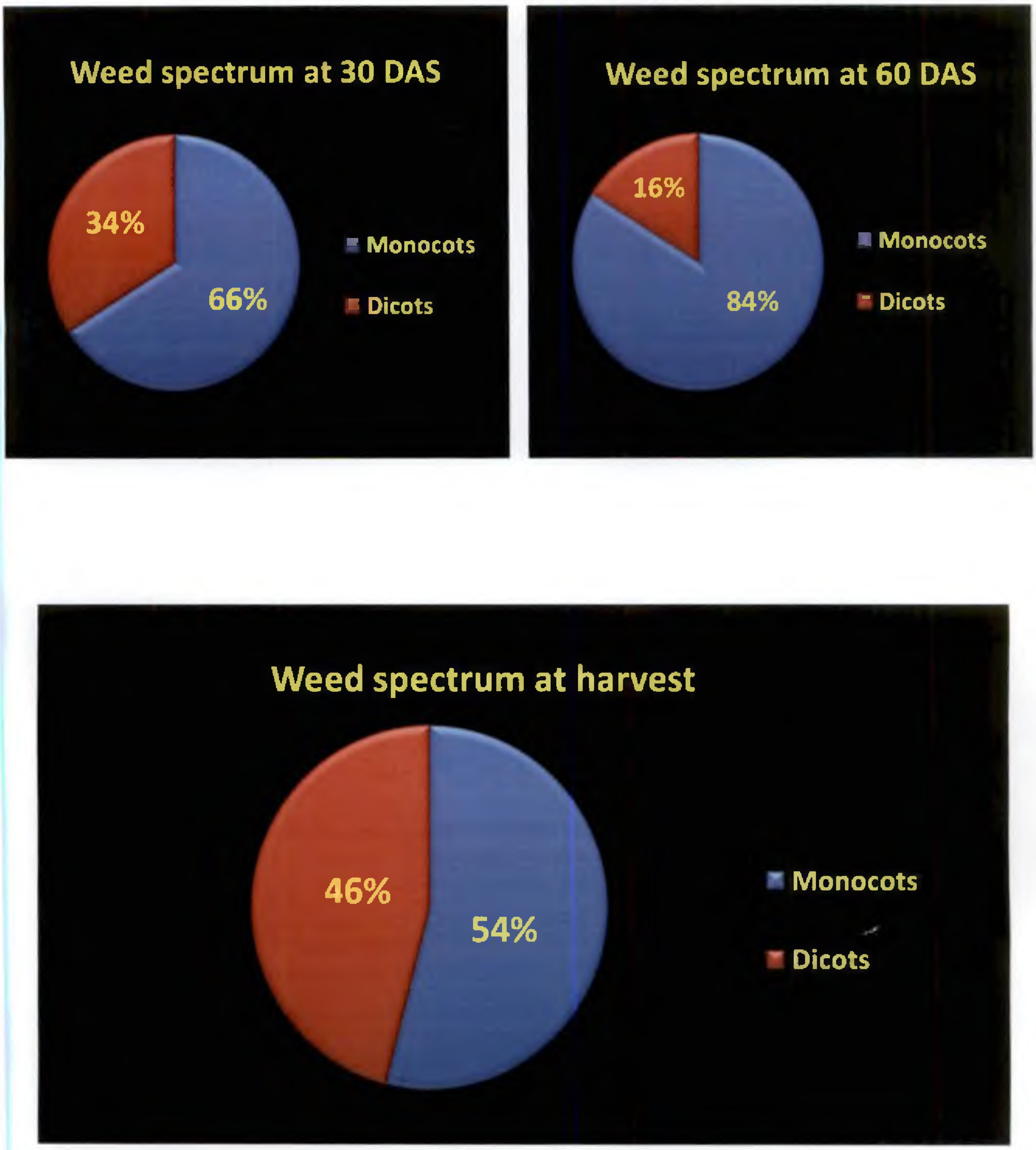

Fig. 15. Weed spectrum in the experimental plot at various stages of crop growth

A comparison of density of Guinea grass in different irrigation levels show that the density was higher (314.48/m^2) in higher irrigation regime (I_3) which was almost 56 per cent higher as compared to other irrigation levels which indicate the water loving nature of this grass species. Breveden (2013) also reported that the germination and establishment of *Digitaria eriantha* was high when moisture supply was sufficient and if more severe the water stress, then greater the reduction in germination percentage. Similar results were also reported by Pareja and Staniforth (1985). The density of Guinea in other irrigation levels varied from 146.82 to 189.68 number/m^2 and was statistically comparable probably because the moisture supply was not sufficient to induce germination of maximum number of seeds. It can also be seen that unlike the graminae species Guinea, the density of dicot weeds were minimum in higher level of irrigation (125% Ep). Of the total weed density dicots contributed 25 per cent in I_3 (125% Ep). This may be due to the high moisture status which dicots do not prefer and also due to competition from Guinea which dominated and suppressed the growth of dicots. Suria *et al.* (2011) stated that grassy weeds constituted about 80% of total weed community in aerobic rice which also indicated that when graminaceous weeds dominated, density of dicots was less. It can also be seen that by 60 days of sowing *Panicum maximum* was the only weed species found. This indicate the highly aggressive nature of this weed species which continued its germination and growth even when there was a good stand of rice.

A perusal on data on species wise count of dicot at 30 DAS showed that *Borreria hispida* was the dominant one. However its density was not influenced by irrigation or fertilizer levels. However the higher density of *Borreria hispida* (48.41 number/m^2) was recorded in the higher irrigation level compared to 21.23 number/m^2 under life saving irrigation. In the case of *Melochia corchorfolia*, significant influence of irrigation on weed density could not be observed probably because the moisture requirement of the weed is not high and even the lower level of irrigation was sufficient for it. However, effect of irrigation level on density of *Cleome* spp., *Centrosema pubescens* and *Calopogonium mucunoides* was observed with the higher density recorded under 75% Ep which again points to the low water requirement of these weed species for germination and establishment as these are typical upland species.

