IRRIGATION SCHEDULING AND LIVE MULCHING IN UPLAND RICE (*Oryza sativa* L.)

by

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(2016-11-031)

THESIS

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ii.

DECLARATION

I, hereby declare that this thesis, entitled **"IRRIGATION SCHEDULING AND LIVE MULCHING IN 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 of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

a.i.	Active ingredient
et al.	And other co workers
@	At the rate of
BCR	Benefit cost ratio
cm	Centimetre
CD	Critical difference
ETc	Crop evapotranspiration
CPE	Cumulative Pan Evaporation
DAS	Days after sowing
^oC	Degree Celsius
^oE	Degree East
^oN	Degree North
DMP	Dry matter production
dS m^{-1}	Deci Siemens per metre
ET	Evapotranspiration
FYM	Farmyard manure
Fig.	Figure
g	Gram
HI	Harvest index
ha	Hectare
IW	Irrigation water
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
m ha	Million hectare
m	Metre

Mg m^{-3}	Mega gram per cubic metre
mm	Millimetre
viz.	Namely
N	Nitrogen
NS	Non significant
No.	Number
PI	Panicle initiation
PE	Pan Evaporation
%	Per cent
ha^{-1}	Per hectare
m^{-2}	Per square metre
P_2O_5	Phosphate
K_2O	Potash
K	Potassium
RBD	Randomized Block Design
RH	Relative humidity
RLWC	Relative leaf water content
m^2	Square metre
₹	Rupees
SE	Standard error
i.e.	That is
t ha^{-1}	Tonnes per hectare
WUE	Water use efficiency
WP	Wettable powder

APPENDIX

Sl. No.	Title	Appendix No.
1	Weather parameters during the cropping period (26th May to 25th September)	1

INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa* L.) which plays an important role in supplying food to the majority of the world population is cultivated in a wide range of ecosystems. In India, out of 42.7 m ha of land under rice, about 21.9 per cent of the area is exposed to risk prone upland ecology (Mishra, 1999).

Yadav *et al*. (2011) reported that the estimated water availability for agriculture which is 83.3 per cent of total water used today will shrink to 71.6 per cent in 2025 and to 64.6 per cent in 2050. By 2025, 17 m ha of irrigated rice areas may experience "physical water scarcity" and 22 m ha may have "economic water scarcity" in Asia (Bouman and Tuong, 2001). Due to shrinking of water resources we cannot sustain even the existing level of rice production. In this context, it is necessary to enhance water productivity of rice especially for upland rice cultivation which is becoming popular.

Upland rice cultivation is a resource conservation technology as it requires less irrigation and labour and is amenable for mechanization. Cultivation of upland rice in Kerala is also known as modan cultivation. It accounts to 13.4 % of the total rice area and average productivity is in the range of 1000 to 1500 kg ha^{-1} (Kumari *et al*., 2011). The total area under rice cultivation decreased from 8.50 lakh ha to 1.99 lakh ha over the last three decades (FIB, 2017).

The major abiotic stress in upland rice is moisture and soil moisture stress during critical periods of tillering, panicle initiation, flowering and grain filling can adversely affect the growth and yield of upland rice. Soil moisture plays a key role in rice production and it affects the plant development by influencing its vital physiological and biochemical processes and nutrient uptake. Water should be used efficiently and judiciously not only for getting higher yield but also for higher water use efficiency, thereby water requirement can be reduced and additional area can be brought under irrigation.Therefore an optimum irrigation schedule with suitable depth and time of application has to be developed for obtaining higher yield and water use efficiency.

In upland rice, the major way of soil moisture depletion is by evaporation. Mulching is a potential method for efficient water use in upland rice cultivation. Live mulching with legumes is a beneficial practice for enhanced moisture conservation and is found to be benefiting both short and long term productivity of crops by improving soil physical properties, reducing runoff and erosion, suppressing weeds and transferring symbiotically fixed N to the crop. *In situ* green manuring with cowpea and its subsequent incorporation into the soil is found to reduce evaporation, improve soil fertility, add organic matter, improve water holding capacity of the soil and there by improves the sustainability and water productivity of upland rice ecosystem.

Studies on the combined effect of water management practices and mulching on the productivity of upland rice are limited. There is a scope for increasing upland rice production through a proper irrigation schedule in combination with *in situ* moisture conservation by live mulching with cowpea. Hence the present study entitled "Irrigation scheduling and live mulching in upland rice (*Oryza sativa* L.)" was undertaken with the following objectives

- To standardize the irrigation schedule for economizing water use
- To study the effect of live mulching with cowpea on growth and yield of upland rice
- To work out the economics of cultivation

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Upland rice is mainly grown as a rainfed crop in the first crop season of Kerala. Frequent monsoon failure has created moisture stress in soil which has an adverse effect on growth and yield of upland rice. Studies on irrigation scheduling and moisture conservation strategies like live mulching with cowpea are limited. Therefore the present study is envisaged to develop an optimum irrigation schedule in combination with moisture conservation strategies like live mulching. Attempts have been made to review the important research works on irrigation scheduling and mulching on growth characters, yield attributes, grain yield, straw yield, nutrient uptake, physiological parameters, root characters, soil moisture studies, weed dry weight and soil properties.

2.1 INFLUENCE OF IRRIGATION

Proper irrigation scheduling is crucial for efficient water management in crop production; especially under water scarcity conditions (Zeng *et al.*, 2009).

2.1.1 Growth Characters

Thomas (2000) in studies on upland rice obtained taller plants at frequent irrigations with an IW/CPE of 1.5. Maheswari *et al.* (2007) reported that higher plant height was produced at IW/CPE of 1.2 in aerobic rice. The severe water stress at mid-tillering stage significantly reduced the plant height and the number of panicle hill^{-1} and delayed flowering in semi dwarf rice (Davatgar *et al.*, 2009). Irrigation application at IW/CPE ratio of 1.5 up to PI and 2.0 from PI to harvesting recorded 74.1 cm plant height which was significantly higher compared to IW/CPE ratio of 1.0 up to PI and 1.5 from PI to harvesting in aerobic rice (Malamasuri *et al.*, 2014). Choudhary (2016) reported that scheduling of irrigation in direct seeded basmati rice at 2 days interval through sprinkler at 150 % PE produced taller plants compared to other irrigation treatments. Jolly (2016) obtained taller plants at irrigation provided with IW/CPE of 1.2 compared to IW/CPE of 0.6 in upland rice.

Moisture stress has a pronounced effect on tiller number. Shahanila (2015) opined that irrigation at 125 % PE recorded higher number of tillers hill^{-1} compared with 100 % PE, 75 % PE and life saving irrigation in upland rice. Choudhary (2016) reported the favourable influence of irrigation on tiller production and obtained higher tiller number m^{-2} at irrigation given at 2 days interval through sprinkler at 150 % PE. Higher number of tillers was recorded in the treatment irrigation at IW/CPE of 1.2 compared to other IW/CPE ratios of 0.6, 0.8 and 1.0 (Jolly, 2016).

Leaf area index is an important parameter which determines the capacity of the plants to trap solar energy for photosynthesis. Maheswari *et al*. (2008) reported that irrigation at IW/CPE of 1.2 recorded higher leaf area index in aerobic rice. Akinbile and Sangodoyin (2011) pointed out that LAI was higher in the treatment receiving water daily at full irrigation capacity (100 % ET) and the lowest in the treatment receiving water four days in a week at low irrigation capacity (25 % ET). According to Jolly (2016) higher leaf area index was recorded by irrigation at IW/CPE of 1.2 which was significantly superior to IW/CPE ratios of 0.6, 0.8 and 1.0 in upland rice.

Dry matter accumulation is an important index indicating the photosynthetic efficiency of the crop which ultimately influences the crop yield. It is a direct index of plant proliferation. According to Thomas (2000) irrigation at IW/CPE of 1.5 registered the highest dry matter production compared to IW/CPE of 1.0 and rainfed control. Choudhary (2016) reported that dry matter accumulation varied significantly in response to irrigation schedule and obtained high DMP at all irrigation schedules except rainfed control. Higher dry matter production was recorded by the treatment irrigation at IW/CPE of 1.2 compared to IW/CPE ratios of 0.6, 0.8 and 1.0 (Jolly, 2016).

2.1.2 Yield Attributes and Yield

Irrigation at IW/CPE of 2.5 recorded significantly higher number of productive tillers hill^{-1}, filled spikelets and thousand grain weight in aerobic rice (Shekara *et al*., 2010). Narolia *et al*. (2014) revealed that irrigation at 100 % CPE resulted in significantly higher panicle length and weight, filled spikelets panicle^{-1} and test weight compared to irrigation at 75 % and 100 % CPE in direct seeded rice. Higher number of panicles hill^{-1} was produced when irrigation was scheduled at 125 % PE in upland rice (Shahanila, 2015). The number of filled spikelets was higher in treatments receiving frequent irrigations compared to wider irrigation treatments in upland rice (Jolly, 2016).

Grain yield is a function of various growth and yield attributing parameters like dry matter accumulation, effective tillers, panicle length, number of grains panicle^{-1} and thousand grain weight. It is the most important parameter to compare effectiveness of different treatments. Higher straw yield was recorded at irrigation given at IW/CPE of 2.0 compared to IW/CPE ratios of 1.5 and 1.0 in upland rice (Ramamoorthy *et al.*, 1998).Thomas (2000) reported that grain yield was reduced due to moisture stress experienced at different growth stages mostly during the reproductive phase and obtained highest grain and straw yields at IW/CPE of 1.2. It was found that irrigation at 2 days interval recorded significantly higher yield compared to 3 days interval due to significantly higher values of effective tillers and number of grains panicle^{-1} (Gill and Singh, 2008). Shekara *et al.* (2010) opined that the irrigation scheduled at IW/CPE ratio of 2.5 recorded higher grain yield of 6.21 t ha $^{-1}$ and 6.58 t ha $^{-1}$ in direct seeded rice during first and second years respectively as compared to IW/CPE of 1.0. Studies in aerobic rice by Malamasuri *et al.* (2014) revealed higher grain yield with irrigation scheduled at IW/CPE ratio of 1.5 up to PI and 2.0 from PI to harvesting. As reported by Narolia *et al.* (2014) maximum grain and straw yields were obtained with irrigation at 150 % CPE. Irrigation at 2 days interval gave significantly higher yield compared to 3 days interval (Kaur, 2015). Jolly (2016) obtained the highest grain and straw yields for irrigation scheduled at IW/CPE ratio of 1.2 compared to other IW/CPE ratios of 0.6, 0.8 and 1.0. Joshi (2016) found that continuous submergence with 2.5 cm water depth throughout the crop period gave good yield as compared to 5 cm depth of irrigation in upland rice.

Thomas (2000) obtained higher HI at irrigation given with IW/CPE of 1.5 compared to IW/CPE of 1.0 and rainfed control. Water stress at flowering and grain filling periods were crucial and stress during these periods significantly lowered HI compared to stress during tillering stage in rice (Sokoto and Muhammad, 2014).