No significant influence of fertilizer levels on species wise weed count was observed as weeds have low nutrient requirement and are good competitors with ability to absorb nutrients from soil even if no nutrients are supplied.

By 60 DAS of rice there was a drastic reduction in weed density as the experimental plots were kept weed free with periodical manual removal of weeds. Due to this fact, no response to irrigation levels or fertilizer levels could be observed. Almost 84 per cent of weed density was constituted by *Panicum maximum.* However at the harvest stage of rice, apart from Guinea which was the dominant species, some dicots also could be observed as weeding was not undertaken towards later phases of growth of rice. On an average of the total weeds present 54 per cent was *Panicum maximum* and 46 per cent was dicot weeds. An increase in density from 60 DAS to harvest was due to subsequent germination of weed seeds from soil seed bank. Lower density of all the weed species recorded in plots given life saving irrigation was probably due to insufficient moisture supply which led to senescence of weeds which are ephimeral in nature. Though *Cleome* spp. was observed at 30 DAS, at harvest stage it could not be observed.

At harvest stage, response to moisture supply was observed in the case of *Panicum maximum* as well as total number of dicot weeds. However species wise weed count indicates only some dicots is showing response to irrigation level. It can be inferred that *Borreria hispida* is highly sensitive to moisture stress as the density was very low under life saving irrigation (3.09 number/m^2). But supply of even 75% Ep was sufficient to maintain comparable density as that in 125% Ep which indicate the plant adaptation to survive under low moisture condition upto 75% Ep. In the case of *Melochia corchorifolia* , though density was low, response to moisture level could be observed with the higher density observed under higher level of irrigation. At 30 DAS, no response to irrigation level could be observed in the case of these two weeds probably due to the fact that at 30 DAS, plant requirement of moisture as well as competition from rice plant was low.