2.1.3 Physiological and chemical estimation

Ramakrishnayya and Murthy (1991) reported that relative leaf water content and leaf water potential were reduced in rice subjected to moisture stress. There was a 50 % reduction in RLWC on exposure to moisture stress in upland rice (Das *et al.*, 2000).

Sheela (1993) opined that upland and drought tolerant varieties of rice recorded more proline content than the susceptible ones under rainfed low land conditions. Accumulation of proline enhances drought tolerance (Vajrabhaya *et al.*, 2001). Maheswari *et al.* (2008) observed increased proline content with decreased soil moisture level in aerobic rice. Proline accumulation in the leaves of water-deficit stressed plants may play a role as a stress indicator (Cha-um *et al.*, 2010). Jinsy (2014) studied the effect of aerobic rice varieties on proline accumulation and found that drought tolerant varieties accumulated more proline than susceptible varieties.

Chlorophyll content increased significantly under irrigation and was the highest at IW/CPE ratio of 1.2 followed by IW/CPE ratios of 1.0, 0.8 and micro sprinkler irrigation in aerobic rice (Maheswari *et al.*, 2008).

N uptake by both grain and straw increased with increasing IW/CPE ratios and was higher at IW/CPE of 1.6 compared to 0.8 and 1.2 (Jadhav and Dahiphale, 2005). Edwin and Anal (2008) reported the highest N, P and K uptake in rice at irrigation given at 5 cm depth on the day of disappearance of ponded water. Nitrogen uptake by grain and straw tended to increase with increase in IW/CPE ratio from 0.8 to 1.2 (Murthy and Reddy, 2013). Kaur and Mahal (2014) reported that N, P and K uptake were affected significantly by irrigation. They obtained the highest P and K uptake by grains and straw in rice irrigated at 30 mm CPE and was significantly superior to irrigation at 50 mm and 70 mm CPE.

2.1.4 Root studies

Shoot and root dry weight was reduced in both drought resistant and susceptible cultivars of rice due to moisture stress (Deka and Baruah, 1998). In rice, root length was largely suppressed under severe stress compared with mild stress (Kondo *et al*., 2000). Thomas (2000) opined that root characters like root length, root weight and root volume were the highest at irrigation given at IW/CPE of 1.5 compared to IW/CPE of 1.0 and rainfed control. Root weight was the highest under mild water stress given at 50 % flowering followed by severe water stress at mid-tillering stage in rice (Davatgar *et al.,* 2009).

2.1.5 Soil moisture estimation

Jolly (2016) reported that with increasing level of irrigation, both consumptive use and water requirement were increased and consumptive use was the highest at irrigation given at IW/CPE of 1.2 compared to IW/CPE of 0.6 in upland rice. EL-Sayed *et al*. (2017) obtained the highest daily consumptive use at irrigation given at 30 % soil moisture depletion compared to 85 % soil moisture depletion in all growth stages of rice.

Irrigation scheduled at IW/CPE ratio of 1.0 recorded higher water use efficiency compared with IW/CPE ratios of 2.5, 2.0, 1.5 (Shekara *et al*., 2010). Kumar *et al*. (2015) reported the highest water use efficiency at irrigation given at 2.5 cm submergence 5 days after disappearance of ponded water. The highest water use efficiency was recorded at irrigation provided at 1.2 IW/CPE and the lowest at 0.6 IW/CPE in upland rice (Jolly, 2016).

2.1.6 Soil properties

Balasubramanian and Krishnarajan (2001) reported the highest levels of soil available NPK with irrigation of 2.5 cm depth three days after disappearance of ponded water in direct seeded rice. Irrigation scheduled at IW/CPE of 2.5 recorded highest N, P and K uptake and lower available nutrients in the soil (Shekara *et al.*, 2010).

2.1.7 Major weeds

In upland irrigated rice, the most critical period for crop-weed competition was on 15 to 30 DAS (Shelke *et al.*, 1986). 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. The crop is very sensitive to weeds during tillering to just before heading stages (Singh *et al.*, 1989). 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 (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).

2.2 INFLUENCE OF LIVE MULCHING

Ratilla and Escalada (2006) reported that cowpea was the most suitable green manure crop for upland rice.

2.2.1 Growth characters

Hemalatha *et al.* (2000) reported that green manuring produced taller plants, higher number of tillers hill^{-1}, leaf area index and dry matter production in rice. Green manure significantly increased the plant height and number of tillers in upland rice (Kayeke *et al.*, 2007). Jat *et al.* (2011) reported that plant height, number of tillers m^{-2}, dry matter accumulation hill^{-1} and leaf area index were higher with incorporation of cowpea residue compared to no residue incorporation in aromatic hybrid rice. *In situ* green manuring with sunn hemp produced taller plants with high tiller number hill^{-1} leading to overall productivity enhancement in upland rice as reported by Kumar *et al.* (2011). Fabunmi and Balogun (2015) reported taller maize plants in cowpea green manure plots compared to control plots.

2.2.2 Yield attributes and yield

Misra *et al.* (1969) obtained the highest grain yield of rice in integrated nutrient management system involving green manuring and chemical fertilizer. Mathew *et al.* (1991) in an experiment with cowpea incorporated in semi dry rice obtained 10 -15 t ha $^{-1}$ of green matter and higher yield and yield attributes. Matiwade (1992) reported that grain and straw yield were the highest with green manuring of *Sesbania rostrata*. Among the grain legumes, incorporation of cowpea and black gram haulms showed a positive influence on yield and yield attributes of rice (Siddeswaran, 1992). Rajshekhar *et al.* (2004) reported higher grain yield in maize with lucerne green manure. Jat *et al.* (2011) reported significantly higher yield attributes and grain yield of aromatic hybrid rice with the incorporation of cowpea residue compared to no residue incorporation. Green manuring with legumes increased the grain and straw yield of rice and improved the soil organic fertility in rice-wheat system (Shah *et al.*, 2011). Number of tillers m^{-2} and grains $panicle^{-1}$ were higher in mulched treatment compared to non mulched plots (Gaire *et al.*, 2013). Cowpea green manure increased grain yield of rice by 0.7 t ha^{-1} (Fabunmi and Balogun, 2015). Raising of cowpea as a intercrop in dry seeded semi dry rice and its subsequent incorporation at six week age not only added substantial quantity of green manure but also improved yield, yield attributes and overall productivity of the system (KAU, 2016).

2.2.3 Physiological and chemical estimation

Siddeswaran (1992) reported that green manuring improved the soil total N and available P but soil available K decreased with organic mulching. N uptake of maize was significantly higher under mulching with leucaena compared to control (Sharma and Behera 2010). Kumar (2016) obtained higher uptake of N, P and K in upland rice with 50 % N substituted through FYM indicating that application of organic sources favourably influenced the nutrient uptake.

2.2.4 Root studies at harvest

Singh *et al.* (2000) reported that green manuring increased the root length density significantly over control. Mandal *et al.* (2003) reported that green manuring of legumes in rice-wheat system improved the root growth.

2.2.5 Soil moisture estimation

Green manuring with *Mucuna pruriens* recorded higher water holding capacity (Hulugalle *et al.*, 1986). Mulching reduced evaporation from soil surface and allowed redistribution of moisture within the soil profile, leading to retention of soil moisture in wheat (Sharma *et al.*, 1998). Incorporation of mucuna residues improved water retention capacity of the soil compared to other legumes (Kayinamura *et al.*, 2000).The use of *Sesbania aculeata* as a green manure improved the available soil water holding capacity (Sultani *et al.*, 2007). Mulching of tender twigs of *Leucaena leucocephala* improved moisture status of the soil (Sharma and Behera, 2010).

2.2.6 Soil Properties

Green manures or cover crops improved soil chemical and physical properties (Lal *et al.,* 1978). Green manuring maintained inherent fertility and improved organic matter content of soil (Gauther and Guilbeau, 1979). Yan and Li (1985) opined that incorporation of legumes in soil increased organic matter content, available N, P and K compared to control (without green manuring). Green manures improved soil physical and chemical properties (Buresh and De Datta, 1991). Green manuring of rice with *Sesbania rostrata* improved the status of organic carbon content (Matiwade, 1992). Bulk density was lower in green manuring plot compared to no green manuring plot (Narayan and Lal, 2006). Lower bulk density was obtained in cowpea green manuring plot in upland rice (Ratilla and Escalada , 2006). According to Singh (2014) *Sesbania aculeata* improved soil organic matter and available nutrient content in soil.

2.1.7 Major weeds

Kayeke *et al.* (2007) reported that total weed count and weed dry weight decreased significantly in green manure treated plots in upland rice. Nalini *et al.* (2008) observed that green manuring with *Sesbania aculeata* significantly reduced weed density and dry weight in semi-dry rice. The weeds were lower in green manure plot (Recalde *et al.*, 2015).

2.3 COMBINED INFLUENCE OF IRRIGATION AND MULCHING

2.3.1 Growth characters

Purushotamdas (2009) opined that the combined application of irrigation at IW/CPE of 0.8 and ground nut shell mulch recorded the highest leaf area index in summer pearl millet. Hingonia (2015) obtained higher number of tillers and leaf area index in rice husk mulching (6 t ha^{-1}) and two irrigations at 35 and 85 DAS in barley. According to Meena (2016) application of maize stover mulch (6 t ha^{-1}) in combination with irrigation given at 50 per cent soil moisture depletion recorded the maximum dry matter production at 60 DAS. Irrigation at 0.9 IW/CPE ratio with the application of FYM at 7.5 t ha^{-1} + vermicompost at 3 t ha^{-1} increased total tiller number (Verma, 2017).

2.3.2 Yield attributes and yield

Pirboneh *et al.* (2012) revealed that irrigation at 6 days interval with 2 cm straw mulch m^{-2} produced the highest fruit yield in brinjal. The interaction effect of irrigation and straw mulching improved the grain yield in wheat (Ram *et al.*, 2013). Drip irrigation at 125 % pan evaporation and black polythene mulch produced the highest grain yield in maize compared to non mulched treatment (Awasthy, 2014). Hingonia (2015) reported higher values for yield attributes viz., number of earheads m^{-2}, ear length, grains ear^{-1} and test weight for rice husk mulching at 6 t ha^{-1} combined with two irrigations at 35 and 85 DAS in barley. Digra *et al.* (2016) opined that irrigation at IW/CPE ratio of 1.0 with full row straw mulching recorded the maximum yield in rapeseed. Scheduling of irrigation to wheat at IW/CPE of 0.8

at vegetative phase, 1.0 at reproductive phase in combination with application of FYM at 7.5 t ha $^{-1}$ + vermicompost 3 t ha $^{-1}$ recorded the maximum yield (Verma, 2017).

2.2.3 Physiological and chemical estimation

Hingonia (2015) obtained the maximum N, P and K uptake in barley for the combined application of rice husk mulching (6 t ha^{-1}) and two irrigation at 35 and 85 DAS. Incorporation of 10 t ha^{-1} FYM, plastic mulching before planting and irrigation at 4 cm depth improved the relative leaf water content of brinjal (Kaur, 2015). The combination of irrigation given at 25 per cent soil moisture depletion and application of 6 t ha^{-1} maize stover mulch recorded the highest phosphorus uptake in malt barley (Meena, 2016). Irrigation at IW/CPE of 0.9 combined with the application of FYM at 7.5 t ha^{-1} + vermicompost at 3 t ha^{-1} recorded the maximum plant N uptake in wheat (Verma, 2017).

2.2.4 Root studies

According to Kaur (2015) at lower (2 cm) level of irrigation, organic mulching resulted in significantly higher root volume and root dry weight compared to no mulching and plastic mulching.

2.2.5 Soil moisture estimation

Plastic film mulching with drip irrigation recorded lower water consumption and higher water use efficiency (Haibing *et al.*, 2013). Yaseen *et al.* (2014) reported that combination of irrigation and mulching produced the maximum water use efficiency in maize. Alebachew (2017) reported that the maximum water use efficiency was recorded at irrigation level of 70 % ETc with sugarcane leaf mulch in tomato.

2.2.6 Soil Properties

Yaseen *et al.* (2014) observed that higher soil bulk density was observed under irrigation with 558.8 mm water and no mulching in maize. The combination of drip, furrow and flood irrigation methods with wheat straw mulch at 4 t ha^{-1} recorded lower soil bulk density. According to Shivaji (2017) higher soil moisture content was recorded in drip irrigation with polythene mulch followed by drip irrigation with soybean straw mulch in watermelon.

2.1.7 Major weeds

According to Shrivastava *et al.* (1994) weed infestation was reduced in drip irrigation with black polythene mulch. Drip irrigation with or without black polythene mulch recorded less weed dry weight compared to surface irrigation (Lingaiah, 2003). Choudhary *et al.* (2012) reported that drip irrigation at 1.0 PE along with black polythene as well as straw mulch restricted weed growth in capsicum.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment on "Irrigation scheduling and live mulching in upland rice (*Oryza sativa* L.)" was laid out in farmer's field at Peringammala, Kalliyoor, Thiruvananthapuram during *Virippu* 2017. The objective of the study was to standardize irrigation schedule for economizing water use and to study the effect of live mulching with cowpea on growth and yield of upland rice. The materials used and methods followed are briefly described below.

3.1 MATERIALS

3.1.1 Experimental Site

The field experiment was conducted in the field of Sri. Madhusoodhanan Nair, M.S. Sadhanam, Peringammala, Kalliyoor, Thiruvananthapuram located at 8° 41' 56''N latitude, 77° 01' 92''E longitude and an altitude of 28 m above mean sea level.

3.1.2 Soil

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

3.1.3 Climate

The weather parameters prevailed during the experimental period were given in Appendix I and Fig.1.

The weather parameters were recorded for the standard weeks during the crop period. The maximum temperature and minimum temperature ranged from 29.8 °C to 33.6 °C and 23.6 °C to 25.8 °C respectively. A total rainfall of 679 mm was recorded

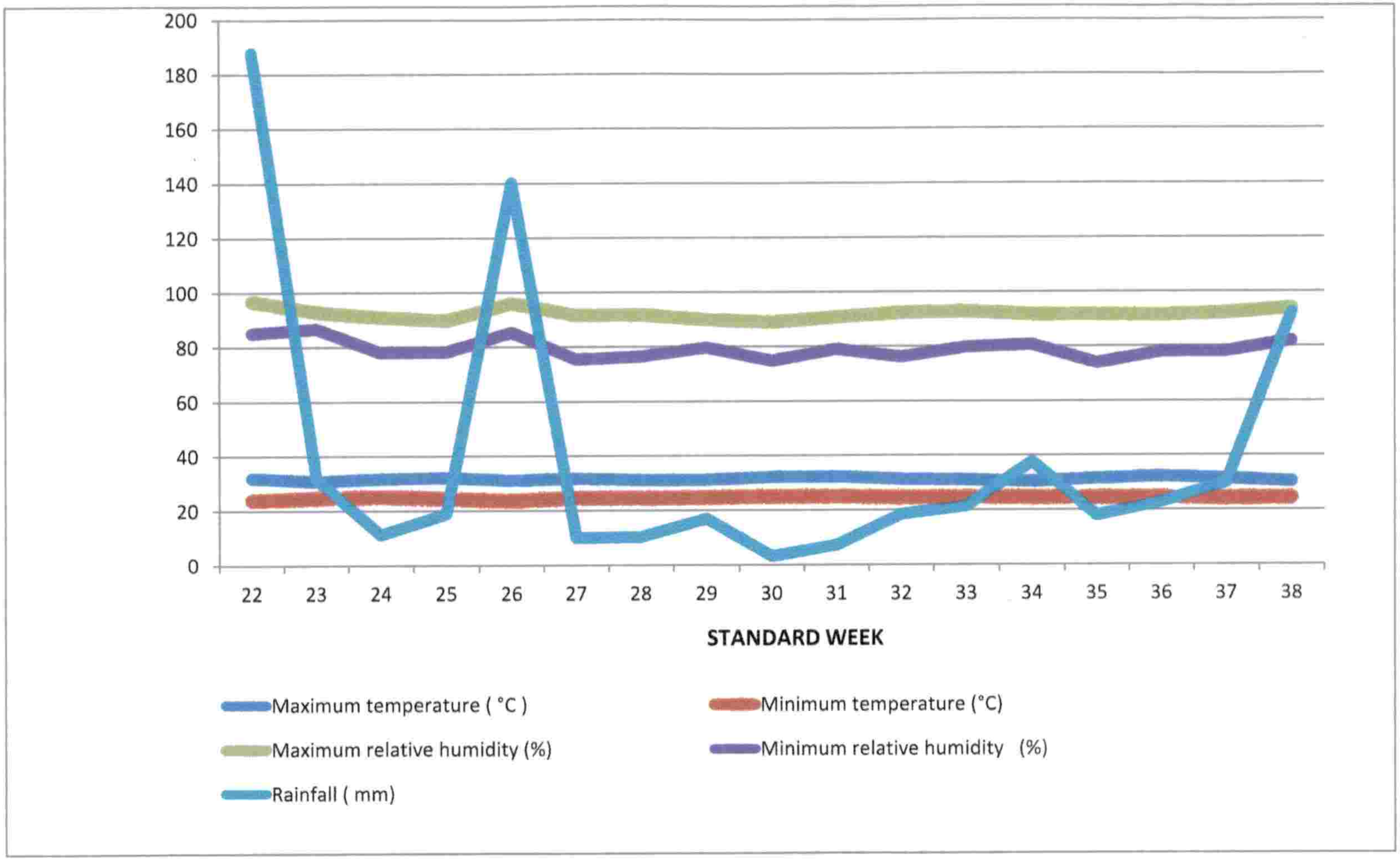


Fig.1. Weather data during cropping period (26th May to 25th September)

Table 1. Physico-chemical parameters of soil

Particulars	Value	Method used
a. Physical properties		
Bulk density (Mg m^{-3})	1.52	Core method (Blake, 1965)
Particle size composition		
Sand (%)	44.30	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Silt (%)	5	
Clay (%)	34.4	
Texture	Sandy clay loam	
Soil moisture constants		
Field capacity (%)	16	Field method
Permanent wilting point (%)	10	Field method
b. Chemical properties		
pH	5.02 (strongly acidic)	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1958)
Electrical Conductivity (dS m^{-1})	0.7	Soil water suspension of 1:2.5 and read in EC meter (Jackson, 1958)
Organic carbon (%)	0.60 (medium)	Walkley and Black method (Walkley and Black, 1934)
Available N (kgha^{-1})	125.44 (low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	43.68 (high)	Ascorbic acid reduced molybdophosphoric blue colour method (Bray and Kurtz,1945)
Available K_2O (kg ha^{-1})	427.22 (high)	Neutral normal ammonium acetate extract using Flame photometer (Jackson, 1958)

during the crop period. Relative humidity ranged from 85 to 98 per cent. The evaporation varied from 2 to 4.8 mm.

3.1.4 Season

The field experiment was carried out during first crop season (*Virippu*) of the year 2017. The crop was sown on 26th May, 2017 and harvested on 25th September 2017.

3.1.5 Crop and Variety

Prathyasa (MO 21) released from Rice Research Station (RRS) Moncompu, Kerala Agriculture University was used for the study. It is a non lodging, photo insensitive and semi tall variety with 105 - 110 days duration. The grains are red, long and bold. Average grain and straw yield is 5.0 t ha^{-1} and 6.5 t ha^{-1} respectively. It is moderately resistant to gall midge, brown plant hopper, sheath blight and sheath rot.

Aiswarya, released from Kerala Agricultural University was used as cowpea variety. It contains 18.50 % crude protein and 20.00 % crude fibre. It is tolerant to mosaic virus and moderately resistant to leaf spot and leaf hoppers.

3.1.6 Source of Seed Material

Seeds of Prathyasa variety were collected from RRS Moncompu. Seeds of fodder cowpea variety Aiswarya were purchased from IFSRS Karamana.

3.1.7 Manures and Fertilizers

Farmyard manure (FYM) containing 0.50 per cent N, 0.20 per cent P_2O_5 and 0.40 per cent K_2O was the source of organic manure.The fertilizers used for the study were urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

3.1.8 Irrigation

Irrigation was scheduled as per irrigation treatments and the required quantity of water was measured using water meter.

3.2 DESIGN AND LAYOUT

Design	: RBD
Treatments	: 14
Replication	: 3
Plot size (Gross)	: 5 m x 4 m
Plot size (Net)	: 4.6 m x 3.8 m
Spacing	: 20 cm x 10 cm
Season	: *Virippu* 2017

3.2.1 Treatments

Irrigation levels (I) - 7

I_1: Irrigate at 3 cm depth at 10 mm CPE

I_2: Irrigate at 3 cm depth at 20 mm CPE

I_3: Irrigate at 3 cm depth at 30 mm CPE

I_4: Irrigate at 2 cm depth at 10 mm CPE

I_5: Irrigate at 2 cm depth at 20 mm CPE

I_6: Irrigate at 2 cm depth at 30 mm CPE

I_7: Rainfed control

Live Mulching (M) - 2

M_1: No live mulching

M_2: Live mulching with cowpea

Total treatment combinations: 14

T_1 - i_1m_1	**T_5 - i_3m_1**	**T_9 - i_5m_1**	**T_{13} - i_7m_1**
T_2 - i_1m_2	**T_6 - i_3m_2**	**T_{10} - i_5m_2**	**T_{14} - i_7m_2**
T_3 - i_2m_1	**T_7 - i_4m_1**	**T_{11} - i_6m_1**	
T_4 - i_2m_2	**T_8 - i_4m_2**	**T_{12} - i_6m_2**	

3.3 CULTIVATION PRACTICES

3.3.1 Land Preparation

The land was ploughed and leveled by using a tiller. Before starting the experiment, composite soil samples were taken for analysis. Plots of 5 m x 4 m were made with bunds of width 30 cm on all the four sides. Irrigation and drainage channels were provided.

3.3.2 Seeds and Sowing

Prathyasa seeds were dibbled at 85 kg ha^{-1} at a spacing of 20 cm x 10 cm. One row of cowpea variety Aiswarya was sown between two rows of rice in the respective treatment plots. Two seeds of cowpea were dibbled per hole at a spacing of 10 cm within the row. In unmulched treatment cowpea seeds were not sown. In mulched plots cowpea was incorporated in to the field at six weeks active growth stage.