5.9.2 Weed dry weight

Weed dry weight gives a good assessment of weed competition rather than density. Data on weed dry weight at 30 days clearly indicate that increase in moisture supply favours weed growth. Maximum dry weight of 365.28 kg/ha was observed under 125% Ep irrigation. These are in conformity with the findings of Narolia *et al.* (2014) who reported that dry weight of weeds increased significantly up to irrigation at 100% cumulative pan evaporation. It was also reported that 75% Ep, 100% Ep as well as life saving irrigation had comparable weed dry weight values probably because the variation in moisture level was not very high considering the growth stages of weeds as well as crop.

At 60 DAS and at harvest, a clear trend with respect to moisture level and weed dry weight could not be observed as hand weeding was carried out regularly.

5.10 ECONOMICS OF CULTIVATION

Analysis of economics of cultivation is an important factor deciding the feasibility of a technology. The cultivation of upland rice under varying irrigation and fertilizer level indicate that income can be maximized by optimizing irrigation as well fertilizer levels.

The variation in total cost of production was not very wide as the total cost involved in irrigation was not very high but return varied widely with change in irrigation due to difference in yield. It could be seen that maximum net return from

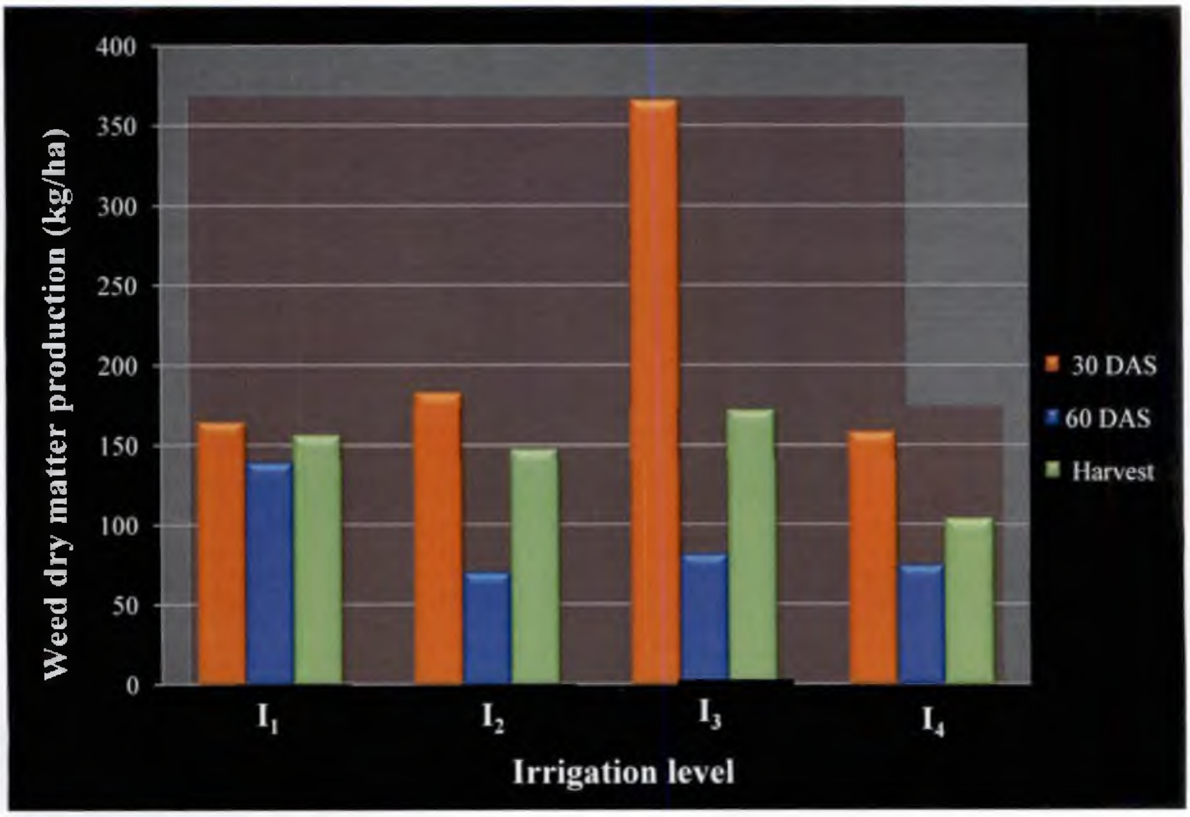

Fig. 16. Weed dry weight as influenced by irrigation levels

plots which received higher irrigation (irrigation at 125% Ep) along with lower fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3). These are in conformity with the findings of Narolia *et al.* (2014) who reported that maximum net return and benefit: cost (B: C) ratio in direct seeded rice was under irrigation applied at 150% CPE (Cumulative Pan Evaporation). This resulted from higher grain and straw yield under this treatment. In terms of gross return per hectare, 125% Ep and higher fertilizer level of 90:45:45 N, P_2O_5, K_2O kg/ha (F_1) was the best due to the fact that grain and straw yield was high. However, an increase in cost of production of Rs. 2729 per hectare due to increase in fertilizer dose compared to the lower fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) resulted in a decrease in net return. This was due to low fertilizer response of upland rice.

Supply of life saving irrigation resulted in the lower values of return as well as B: C ratio as the yield was very poor due to severe moisture stress experienced by the crop. It could be seen that if the crop is supplied with a minimum fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) merely by supplying irrigation return can be increased almost three fold. This was the trend in all fertilizer levels also, as the crop response to irrigation well whereas the response to fertilizer application was very poor as indicated by comparable yield levels under varying fertilizer levels. This data clearly indicates that for maximum return from sprinkler