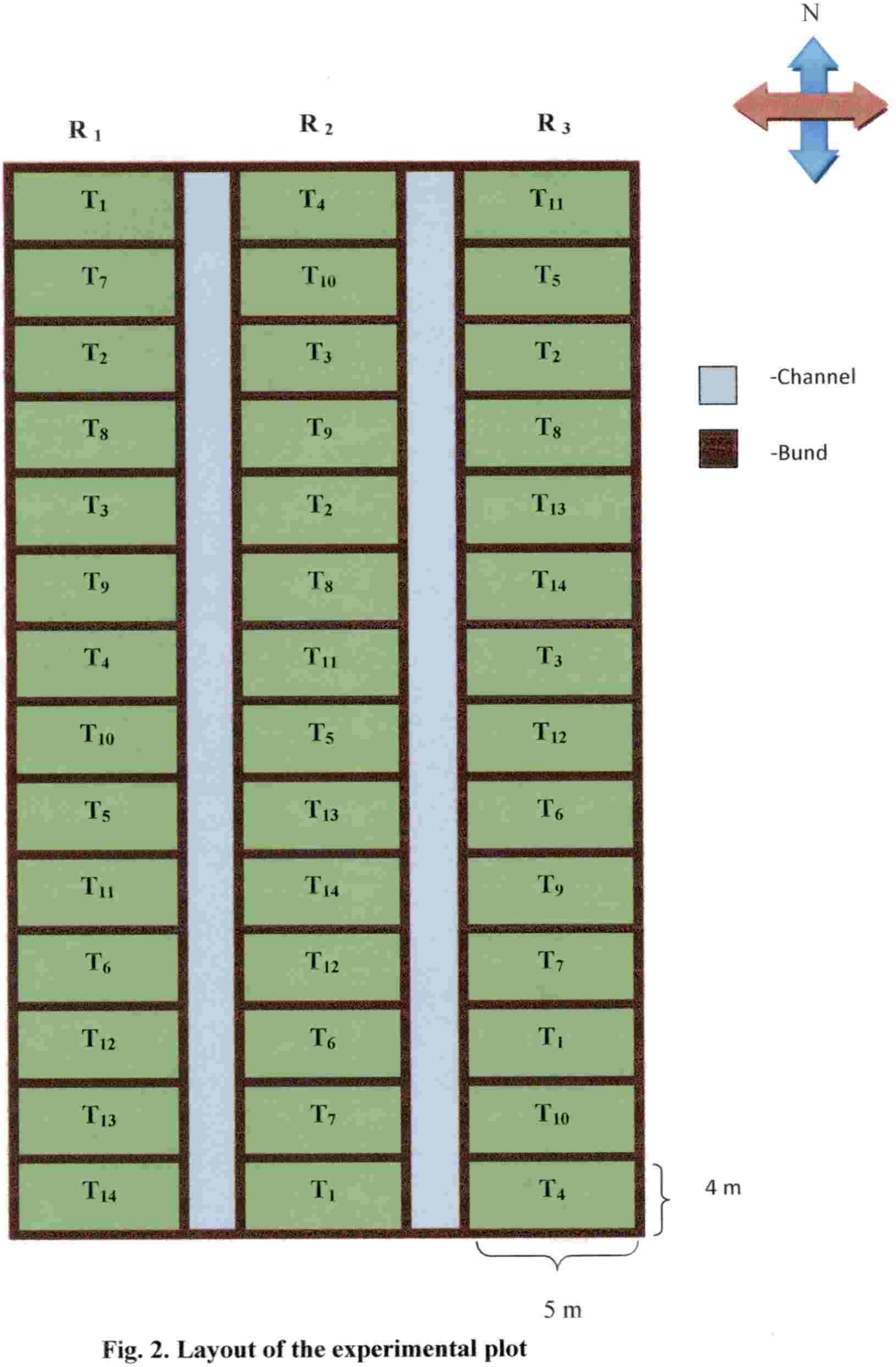


Fig. 2. Layout of the experimental plot

Plate 1. General view of experimental site

3.3.3 Application of Manures and Fertilizers

Farm yard manure @ 5 t ha^{-1} was added to all the plots uniformly. The fertilizer recommendation of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} were followed in all plots. Nitrogen was applied in three equal split doses, first as basal dressing, second at active tillering stage and third at panicle initiation stage. The entire dose of phosphorus was applied as basal. Potassium was applied as two split doses, half as basal and half at panicle initiation stage.

3.3.4 Thinning and Gap Filling

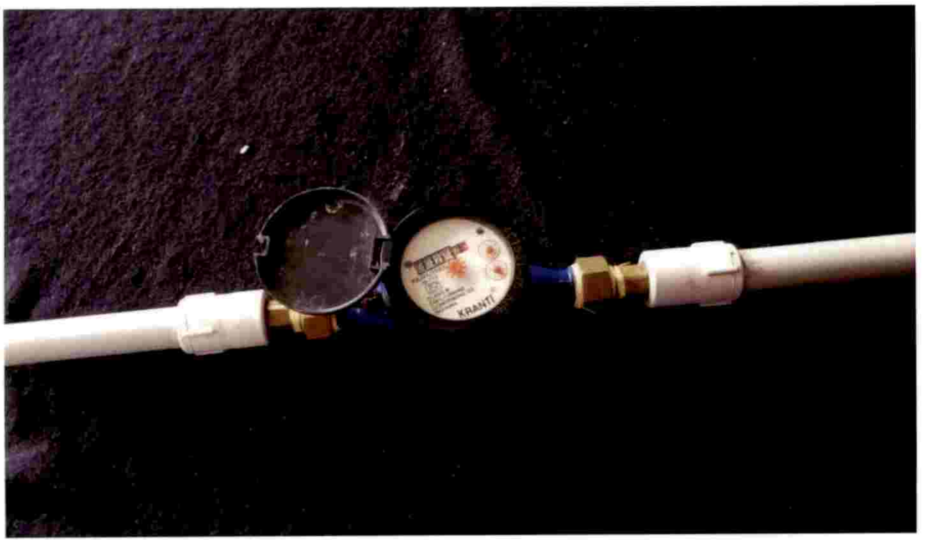
The seeds germinated within 7 days. Thinning and gap filling were done at 15 DAS to maintain uniform population at two seedlings $hill^{-1}$.

3.3.5 Water Management

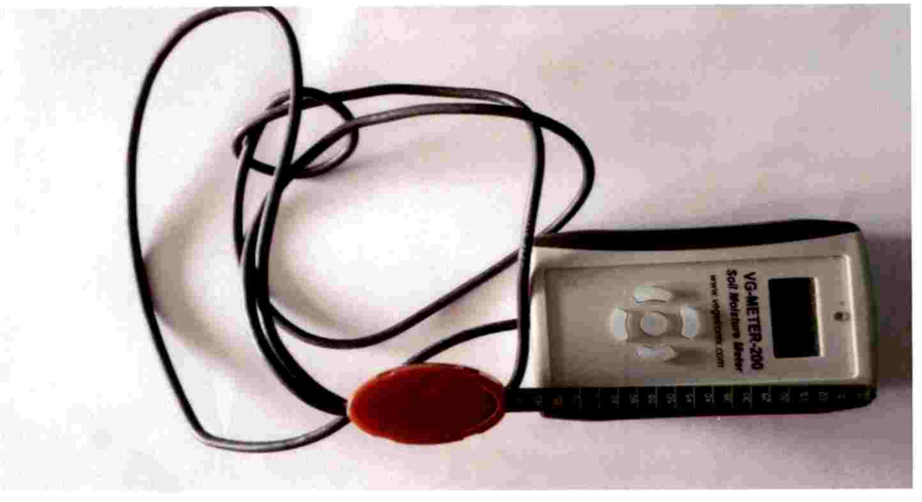
One pre sowing irrigation was given to the field on the day before sowing with 10 mm depth of water and rice seeds were dibbled on 26th May, 2017. A common irrigation was also given to all plots on 15th June, 2017 with 10 mm depth of water to ensure uniform establishment of seedlings. The differential irrigation according to treatments was started after 15th June 2017. The evaporation readings from a USWB Class A open evaporimeter were recorded daily and whenever the cumulative pan evaporation values attained the treatment values, irrigation was given to the concerned plots with 20 mm and 30 mm depth of water as per treatments. The irrigation water was measured using a water meter. The details of irrigation are presented in Table 2.

3.3.6 Weed Management

One hand weeding was carried out at 20 DAS.



Water meter –For applying measured quantity of water as per treatments



Moisture meter – For measuring soil moisture content

Plate2. Equipments used for moisture estimation

Table 2. Details of irrigation

Treatment	Number of Irrigations	Date of irrigation
I_1	17	17/06/17,19/06/17, 21/06/17, 05/06/17, 07/07/17, 09/07/17, 14/07/17, 16/07/17, 24/07/17, 26/07/17, 28/07/17, 30/07/17,01/08/17, 03/08/17, 12/08/17, 14/08/17, 04/09/17
I_2	8	19/06/17, 07/07/17, 16/07/17, 27/07/17, 31/07/17, 04/08/17, 15/08/17, 06/09/17
I_3	4	21/06/17, 10/07/17, 29/07/17, 04/08/17
I_4	17	17/06/17,19/06/17, 21/06/17, 05/06/17, 07/07/17, 09/07/17, 14/07/17, 16/07/17, 24/07/17, 26/07/17, 28/07/17, 30/07/17,01/08/17, 03/08/17, 12/08/17, 14/08/17, 04/09/17
I_5	8	19/06/17, 07/07/17, 16/07/17, 27/07/17, 31/07/17, 04/08/17, 15/08/17, 06/09/17
I_6	4	21/06/17, 10/07/17, 29/07/17, 04/08/17
I_7	0	

I_1: Irrigate at 3 cm depth at 10 mm CPE

I_2: Irrigate at 3 cm depth at 20 mm CPE

I_3: Irrigate at 3 cm depth at 30 mm CPE

I_4: Irrigate at 2 cm depth at 10 mm CPE

I_5: Irrigate at 2 cm depth at 20 mm CPE

I_6: Irrigate at 2 cm depth at 30 mm CPE

I_7: Rainfed control

3.3.7 Plant Protection

To control sheath blight, Carbendazim (Bavistin 50 WP) @ 125g *a.i.* ha $^{-1}$ was applied. To control rice bug, two sprays of Malathion (750 mL ha^{-1}) were given at flowering and milking stage of the crop.

3.3.8 Harvest

The crop was harvested on 25th September, 2017. The plants from net plot area and border rows were harvested separately from each plot. Threshing was done manually and the produce was cleaned, dried and weighed. Weight of grain and straw were expressed as kg ha^{-1}.

3.4 OBSERVATIONS

3.4.1 Observations on growth components

3.4.1.2 Plant Height

Five plants were selected randomly and height of the plants was measured in cm from base of the stem to tip of the top most leaf at 30 DAS, 60 DAS and at harvest.

3.4.1.2 Tiller Number m^{-2}

The tiller number m^{-2} at 60 DAS was recorded from net plot area and mean values were computed and recorded.