irrigated upland rice, an irrigation regime of 125% Ep and fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha (F_3) is ideal. In case severe water scarcity the crop may be supplied at least 75% Ep irrigation water so that net return can be enhanced considerably. Comparable values in net return in 125% Ep along with 70:35:35 N, P_2O_5, K_2O kg/ha and 125% Ep along with 60:30:30 N, P_2O_5, K_2O kg/ha also suggest that it is better to go for lower dose of fertilizer for getting maximum net return as well as B: C ratio.

FUTURE LINE OF WORK

Only one season data could be taken in the present experiment. The experiment may be repeated for two more seasons in order to confirm the results. For the present study, the high yielding rice variety Uma was used. It is preferable to use drought tolerant or aerobic rice varieties in future research and it should be studied in combination with different irrigation regimes. In the present study, it could be seen that there was a linear increase in growth parameters as well as yield and yield attributes of upland rice with increase in irrigation level. Hence further studies are needed to study the effect of higher levels of sprinkler irrigation above 125% Ep on upland rice, as the WUE can be further enhanced by drip irrigation method. So studies in this system may also be conducted. Also, there is scope for reducing fertilizer level as fertilizer use efficiency is high under sprinkler irrigation. Hence lower doses may also be tried. One problem faced in the present study was severe incidence of fungal disease sheath blight due to high humidity and leaf wetness due to daily irrigation. Hence to overcome this drip irrigation may also be tried. In order to reduce the cost of cultivation, pre-emergence and post-emergence herbicides can be tried instead of manual weeding.

SUMMARY

6. SUMMARY

Rice is the most important staple food in Asia even today and hence Asia's food security depends largely on the irrigated rice fields. The increasing scarcity of water threatens the sustainability of irrigated rice ecosystems and hence new ways must be explored to produce rice with less water. A field experiment was conducted during February to June 2014 at Instructional Farm of KAU, Vellanikkara, Thrissur to standardize irrigation and nutrient requirement of sprinkler irrigated high yielding rice variety grown in upland condition.

The experiment was laid out in split plot design with four main plots and three sub plots and replicated thrice. The treatments included four levels of irrigation; irrigation @ 75% pan evaporation (Ep) (I_1), 100% Ep (I_2), 125% Ep (I_3) and life saving irrigation (I_4) and three fertilizer levels; 90:45:45 N, P_2O_5, K_2O kg/ha (F_1), 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3). The rice variety was Uma and the plot size was 25 m^2. The soil of the experimental plot was sandy loam with a pH of 5.48 and available water holding capacity of 36%. Seeds were dibbled at a spacing of 20 cm x 10 cm and harvesting was done at 121 days after sowing.

Observations on plant height and number of tillers per hill (at 30 and 60 DAS and at harvest), yield and yield attributes like number of panicles per hill, number of grains per panicle, chaff percentage and thousand grain weight were recorded. Nutrient content and uptake by rice, soil moisture content at critical crop growth stages and field water use efficiency were also estimated. Observations on species wise weed count and weed dry matter production were recorded at 30 and 60 DAS and at harvest of the crop. Economics of production was also worked out. The present investigation came out with the following findings.

6.1 CROP GROWTH AND YIELD PARAMETERS

The results of the study indicated that levels of irrigation have significant influence on plant height and number of tillers per hill. With increase in irrigation level, plant height and tiller number increased. Throughout the growth stages, sprinkler irrigation @125% Ep registered higher values of crop growth parameters while the least values were noticed under life saving irrigation.

With regard to fertilizer level, higher plant height and tiller number were observed with 90:45:45 N, P_2O_5, K_2O kg/ha though the fertilizer levels had no significant effect on these parameters. Interaction between irrigation and fertilizer levels failed to show any significant effect on plant height and tiller number.

The number of panicles per hill, number of grains per panicle, chaff percentage, dry matter production at harvest, grain and straw yield were increased up to the irrigation level of 125% Ep. In general, irrigation schedule of 125% Ep registered higher yield and yield attributes of rice followed by irrigation at 100% Ep. There was an increase in grain and straw yield of rice with increase in levels of irrigation. The higher grain and straw yield were recorded in the irrigation schedule of 125% Ep while the lower yield was recorded under life saving irrigation. Significant differences could not be observed among fertilizer levels with regard to yield and yield attributes.

6.2 DRY MATTER PRODUCTION

There exist a linear relationship between irrigation levels and dry matter production which increased up to the irrigation level of 125%. Low dry matter production was noticed under life saving irrigation.

The effect of fertilizer levels on dry matter production of rice was also found to be significant and higher dry matter production of rice under 90:45:45 N, P_2O_5, K_2O kg/ha fertilizer level.

6.3 NUTRIENT CONTENT AND UPTAKE BY RICE

At 30 DAS, N and K content in rice were found to be not altered with irrigation levels. However P content was altered by irrigation level and significantly higher value was observed in the irrigation schedule of 125% Ep. The content of all the three major nutrients in plant tissues showed a declining trend from 30 DAS to 60 DAS. The average N content decreased from 2.49 to 2.13 per cent. However the P content remained more or less constant. The effect of irrigation level on K content was not significant where N and P content varied with irrigation water supplied. However no definite trend could be observed. In general, nutrient content was low in treatments 75% Ep (I_1) and life saving irrigation (I_4) and high content was in 125% Ep irrigation level. It was found that N and P content in rice grain were altered by moisture regime whereas K content is not influenced. N content in straw was not influenced by moisture regime. An opposite trend was seen with respect to P and K content in straw which varied with irrigation levels.

It could be seen that N content at 30 and 60 DAS and K content at 30 DAS in rice plant was not influenced by fertilizer level. However, fertilizer level showed significant influence in the case of the P content at 30 and 60 DAS and higher P content was observed in plants which received higher doses of P at 30 DAS. N, P and K content of grain was not altered by fertilizer levels. However in case of straw, fertilizer levels showed significant effect on K content and higher content was recorded with the higher fertilizer level, 90:45:45 N, P_2O_5, K_2O kg/ha.

Uptake of all the three major nutrients was higher in the plots receiving higher levels of irrigation (125% Ep) and the lower was under life saving irrigation. There were no significant differences between fertilizer levels with regard to P and K uptake, however higher fertilizer level registered higher N uptake.

6.4 MOISTURE STUDIES

A negative correlation between field water use efficiency and moisture availability was observed. Higher field water use efficiency of 9.11 kg ha^{-1} mm^{-1} was noticed in the irrigation schedule of 75% Ep (I_1) and lower in the higher level of irrigation (125% Ep).