3.4.1.3 Leaf Area Index (LAI)

Five plants were tagged and maximum length and breadth of 3rd leaf from top were taken at 60 DAS. The mean value was multiplied with total number of leaves. Yoshida *et al.* (1976) suggested a formula for LAI.

$$LAI = \frac{K\,(L \times W) \times \text{Number of leaves hill}^{-1}}{\text{Land area occupied by the plant}}$$

Where, K - Constant factor (0.75)

L - Maximum length of the 3rd leaf blade from the top (cm)

W - Maximum width of the leaf blade (cm)

3.4.1.4 Dry Matter Production

The observational plants were uprooted, washed, sun dried and oven dried at 70±5 °C to constant weight. Dry matter production was recorded at harvest and expressed in kg ha^{-1}.

3.4.2 Observation on yield attributes and yield

3.4.2.1 Number of Productive Tillers m^{-2}

The number of productive tillers were recorded from 1 m^2 area of each plot at harvest and mean values were calculated accordingly.

3.4.2.2 Length of Panicle

Panicle length was measured from the point of scar to the tip of the panicle obtained from five centre panicles of the tagged hills and mean length of panicle was measured and expressed in cm.

3.4.2.3 Weight of Panicle

The panicles collected for measuring panicle length were weighed using an electronic balance and mean weight of panicle was recorded and expressed in g.

3.4.2.4 Number of Spikelets $Panicle^{-1}$

The spikelets from each panicle was removed and counted from the five sample plants in each plot and the mean value was worked out.

3.4.2.5 Number of Filled Grains Panicle $^{-1}$

From the five sample plants, the number of filled grains panicle^{-1} was counted and average value was recorded.

3. 4.2.6 Sterility Percentage

Sterility percentage was calculated using the formula

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.4.2.7 Thousand Grain Weight

From the five sample plants, thousand grains were separated from clean produce in each plot and mean weight was expressed in g.

3.4.2.8 Grain Yield

The grains were harvested from each net plot area separately and dried in sun to a moisture content of 14 per cent and its weight was recorded and expressed in kg ha^{-1}.

3.4.2.9 Straw Yield

The harvested straw from each net plot area was collected separately and dried in the sun for three consecutive days and weight was expressed in kg ha^{-1}.

3.4.2.10 Harvest Index

The harvest index was calculated by using the formula suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.4.3 Physiological and chemical estimations

3.4.3.1 Relative Leaf Water Content (RLWC)

The method proposed by Weatherley (1950) which later modified and described by Slatyer and Barrs (1965) was used to estimate RLWC and expressed in percentage.

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

3.4.3.2 Proline Content

Proline content of leaves was estimated by the method described by Bates *et al.* (1973) and expressed as $\mu mol\ g^{-1}$ of fresh weight.

3.4.3.3 NPK uptake

NPK uptake was estimated by multiplying nutrient content of the sample and respective dry weight of plant samples and expressed in $kg\ ha^{-1}$.

$$\text{Nutrient uptake} = \frac{\text{Percentage of nutrient} \times \text{Total dry matter production } (kg\ ha^{-1})}{100}$$

3.4.3.4 Chlorophyll Content

The chlorophyll content was estimated by method prescribed by Reddy *et al.* (1992). The amount of pigments was calculated using the formula detailed below and expressed in $mg\ g^{-1}$ of fresh weight.

$$\text{Chlorophyll a} = [12.7\ (\text{OD at } 663) - 2.69\ (\text{OD at } 645)] \times \frac{V}{W \times 1000}$$

$$\text{Chlorophyll b} = [22.9\ (\text{OD at } 645) - 4.68\ (\text{OD at } 663)] \times \frac{V}{W \times 1000}$$

$$\text{Total chlorophyll} = [20.2\,(\text{OD at } 645) + 8.02(\text{OD at } 663)] \times \frac{V}{W \times 100}$$

Where, OD – optical density, W – fresh weight of leaves, V – final volume of extract

3.4.4 Root studies

3.4.4.1 Root Length

At the harvest stage, the five sample plants were uprooted carefully, root portion was separated, cleaned and measured the length. The mean value was calculated and expressed in cm.

3.4.4.2 Root Volume

Root volume plant^{-1} was found out by displacement method (Misra and Ahmed, 1989) and expressed in cm^3 plant^{-1}.

3.4.4.3 Root Weight

At the time of harvesting, five sample plants were uprooted, root portion was separated, cleaned and dried in a hot air oven at 70±5°C to constant weight and was recorded in g.

3.4.4.4 Root Shoot Ratio

Root and shoot dry weights were recorded separately and root to shoot ratio was worked out.

3.4.5 Soil moisture estimation

3.4.5.1 Soil Moisture Estimation at 15 cm Depth of Root zone

Soil moisture estimation was done by using a standard moisture meter. The moisture meter was inserted at 15 cm soil depth in all the plots and moisture readings were recorded prior to irrigation and after irrigation.

3.4.5.2 Irrigation Requirement

The irrigation was scheduled to the crop after sowing as per the treatments. Measured quantity of irrigation water was given to the respective plots according to the treatments by using water meter. Moisture content before and after irrigation was worked out using moisture meter. Then consumptive use was worked out from the data on soil moisture depletion suggested by Dastane (1972).

$$\text{Consumptive use (CU)} = \sum_{i=1}^{n} \frac{M1i - M2i}{100} \times D_b \times \text{depth of soil (cm)}$$

Where, n - number of soil layers considered in root zone depth D

M1i - soil moisture percentage at first sampling in i^{th} layer

M2i - soil moisture percentage at second sampling in the i^{th} layer

D_b - bulk density

3.4.5.3 Water Use Efficiency

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

3. 4.6 Soil properties

3.4.6.1 Physical Properties

Soil samples were collected from undisturbed top soil at 0-15 cm depth using core sampler and analyzed for bulk density before sowing and at the end of the crop period (Gupta and Dakshinamoorthy, 1980).

$$\text{Bulk density } (D_b)\ (\text{Mg m}^{-3}) = \frac{\text{Weight of soil solid (Mg)}}{\text{Total volume of soil } (\text{m}^3)}$$

Water holding capacity can be determined by using the formula given by Gupta and Dakshinamoorthy (1980).

$$WHC = \frac{\text{Weight of moisture in soil}}{\text{Dry weight of soil}} \times D_b \times 100$$

Where, D_b - Bulk density

3.4.6.2. Chemical Analysis

Initial status of major nutrients in soil was estimated. Composite soil samples were collected before land preparation and soil analysis was done for the physico-chemical characteristics of the soil using the standard procedures. After experiment also, soil samples were taken from individual plots and NPK and organic carbon were analyzed.

3.4.7 Major Weeds of Upland Rice

Observations on weed species and weed dry weight were recorded by the quadrat method. The weeds uprooted from the quadrat were cleaned, air dried and then oven dried at 75 ± 5 ^{0}C and dry weight was recorded in kg ha^{-1}.

3.4.8 Pest and Disease Incidence

Observations on the incidence of major pests and diseases were made.

3.4.9 Economic Analysis

Based on the prevailing input cost and market price of grain and straw at the time of experimentation, cost of cultivation for all the treatments were worked out. The net income was calculated by deducting the cost of cultivation from the gross return. The benefit cost ratio (BCR) was worked out as follows.

$$BCR = \frac{\text{Gross return ha}^{-1}\text{ (₹)}}{\text{Cost of cultivation ha}^{-1}\text{(₹)}}$$

3.4.10 Statistical Analysis

The data generated from the experiment were subjected to an analysis of variance (F- test) as per the methods suggested by Panse and Sukhatme (1985). Wherever significant differences among treatments were observed, CD values at 5 per cent level of significance were calculated for comparison of means.

RESULTS

4. RESULTS

The experiment entitled "Irrigation scheduling and live mulching in upland rice (*Oryza sativa* L.)" was undertaken during *Virippu* 2017 at farmer's field. The observations recorded on growth components, yield attributes, yield, physiological parameters, nutrient uptake, root studies, soil moisture estimation, soil physical and chemical properties, weed dry weight and economics of cultivation were analyzed statistically and results presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Plant Height

The results on mean height of plant recorded at 30 DAS, 60 DAS and at harvest as influenced by irrigation (I), mulching (M) and interaction are presented in Table 3a and 3b.

At 30 DAS, the results revealed that irrigation (I), mulching (M) and their interaction had no significant effect on plant height.

At 60 DAS, I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest plant height of 99.54 cm and the shortest plants of 70.41cm were produced by I_7 (rainfed control). The treatment I_1 was on par with I_4 (irrigation at 2 cm depth at 10 mm CPE) and significantly superior to other treatments. Non mulched treatment (M_1) recorded the highest plant height of 88.19 cm and was significantly superior to M_2 (live mulching with cowpea).The interaction effect was not significant.

At harvest, irrigation treatment I_4 (irrigation at 2 cm depth at 10 mm CPE) registered the highest plant height of 105.50 cm and was on par with I_2, I_5 and I_1.The treatment I_7 (rainfed control) produced the shortest plants of 81.87 cm. Mulching did not exert a significant effect on plant height. The interaction effect was not significant.

Table 3a. Effect of irrigation and mulching on plant height at different growth stages, cm

Treatments	Plant height		
	30 DAS	60 DAS	At harvest
Irrigation (I)			
I_1	54.03	99.54	102.61
I_2	54.01	93.08	104.50
I_3	52.49	75.20	94.50
I_4	53.48	98.63	105.50
I_5	53.30	91.12	102.62
I_6	52.96	75.18	90.49
I_7	52.37	70.41	81.87
SEm(±)	0.53	1.82	2.59
CD (0.05)	NS	5.306	7.520
Live Mulching (M)			
M_1	53.65	88.19	98.03
M_2	52.82	84.15	96.85
SEm(±)	0.29	0.98	1.39
CD (0.05)	NS	2.835	NS

Table 3b. Interaction effect of irrigation and mulching on plant height at different growth stages, cm

Treatments	Plant height		
	30 DAS	60 DAS	At harvest
I X M interaction			
i_1m_1	54.50	101.37	104.89
i_1m_2	53.57	97.70	100.33
i_2m_1	54.00	95.99	103.00
i_2m_2	54.01	90.17	106.00
i_3m_1	53.03	77.80	93.22
i_3m_2	51.95	72.61	95.78
i_4m_1	54.04	103.17	110.89
i_4m_2	52.92	94.10	100.11
i_5m_1	53.94	93.77	101.22
i_5m_2	52.67	88.47	104.00
i_6m_1	53.31	76.40	92.00
i_6m_2	52.61	73.97	89.00
i_7m_1	52.71	68.83	81.06
i_7m_2	52.02	72.00	82.67
SEm (±)	0.76	2.58	3.66
CD (0.05)	NS	NS	NS

4.1.2 Number of Tillers m^{-2}

The results on tiller number m^{-2} at 60 DAS influenced by treatments are presented in Table 4a and 4b.

The results revealed a significant influence of irrigation on number of tillers m^{-2}. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest tiller number m^{-2} of 357.00 and was significantly superior to other treatments. The lowest tiller number m^{-2} (210.00) was recorded by I_7 (rainfed control).