Field water use efficiency was not significantly influenced by fertilizer levels. However, the higher fertilizer level F_1 (90:45:45 N, P_2O_5, K_2O kg/ha) registered maximum field water use efficiency.

At all the three critical growth stages of rice (panicle initiation, flowering and milk stage) soil moisture content increased with increase in irrigation level in all the three soil layers. Throughout the growth period, irrigation at 125% Ep (I_3) registered maximum soil moisture content while the lower moisture content was noticed under life saving irrigation (I_4) in all the three soil layers. In general, moisture extraction from top 0-30 cm soil layer was high as compared to other layers.

6.5 WEED DENSITY AND DRY WEIGHT

Major graminaceous weed found in the experimental plot was *Panicum maximum* (Guinea grass). Apart from Guinea grass, some dicot weeds also observed which included *Borreria hispida*, *Cleome* spp., *Melochia corchorifolia* and the green manure legumes *Centrosema pubescens* and *Calopogonium mucunoides.*

At 30 DAS, density of Guinea grass was high (314.48/m^2) in higher irrigation regime of 125% Ep (I_3). Opposite to this, the density of dicot weeds was minimum in higher level of irrigation. Among the dicots present, *Borreria hispida* was the dominant one and its density was high in the higher irrigation level. However, effect of irrigation level on density of *Cleome* spp., *Centrosema pubescens* and *Calopogonium mucunoides* was observed with the higher density recorded under 75% Ep irrigation level. At 30 DAS and at harvest, higher weed dry weight was observed under 125% Ep irrigation.

By 60 DAS of rice there was a drastic reduction in weed density as the experimental plots were kept weed free with periodical manual removal of weeds. Due to this fact, no response to irrigation levels or fertilizer levels could be observed.

6.6 ECONOMICS OF CULTIVATION

The analysis indicated that upland rice cultivation with 125% Ep irrigation and 60:30:30 N, P_2O_5, K_2O kg/ha was the best option as it resulted in the higher net return of Rs. 23728 per hectare.

6.7 CONCLUSION

It can be concluded that irrigation at 125% Ep along with 60:30:30 N, P_2O_5, K_2O kg/ha is suited for sprinkler irrigated upland rice cultivation as it gave higher yield and net returns. However, the yield of rice was low in this system as compared to that of flooded situation probably due to the moisture stress experienced by the crop even with 125% Ep irrigation.

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* Original not seen

APPENDIX I

DAILY PAN EVAPORATION DATA

Date	Evaporation (mm)	Rainfall (mm)
03.02.14	7.1	00.0
04.02.14	6.3	00.0
05.02.14	4.0	00.0
06.02.14	5.5	00.0
07.02.14	6.1	00.0
08.02.14	6.0	00.0
09.02.14	5.9	00.0
10.02.14	5.5	00.0
11.02.14	5.2	00.0
12.02.14	3.4	00.0
13.02.14	1.5	00.0
14.02.14	3.5	00.0
15.02.14	4.1	00.0
16.02.14	3.8	00.0
17.02.14	4.1	00.0
18.02.14	5.0	00.0
19.02.14	3.9	00.0
20.02.14	5.4	00.0
21.02.14	5.2	00.0
22.02.14	5.1	00.0
23.02.14	4.9	00.0
24.02.14	5.4	00.0
25.02.14	7.8	00.0
26.02.14	7.2	00.0
27.02.14	6.4	00.0
28.02.14	5.4	00.0
01.03.14	4.7	00.0
02.03.14	4.8	00.0
03.03.14	4.9	00.0
04.03.14	4.0	00.0
05.03.14	5.2	00.0
06.03.14	5.5	00.0
07.03.14	5.7	00.0
08.03.14	6.4	00.0
09.03.14	6.5	00.0
10.03.14	4	00.0

11.03.14	6.1	00.0
12.03.14	7.4	00.0
13.03.14	7.2	00.0
14.03.14	7.9	00.0
15.03.14	8.2	00.0
16.03.14	7.0	00.0
17.03.14	8.5	00.0
18.03.14	7.6	00.0
19.03.14	7.4	00.0
20.03.14	5.7	00.0
21.03.14	5.8	00.0
22.03.14	6.0	00.0
23.03.14	5.0	00.0
24.03.14	3.8	00.0
25.03.14	5.2	00.0
26.03.14	6.7	00.0
27.03.14	8.9	00.0
28.03.14	6.7	00.0
29.03.14	6.9	00.0
30.03.14	5.2	00.0
31.03.14	5.6	00.0
01.04.14	5.2	00.0
02.04.14	4.4	00.0
03.04.14	5.1	00.0
04.04.14	5.1	00.0
05.04.14	5.2	00.0
06.04.14	5.0	00.0
07.04.14	4.4	00.7
08.04.14	4.5	00.0
09.04.14	3.6	00.0
10.04.14	5.1	29.0
11.04.14	3.5	00.0
12.04.14	5.6	11.0
13.04.14	4.5	00.0
14.04.14	2.3	00.0
15.04.14	3.9	00.0
16.04.14	3.9	00.0
17.04.14	4.9	6.30
18.04.14	3.9	5.90
19.04.14	4.5	1.40
20.04.14	4.3	00.0

21.04.14	5.1	00.0
22.04.14	4.9	00.0
23.04.14	4.9	00.0
24.04.14	4.4	00.0
25.04.14	3.0	00.0
26.04.14	4.0	00.0
27.04.14	4.4	14.6
28.04.14	3.3	00.0
29.04.14	3.4	00.0
30.04.14	4.5	00.0
01.05.14	3.9	00.0
02.05.14	5.4	00.0
03.05.14	5.1	00.0
04.05.14	4.3	68.4
05.05.14	3.1	00.0
06.05.14	2.7	00.9
07.05.14	0.9	89.9
08.05.14	0.8	99.0
09.05.14	1.8	31.2
10.05.14	3.2	00.0
11.05.14	4.0	00.0
12.05.14	3.8	00.0
13.05.14	3.3	00.0
14.05.14	4.0	00.0
15.05.14	5.0	00.0
16.05.14	4.7	00.0
17.05.14	3.9	00.0
18.05.14	4.0	00.0
19.05.14	3.0	00.0
20.05.14	2.7	00.0
21.05.14	2.6	00.0
22.05.14	4.0	00.0
23.05.14	3.8	00.0
24.05.14	2.9	00.0
25.05.14	3.0	00.0
26.05.14	3.7	00.0
27.05.14	3.4	00.0
28.05.14	5.9	38.0
29.05.14	2.8	00.0
30.05.14	3.2	00.0
31.05.14	3.1	1.20

APPENDICES

APPENDIX II

DETAILS OF COST OF CULTIVATION

a) Cost of inputs per hectare

Sl No.	Inputs	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Seed	80 kg	19/kg	1520
2	FYM	5 t	600/t	3000
3	Urea			
	F_1	195.65 kg	6/kg	1174
	F_2	152.17 kg		913
	F_3	130.43 kg		783
4	Bone meal			
	F_1	225 kg		6525
	F_2	175 kg	29/kg	5075
	F_3	150 kg		4350
5	MOP			
	F_1	75.00 kg	19/kg	1425
	F_2	58.33 kg		1108
	F_3	66.67 kg		1267
6	PP chemicals	-	-	1500

b) **Cost of cultivation**

Sl No.	Particulars	Women (280/day) /Men (450/day)	Total cost (Rs.)
1	Land preparation(tractor ploughing twice) @ 600/hr	8hrs	4800
2	Application of FYM	5 women	1400
3	Sowing	40 women	11200
4	Spraying PP chemicals	4 men	1800
5	Fertilizer application and irrigation in life saving irrigation plots	8 men	3600
7	Weeding	40 women	11200
8	Harvesting and threshing	40 women	11200

c) **Cost of electricity**

Sl No.	Treatments	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	I_1 **(Sprinkler irrigation @ 75% Ep)** Electricity cost	86 units	2.9	250
2	I_2 **(Sprinkler irrigation @ 100% Ep)** Electricity cost	115 units	2.9	334
3	I_3 **(Sprinkler irrigation @ 125% Ep)** Electricity cost	143 units	2.9	415

d) **Cost of sprinkler unit** - Rs. 100000 per hectare

One tenth of the cost of the sprinkler unit is taken for calculating the B: C ratio assuming that the system will serve for 10 years

FERTIGATION IN SPRINKLER IRRIGATED UPLAND RICE (*Oryza sativa* L.)