Mulching had no significant effect on tiller number m^{-2}.

The interaction between irrigation and mulching had a pronounced effect on tiller number m^{-2}. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest tiller number m^{-2} (390.00) and was superior to rest of the treatment combinations. The treatment combination i_7m_2 (rainfed control and live mulching with cowpea) recorded the lowest tiller number m^{-2} (176.00).

4.1.3 Leaf Area Index (LAI)

The results on LAI at 60 DAS (Table 4a and 4b) revealed that treatments differed significantly. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest leaf area index of 4.55 and was superior to rest of the treatments. The treatment I_7 (rainfed control) recorded the lowest leaf area index of 3.63.

Mulching, though not significant M_2 (live mulching with cowpea) recorded the highest leaf area index (4.12). The interaction effect was not significant.

Table 4a. Effect of irrigation and mulching on tiller number m^{-2} at 60 DAS, LAI at 60 DAS and DMP at harvest.

Treatments	Tiller number m^{-2} at 60 DAS	LAI at 60 DAS	DMP at harvest (kg ha^{-1})
Irrigation (I)			
I_1	357.00	4.55	6049
I_2	315.67	4.26	5496
I_3	275.50	3.99	4719
I_4	320.00	4.32	5763
I_5	288.00	3.94	5103
I_6	280.00	3.88	4362
I_7	210.00	3.63	3610
SEm(±)	2.83	0.06	40.92
CD (0.05)	8.292	0.175	118.983
Live Mulching (M)			
M_1	293.62	4.04	4902
M_2	291.00	4.12	5127
SEm (±)	2.14	0.04	21.87
CD (0.05)	NS	NS	63.603

Table 4b. Interaction effect of irrigation and mulching on tiller number m^{-2} at 60 DAS, LAI at 60 DAS and DMP at harvest.

Treatments	Tiller number m^{-2} at 60 DAS	LAI at 60 DAS	DMP at harvest ($kg\ ha^{-1}$)
I X M interaction			
i_1m_1	324.00	4.63	5898
i_1m_2	390.00	4.49	6200
i_2m_1	323.33	4.12	5421
i_2m_2	308.00	4.39	5572
i_3m_1	284.00	3.87	4647
i_3m_2	267.00	4.11	4790
i_4m_1	306.00	4.42	5624
i_4m_2	334.00	4.22	5903
i_5m_1	308.00	3.87	4964
i_5m_2	268.00	4.00	5242
i_6m_1	266.00	3.81	4224
i_6m_2	294.00	3.95	4499
i_7m_1	244.00	3.57	3537
i_7m_2	176.00	3.69	3682
SEm(±)	4.01	0.09	57.87
CD (0.05)	11.727	NS	NS

4.1.4 Dry Matter Production (DMP)

Result on dry matter production is given in Table 4a and 4b. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest dry matter production of 6049 kg ha^{-1} and was superior to rest of the treatments. The treatment I_7 (rainfed control) recorded the lowest value of 3610 kg ha^{-1}.

Live mulching with cowpea (M_2) recorded the highest dry matter production of 5127 kg ha^{-1} and was superior to the non mulched treatment (M_1). The interaction effect was not significant.

4.2 YIELD ATRIBUTES AND YIELD

4.2.1 Number of Productive Tillers m^{-2}

The results on number of productive tillers m^{-2} (Table 5a) revealed a significant influence of irrigation on number of productive tillers m^{-2}. The treatment I_2 (irrigation at 3 cm depth at 20 mm CPE) recorded the highest number of productive tillers m^{-2} (261.83) and was on par with the treatment I_1. The lowest number of productive tillers m^{-2} (158.67) was registered by the treatment I_7 (rainfed control).

Mulching treatments exerted a positive influence on number of productive tillers m^{-2}. The treatment M_2 (live mulching with cowpea) recorded the highest number of productive tillers m^{-2} (219.91) and was superior to the non mulched treatment (M_1). The interaction effect was not significant.

4.2.2 Length of Panicle

The results on Table 5a and 5b indicates that treatments differed significantly on length of panicle. The highest panicle length of 23.69 cm was recorded by the treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) and was on par with the treatments I_4, I_2 and I_5. The treatment I_7 (rainfed control) recorded the lowest panicle length of 20.54 cm.

Table 5a. Effect of irrigation and mulching on number of productive tillers m^{-2}, length of panicle and weight of panicle

Treatments	Number of productive tillers m^{-2}	Length of panicle (cm)	Weight of panicle (g)
Irrigation (I)			
I_1	249.00	23.69	2.92
I_2	261.83	22.22	2.73
I_3	207.83	21.54	2.62
I_4	235.83	23.36	2.85
I_5	215.33	22.27	2.63
I_6	167.17	21.11	1.91
I_7	158.67	20.54	1.27
SEm (±)	6.40	0.62	0.16
CD (0.05)	18.612	1.823	0.477
Live mulching (M)			
M_1	207.43	21.98	2.37
M_2	219.91	22.22	2.50
SEm(±)	3.42	0.33	0.08
CD (0.05)	9.946	NS	NS

Table 5b. Interaction effect of irrigation and mulching on number of productive tillers m^{-2}, length of panicle and weight of panicle

Treatments	Number of productive tillers m^{-2}	Length of panicle (cm)	Weight of panicle (g)
I X M interaction			
i_1m_1	246.33	23.25	2.87
i_1m_2	251.67	24.12	2.96
i_2m_1	257.33	22.98	2.72
i_2m_2	266.33	21.47	2.74
i_3m_1	199.67	20.83	2.61
i_3m_2	216.00	22.24	2.64
i_4m_1	241.67	23.51	2.81
i_4m_2	230.00	23.21	2.89
i_5m_1	194.67	22.95	2.68
i_5m_2	236.00	21.58	2.57
i_6m_1	161.67	20.27	1.62
i_6m_2	172.67	21.94	2.19
i_7m_1	150.67	20.08	1.22
i_7m_2	166.67	20.99	1.31
SEm(±)	9.05	0.88	0.22
CD (0.05)	NS	NS	NS

Mulching, though not significant, M_2 (live mulching with cowpea) recorded the highest panicle length of 22.22 cm. The interaction effect was not significant.

4.2.3 Weight of Panicle

The data on weight of panicle are presented in Table 5a and 5b.The irrigation treatment I_1(irrigation at 3 cm depth at 10 mm CPE) registered the highest weight of panicle (2.92 g) and was on par with I_2, I_3, I_4 and I_5.The treatment I_7 (rainfed control) recorded the lowest weight of the panicle (1.27 g).

Mulching, though not significant, M_2 (live mulching with cowpea) recorded the highest panicle weight (2.50 g). The interaction between irrigation and mulching was not significant.

4.2.4 Number of Spikelets Panicle^{-1}

The data on number of spikelets panicle^{-1} are presented in Table 6a and 6b.The result revealed a significant influence of irrigation on number of spikelets panicle^{-1}. The treatment I_4 (irrigation at 2 cm depth at 10 mm CPE) recorded the highest number of spikelets (120.02) and was on par with the treatments I_1 and I_2. The treatment I_7 (rainfed control) recorded the lowest number of spikelets (82.94).

Mulching, though not significant M_2 (live mulching with cowpea) recorded the highest number of spikelets (104.81). The interaction between irrigation and mulching was not significant.

4.2.5 Number of Filled Grains Panicle^{-1}

The data on number of filled grains panicle^{-1} are presented in Table 6a and 6b.The result revealed a significant influence of irrigation on number of filled grains panicle^{-1}. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest number of filled grains (116.81) and was on par with I_4. The treatment I_7 (rainfed control) recorded the lowest number of filled grains (72.81).

Table 6a. Effect of irrigation and mulching on number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, thousand grain weight and sterility percentage

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Thousand grain weight (g)	Sterility percentage
Irrigation (I)				
I_1	119.20	116.81	24.09	10.98
I_2	113.99	90.56	23.12	11.07
I_3	99.75	89.44	22.18	12.94
I_4	120.02	110.24	24.00	11.14
I_5	97.56	86.50	22.97	14.03
I_6	90.36	77.47	22.08	17.47
I_7	82.94	72.81	21.99	16.07
SEm(±)	5.34	4.71	0.55	3.15
CD (0.05)	15.543	13.697	1.600	NS
Live mulching (M)				
M_1	102.25	90.42	22.729	14.56
M_2	104.81	93.53	23.107	12.19
SEm(±)	2.86	2.52	0.29	1.68
CD (0.05)	NS	NS	NS	NS

Table 6b. Interaction effect of irrigation and mulching on number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, thousand grain weight and sterility percentage

Treatments	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}	Thousand grain weight (g)	Sterility percentage
I X M interaction				
i_1m_1	117.22	115.89	24.05	11.13
i_1m_2	121.17	117.72	24.12	10.82
i_2m_1	113.33	89.17	22.89	12.90
i_2m_2	114.67	91.94	23.34	9.25
i_3m_1	98.33	87.44	22.07	14.23
i_3m_2	101.17	91.44	22.29	11.64
i_4m_1	119.01	111.33	23.92	11.55
i_4m_2	121.00	109.15	24.09	10.72
i_5m_1	97.00	85.11	22.80	16.11
i_5m_2	98.11	87.89	23.14	11.93
i_6m_1	90.00	75.50	21.46	19.26
i_6m_2	90.72	79.45	22.70	15.68
i_7m_1	79.11	68.45	21.75	16.80
i_7m_2	86.78	77.16	22.24	15.34
SEm(±)	7.56	6.66	0.77	3.15
CD (0.05)	NS	NS	NS	NS

Mulching, though not significant, M_2 (live mulching with cowpea) recorded the highest number of filled grains (93.53). The interaction effect was not significant.

4.2.6 Thousand Grain Weight

The data on thousand grain weight are presented in Table 6a and 6b. The irrigation treatment I_1(irrigation at 3 cm depth at 10 mm CPE) registered the highest thousand grain weight of 24.09 g and was on par with I_2, I_4 and I_5.The treatment I_7 (rainfed control) recorded the lowest thousand grain weight (21.99 g).

Mulching and combined application of irrigation and mulching had no significant influence on thousand grain weight.

4.2.7 Sterility Percentage

The data on sterility percentage are presented in Table 6a and 6b.The results revealed that no significant difference between irrigation (I), mulching (M) and their interaction.

4.2.8 Grain Yield

The data on grain yield are presented in Table 7a and 7b.The treatments differed significantly. The highest grain yield of 2949 kg ha^{-1} was recorded by the treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) and was superior to rest of the treatments. The lowest grain yield of 1533 kg ha^{-1} was recorded by the treatment I_7 (rainfed control).

Live mulching with cowpea (M_2) registered the highest grain yield of 2438 kg ha^{-1} and was significantly superior to non mulched treatment (M_1).

The interaction between irrigation and mulching had a pronounced effect on grain yield. The treatment i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) registered the highest grain yield of 3057 kg ha^{-1} and was

Table7a. Effect of irrigation and mulching on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Irrigation (I)			
I_1	2949	3100	0.49
I_2	2597	2899	0.47
I_3	2287	2432	0.48
I_4	2780	2984	0.48
I_5	2442	2661	0.47
I_6	2057	2302	0.48
I_7	1533	2083	0.43
SEm (±)	18.34	35.65	0.003
CD (0.05)	53.344	103.658	0.011
Live Mulching (M)			
M_1	2318	2584	0.47
M_2	2438	2690	0.47
SEm(±)	9.81	19.06	0.002
CD (0.05)	28.517	55.407	NS

Table7b. Interaction effect of irrigation and mulching on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
I X M interaction			
i_1m_1	2840	3058	0.48
i_1m_2	3057	3143	0.49
i_2m_1	2578	2843	0.47
i_2m_2	2617	2955	0.47
i_3m_1	2255	2392	0.48
i_3m_2	2319	2471	0.48
i_4m_1	2720	2904	0.48
i_4m_2	2840	3063	0.48
i_5m_1	2356	2608	0.47
i_5m_2	2529	2713	0.48
i_6m_1	1986	2238	0.47
i_6m_2	2127	2366	0.47
i_7m_1	1490	2047	0.42
i_7m_2	1575	2119	0.43
SEm (±)	25.94	50.42	0.005
CD (0.05)	75.436	NS	NS

Seedling stage

Tillering stage

Maturity stage

Harvesting stage

Plate3. Experimental field at different growth stages

Before incorporation of cowpea

After incorporation of cowpea

Plate 4.Experimental field before and after incorporation of cowpea

i_1m_2(irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea)

I_7m_1(Rainfed control and no live mulching with cowpea)

Plate 5. Treatment variation at maximum tillering stage

superior to rest of the treatments. The lowest grain yield of 1490 kg ha^{-1} was recorded by i_7m_1 (rainfed control and no live mulching).

4.2.9 Straw Yield

The data on straw yield are presented in Table 7a and 7b. There was a significant difference among the treatments. The treatment I_1(irrigation at 3 cm depth at 10 mm CPE) recorded the highest straw yield of 3100 kg ha^{-1} and was superior to rest of the treatments. The treatment I_7 (rainfed control) recorded the lowest straw yield of 2083 kg ha^{-1}.

Live mulching with cowpea (M_2) registered the highest straw yield of 2690 kg ha^{-1} and was significantly superior to non mulched treatment (M_1). The interaction effect was not significant.

4.2.10 Harvest Index

The data on harvest index are presented in Table 7a and 7b. The treatments differed significantly. The highest harvest index of 0.49 was recorded by the treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) and was on par with the treatments I_3, I_4 and I_6. The treatment I_7 (rainfed control) recorded the lowest value (0.43). Mulching had no significant influence on harvest index. The interaction effect was not significant.

4.3 PHYSIOLOGICAL AND CHEMICAL ESTIMATION

4.3.1 Relative Leaf Water Content at 60 DAS

The result on Table 8a and 8b indicates that treatments differed significantly on relative leaf water content. The treatment I_1(irrigation at 3 cm depth at 10 mm CPE) registered the highest relative leaf water content (80.32 per cent) and was on par with all the treatments except I_7 .The treatment I_7 (rainfed control) recorded the lowest value of 72.69 per cent.

Table 8a. Effect of irrigation and mulching on relative leaf water content at 60 DAS, proline content and chlorophyll content at panicle emergence stage

Treatments	Relative leaf water content (%)	Proline content (μmol g $^{-1}$ FW)	Chlorophyll content (mg g^{-1} FW)
Irrigation (I)			
I_1	80.32	0.42	1.04
I_2	80.18	0.44	0.98
I_3	79.47	0.45	1.01
I_4	79.48	0.43	0.98
I_5	79.01	0.47	1.03
I_6	77.36	0.73	1.02
I_7	72.69	0.94	1.00
SEm(±)	1.75	0.04	0.01
CD (0.05)	5.088	0.080	NS
Live mulching (M)			
M_1	77.56	0.55	1.00
M_2	79.16	0.56	1.02
SEm(±)	0.93	0.02	0.01
CD (0.05)	NS	NS	NS

Table 8b. Interaction effect of irrigation and mulching on relative leaf water content at 60 DAS, proline content and chlorophyll content at panicle emergence stage

Treatments	Relative leaf water content (%)	Proline content (μmol g $^{-1}$ FW)	Chlorophyll content (mg g^{-1} FW)
I X M interaction			
i_1m_1	79.03	0.41	1.03
i_1m_2	81.60	0.44	1.04
i_2m_1	79.64	0.43	0.96
i_2m_2	80.72	0.45	0.98
i_3m_1	79.05	0.44	0.98
i_3m_2	79.88	0.46	1.03
i_4m_1	78.82	0.42	0.99
i_4m_2	80.13	0.43	0.99
i_5m_1	77.73	0.46	1.02
i_5m_2	80.38	0.47	1.03
i_6m_1	77.13	0.72	1.02
i_6m_2	77.59	0.74	1.01
i_7m_1	71.50	0.93	0.98
i_7m_2	73.86	0.94	1.00
SEm(±)	2.47	0.04	0.02
CD (0.05)	NS	NS	NS

Mulching, though not significant M_2 (live mulching with cowpea) recorded the highest value (79.16 per cent). The interaction effect was not significant.

4.3.2 Proline Content at Panicle Emergence Stage

The data on proline content at panicle emergence stage are presented in Table 8a and 8b.

The treatment I_7 (rainfed control) registered the highest proline content of 0.94 μmol g^{-1} and was superior to rest of the treatments. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the lowest value (0.42 μmol g^{-1}).

Mulching and combined application of irrigation and mulching had no significant influence on proline content.

4.3.3 Chlorophyll Content of Leaves at Panicle Emergence Stage

The data on chlorophyll content at panicle emergence stage are presented in Table 8a and 8b. The results revealed that no significant difference between irrigation (I), mulching (M) and their interaction.

4.3.4 Uptake of Nitrogen

The data on uptake of nitrogen at harvest are presented in Table 9a and 9b. The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest N uptake (66.60 kg ha^{-1}) and was on par with I_4. The treatment I_7 (rainfed control) registered the minimum value of 49.31 kg ha^{-1}.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest N uptake (61.61 kg ha^{-1}) and was superior to the non mulched treatment (M_1).

The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) registered highest N uptake (70.57 kg ha^{-1}) and was on par

Table 9a. Effect of irrigation and mulching on NPK uptake, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
I_1	66.60	16.05	79.08
I_2	59.16	13.53	73.41
I_3	53.39	10.86	68.26
I_4	66.29	14.55	75.05
I_5	57.69	11.86	71.33
I_6	55.73	10.08	64.34
I_7	49.31	8.25	60.30
SEm(±)	0.38	0.11	0.45
CD (0.05)	1.105	0.213	1.317
Live Mulching (M)			
M_1	55.01	11.43	69.10
M_2	61.61	12.91	71.40
SEm(±)	0.20	0.06	0.24
CD (0.05)	0.591	0.115	0.704

Table 9b. Interaction effect of irrigation and mulching on NPK uptake, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
I X M interaction			
i_1m_1	62.62	15.08	77.43
i_1m_2	70.57	17.03	80.72
i_2m_1	53.90	12.86	72.26
i_2m_2	64.42	14.20	74.57
i_3m_1	51.69	10.20	66.99
i_3m_2	54.43	11.53	69.53
i_4m_1	62.93	14.06	73.74
i_4m_2	69.65	15.03	76.36
i_5m_1	52.86	10.90	70.43
i_5m_2	62.53	12.83	72.24
i_6m_1	52.03	9.21	63.32
i_6m_2	59.42	10.95	65.35
i_7m_1	48.34	7.72	59.56
i_7m_2	50.27	8.77	61.04
SEm(±)	0.54	0.15	0.64
CD (0.05)	1.563	0.300	NS

with i_4m_2. The minimum value of 48.34 kg ha^{-1} was recorded by i_7m_1 (rainfed control and no live mulching).

4.3.5 Uptake of Phosphorus

The data on uptake of phosphorus at harvest are presented in Table 9a and 9b. The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest P uptake (16.05 kg ha^{-1}) and was superior to rest of the treatments. The treatment I_7 (rainfed control) registered the lowest value of 8.25 kg ha^{-1}.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest P uptake (12.91 kg ha^{-1}) and was superior to the non mulched treatment (M_1).

The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) registered the highest P uptake (17.03 kg ha^{-1}). The lowest value of 7.72 kg ha^{-1}was recorded by i_7m_1 (rainfed control and no live mulching).

4.3.6 Uptake of Potassium

The data on uptake of potassium at harvest are presented in Table 9a and 9b. The results revealed significant difference between irrigation (I) and mulching (M). The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest K uptake (79.08 kg ha^{-1}) and was superior to rest of the treatments. The treatment I_4 (irrigation at 2 cm depth at 10 mm CPE) recorded the next highest K uptake of 75.05 kg ha^{-1} and was significantly superior to rest of the treatments. The treatment I_7 (rainfed control) registered the lowest value of 60.30 kg ha^{-1}.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest K uptake (71.40 kg ha^{-1}) and was superior to the non mulched treatment (M_1).The interaction effect was not significant.

4.4 ROOT STUDIES AT HARVEST

4.4.1 Root Length

The result on Table 10a and 10b indicates that treatments differed significantly on root length. The irrigation treatment I_7 (rainfed control) recorded the highest root length (14.35 cm) and was on par with the treatments I_3, I_5 and I_6. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the lowest value of 10.91 cm.

Among the mulches, the treatment M_2 (live mulching with cowpea) recorded the highest value (13.34 cm) and was superior to the non mulched treatment (M_1). The interaction between irrigation and live mulching with cowpea was not significant.

4.4.2 Root Volume

The result on Table 10a and 10b indicates that treatments differed significantly on root volume. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest root volume of 8.50 cm^3 and was on par with I_2 and I_3. The treatment I_7 (rainfed control) recorded the lowest root volume of 6.35 cm^3.

Mulching, though not significant M_2 (live mulching with cowpea) recorded the highest root volume (7.47 cm^3). Interaction effect was not significant.

4.4.3 Root Weight

The result on Table 10a and 10b indicates that treatments differed significantly on root weight. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest root weight (3.50 g) and was on par with the treatments I_3, I_4 and I_5. The treatment I_6 (irrigation at 2 cm depth at 30 mm CPE)) recorded the lowest root weight (2.17 g).

Mulching, though not significant M_2 (live mulching with cowpea) recorded the highest root weight (3.01 g). Interaction effect was not significant.

Table 10a. Effect of irrigation and mulching on root length, root volume, root weight and root shoot ratio

Treatments	Root length (cm)	Root volume (cm^3)	Root weight (g)	Root shoot ratio
Irrigation (I)				
I_1	10.91	8.50	3.50	0.23
I_2	12.46	7.95	2.86	0.19
I_3	13.05	7.73	3.32	0.20
I_4	11.62	7.18	3.05	0.22
I_5	13.25	6.82	3.02	0.22
I_6	13.99	6.56	2.17	0.19
I_7	14.35	6.35	2.19	0.18
SEm(±)	0.48	0.16	0.20	0.03
CD (0.05)	1.402	0.973	0.576	0.039
Live Mulching (M)				
M_1	12.27	7.11	2.73	0.19
M_2	13.34	7.47	3.01	0.23
SEm(±)	0.26	0.17	0.11	0.02
CD (0.05)	0.756	NS	NS	0.016

Table 10b. Interaction effect of irrigation and mulching on root length, root volume, root weight and root shoot ratio

Treatments	Root length (cm)	Root volume (cm^3)	Root weight (g)	Root shoot ratio
I X M interaction				
i_1m_1	10.75	8.25	3.46	0.19
i_1m_2	11.09	8.75	3.56	0.27
i_2m_1	11.51	7.51	2.79	0.21
i_2m_2	13.40	8.38	2.91	0.18
i_3m_1	12.41	7.45	3.29	0.17
i_3m_2	13.69	8.00	3.34	0.22
i_4m_1	10.33	6.87	2.93	0.18
i_4m_2	12.91	7.50	3.16	0.24
i_5m_1	12.50	6.80	2.65	0.21
i_5m_2	13.98	6.83	3.38	0.24
i_6m_1	14.00	6.62	2.16	0.17
i_6m_2	13.96	6.50	2.20	0.23
i_7m_1	14.33	6.33	1.87	0.16
i_7m_2	14.36	6.37	2.53	0.19
SEm(±)	0.69	0.47	0.28	0.04
CD (0.05)	NS	NS	NS	NS

4.4.4 Root Shoot Ratio

The result on Table 10a and 10b indicates that treatments differed significantly on root shoot ratio. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest root shoot ratio (0.23) and was on par with all the treatments except I_7. The treatment I_7 (rainfed control) recorded the lowest root shoot ratio (0.18).

Among the mulches, M_2 (live mulching with cowpea) recorded the highest root shoot ratio (0.23) and was superior to the non mulched treatment (M_1).The interaction between irrigation and live mulching with cowpea was not significant.

4.6. SOIL MOISTURE ESTIMATION

4.6.1 Consumptive use

The data on consumptive use are presented in Table 11a and 11b.The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest consumptive use (778 mm) and was superior to rest of the treatments. The treatment I_4 (irrigation at 2 cm depth at 10 mm CPE) recorded the next highest value of 733 mm and was superior to rest of the treatments. The treatment I_7 (rainfed control) recorded the lowest value of 394 mm.

Among the mulches, mulched treatment (M_2) recorded the highest consumptive use (604 mm) and was superior to the treatment M_1.

The interaction i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest value of 796 mm and was superior to rest the treatments. The lowest value of 394 mm was recorded by i_7m_1 (rainfed control and no live mulching) and was on par with i_7m_2 (rainfed control and live mulching).

Table 11a. Effect of irrigation and mulching on consumptive use and water use efficiency

Treatments	Consumptive use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
Irrigation (I)		
I_1	778	2.94
I_2	595	3.54
I_3	547	3.71
I_4	733	3.32
I_5	581	3.72
I_6	538	3.58
I_7	394	3.09
SEm(±)	1.42	0.02
CD (0.05)	4.154	0.072
Live Mulching (M)		
M_1	587	3.34
M_2	604	3.51
SEm(±)	0.76	0.01
CD (0.05)	2.223	0.048

Table 11b. Interaction effect of irrigation and mulching on consumptive use and water use efficiency

Treatments	Consumptive use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
I X M interaction		
i_1m_1	761	2.83
i_1m_2	796	3.04
i_2m_1	589	3.51
i_2m_2	601	3.56
i_3m_1	545	3.67
i_3m_2	548	3.77
i_4m_1	709	3.26
i_4m_2	756	3.40
i_5m_1	573	3.60
i_5m_2	590	3.86
i_6m_1	535	3.45
i_6m_2	540	3.70
i_7m_1	394	3.01
i_7m_2	394	3.18
SEm(±)	2.02	0.02
CD (0.05)	5.883	NS

4.6.2 Irrigation requirement

The data on irrigation requirement are presented in the table 12.

4.6.3 Water use efficiency

The data on water use efficiency are presented in Table 11a and 11b. The results revealed significant difference between irrigation (I) and mulching (M).The treatment I_5 (irrigation at 2 cm depth at 20 mm CPE) registered the highest water use efficiency (3.72 kg ha^{-1} mm^{-1}) and was on par with I_3 (irrigation at 3 cm depth at 30 mm CPE). The treatment I_1 (irrigation at 3 cm depth at 10mm CPE) recorded the lowest value of 2.94 kg ha^{-1} mm^{-1}.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest water use efficiency (3.51 kg ha^{-1} mm^{-1}) and was superior to the non mulched treatment (M_1). The interaction effect was not significant.

4.7 SOIL PROPERTIES

4.7.1 Bulk Density

The data on bulk density of soil after the experiment are presented in Table 13a and 13b.The results revealed that no significant difference between irrigation (I), mulching (M) and their interaction.

4.7.2 Water holding capacity

The data on water holding capacity are presented in Table 13a and 13b.The results revealed that no significant difference between irrigation (I), mulching (M) and their interaction.

Table 12. Details of Irrigation requirement , mm

Treatments	Quantity of water applied	Pre sowing irrigation	Common irrigation	Effective rainfall	Total quantity of water used
I_1	510	10	10	475	1005
I_2	240	10	10	475	735
I_3	120	10	10	475	615
I_4	340	10	10	475	835
I_5	160	10	10	475	655
I_6	80	10	10	475	575
I_7	-	10	10	475	495

Table 13a. Effect of irrigation and mulching on bulk density and water holding capacity of the soil after the experiment

Treatments	Bulk density ($Mg\ m^{-3}$)	Water holding capacity (%)
Irrigation (I)		
I_1	1.47	23.30
I_2	1.46	23.11
I_3	1.48	21.24
I_4	1.46	22.38
I_5	1.46	21.80
I_6	1.47	21.37
I_7	1.50	21.08
SEm(±)	0.01	0.73
CD (0.05)	NS	NS
Live Mulching (M)		
M_1	1.48	21.71
M_2	1.47	22.37
SEm(±)	0.01	0.39
CD (0.05)	NS	NS

Table 13b. Interaction effect of irrigation and mulching on bulk density and water holding capacity of the soil after the experiment

Treatments	Bulk density ($Mg\ m^{-3}$)	Water holding capacity (%)
I X M interaction		
i_1m_1	1.47	22.39
i_1m_2	1.46	24.20
i_2m_1	1.47	22.05
i_2m_2	1.45	24.16
i_3m_1	1.48	21.11
i_3m_2	1.48	21.37
i_4m_1	1.47	22.12
i_4m_2	1.46	22.63
i_5m_1	1.47	21.82
i_5m_2	1.45	21.77
i_6m_1	1.47	20.82
i_6m_2	1.48	21.93
i_7m_1	1.50	20.85
i_7m_2	1.49	21.30
SEm(±)	0.02	1.03
CD (0.05)	NS	NS

4.7.3 Soil Organic Carbon

The data on soil organic carbon after harvest are presented in Table 14a and 14b.The results revealed that no significant difference between irrigation (I), mulching (M) and their interaction.

4.6.2 Available Nitrogen

The data on available nitrogen after harvest are presented in Table 14a and 14b.The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_7 (rainfed control) registered the highest available nitrogen (131.67 kg ha^{-1}) and was superior to rest of the treatments. I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the lowest value of 102.24 kg ha^{-1}.

Among the mulching treatments, live mulching with cowpea (M_2) recorded the highest available nitrogen (121.85 kg ha^{-1}).

The interaction i_7m_2 (rainfed control and live mulching with cowpea) recorded the highest value of 135.76 kg ha^{-1} and was superior to rest of the treatments. The lowest value of 92.88 kg ha^{-1} was recorded by i_1m_1 (irrigation at 3 cm depth at 10 mm CPE and no live mulching).

4.6.2 Available Phosphorus

The data on available phosphorus after harvest are presented in Table 14a and 14b.The results revealed significant difference between irrigation (I), mulching (M). The treatment I_7 (rainfed control) registered the highest available phosphorus (39.04 kg ha^{-1}) and was on par with I_6 and I_5. I_1 (irrigation at 3 cm depth at 10mm CPE) recorded the lowest value of 32.53 kg ha^{-1}.

Mulching and the interaction between irrigation and mulching had no significant effect.

Table 14a. Effect of irrigation and mulching on organic carbon, available NPK of the soil after the experiment

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Irrigation (I)				
I_1	0.64	102.24	32.53	235.71
I_2	0.64	111.09	32.68	270.00
I_3	0.62	121.86	32.98	293.00
I_4	0.61	107.79	33.18	254.38
I_5	0.63	119.12	36.11	272.66
I_6	0.62	126.61	37.77	325.57
I_7	0.61	131.67	39.04	351.58
SEm(±)	0.02	0.73	1.33	1.08
CD (0.05)	NS	2.130	3.906	3.174
Live Mulching (M)				
M_1	0.62	112.54	34.29	281.30
M_2	0.63	121.85	35.50	290.96
SEm(±)	0.01	0.39	0.71	0.59
CD (0.05)	NS	1.136	NS	1.694

Table 14b. Interaction effect of irrigation and mulching on organic carbon, available NPK of the soil after the experiment

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
I X M interaction				
i_1m_1	0.64	92.88	31.88	232.40
i_1m_2	0.65	111.59	33.16	239.01
i_2m_1	0.63	107.63	31.64	263.83
i_2m_2	0.64	114.57	33.72	276.16
i_3m_1	0.62	119.14	32.65	287.84
i_3m_2	0.63	124.59	33.32	298.14
i_4m_1	0.61	101.54	32.57	251.29
i_4m_2	0.62	114.06	33.79	257.45
i_5m_1	0.62	116.02	35.44	269.25
i_5m_2	0.63	122.23	36.79	276.08
i_6m_1	0.61	123.06	37.23	319.39
i_6m_2	0.63	130.14	38.31	331.74
i_7m_1	0.60	127.57	38.65	345.04
i_7m_2	0.61	135.76	39.43	358.14
SEm(±)	0.03	1.03	1.90	1.55
CD (0.05)	NS	3.011	NS	4.494

4.6.2 Available Potassium

The data on available potassium after harvest are presented in Table 14a and 14b. The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_7 (rainfed control) registered the highest available potassium (351.58 kg ha^{-1}) and was superior to rest of the treatments. I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the lowest value of 235.71 kg ha^{-1}.

Among the mulching treatments, live mulching with cowpea (M_2) recorded the highest available potassium (290.96 kg ha^{-1}).

The interaction i_7m_2 (rainfed control and live mulching with cowpea) recorded the highest value of 358.14 kg ha^{-1} and was superior to rest of the treatments. The lowest value of 232.40 kg ha^{-1} was recorded by i_1m_1 (irrigation at 3 cm depth at 10 mm CPE and no live mulching).

4.7 MAJOR WEEDS OF UPLAND RICE

4.7.1 Major weed species

Major graminaceous weed found in experimental *plots was Setaria barbata. Borreria hispida, Urena lobata and Cleome* spp. were the dominant broad leaved species.

4.7.2 Weed Dry Weight

The data on weed dry weight after mulching with cowpea are presented in Table 15. The