By

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(2013-11-180)

ABSTRACT OF THE THESIS

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ABSTRACT

Upland rice cultivation is now being promoted by the Kerala government in the context of diminishing area and production of rice. Although traditionally raised as rainfed crop in the first crop season, upland rice can also be grown throughout the year, if irrigation is provided. Micro irrigation techniques are now gaining popularity because of scarcity of water and high water use efficiency. Irrigation through micro sprinklers is advantageous for upland rice. The present study was undertaken to standardize the irrigation and nutrient requirement of high yielding rice variety grown in upland situation.

The experiment was conducted at the Instructional Farm of KAU, Vellanikkara during February to June 2014. The trial was laid out in split plot design with four main plots and three subplots and replicated thrice. The treatments consisted of four levels of irrigation; irrigation @ 75% pan evaporation (Ep) (I_1), 100% pan evaporation (I_2), 125% pan evaporation (I_3) and life saving irrigation (I_4) at 5cm depth at required stages and three fertilizer levels; 90:45:45 N; P_2O_5, K_2O kg/ha (F_1), 70:35:35 N, P_2O_5, K_2O kg/ha (F_2) and 60:30:30 N, P_2O_5, K_2O kg/ha (F_3).

Biometric characters such as plant height and tiller number per hill were higher in the irrigation schedule of 125% pan evaporation at all the crop growth stages. There was no significant difference among fertilizer levels with regard to plant height and tiller number at 30 DAS and at harvest.

The quantity of irrigation water significantly influenced the yield and yield attributes of rice. The highest number of panicles per hill, filled grains per panicle, total biomass production, grain and straw yield were in the highest irrigation level of 125% pan evaporation.

Nitrogen and phosphorus contents in rice were not altered with irrigation levels at 30 DAS. The phosphorus content showed an increasing trend with increase

in irrigation level from 75% to 125% pan evaporation. At 60 DAS, the highest nitrogen content was observed in irrigation at 75% pan evaporation and the highest phosphorus content was under 125% pan evaporation. Nitrogen and phosphorus content in grains were altered by moisture regime whereas potassium content was not influenced. In straw, phosphorus and potassium contents were altered by irrigation levels and higher contents were registered in 100% pan evaporation and life saving irrigation respectively.

The uptake of all the three basic nutrients showed an increasing trend with increase in irrigation level and the highest uptake was recorded under the high irrigation level of 125% pan evaporation. Only nitrogen uptake was significantly influenced by fertilizer levels and the highest uptake was registered with a fertilizer dose of 90:45:45 N, P_2O_5, K_2O kg/ha.

Field water use efficiency showed a decreasing trend with increase in irrigation level and it was higher for crop grown under 75% pan evaporation irrigation level. The results of moisture studies indicated that rice extracted more moisture from the top 30 cm soil layer.

In general, weed density was high under sprinkler irrigation. *Panicum maximum* (Guinea grass) was the only monocot weed found in the experimental plot. *Borreria hispida, Melochia corchorifolia, Centrosema pubescens, Calopogonium mucunoides, Cleome* spp. were the dicot species. Density of monocots and weed dry weight was higher in 125% pan evaporation irrigation whereas density of dicot weeds were higher in 75% pan evaporation. Throughout the crop growth stages, weed density was not significantly influenced by fertilizer levels.

In the present study, the highest return from sprinkler irrigated upland rice was obtained with an irrigation regime of 125% pan evaporation and fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha.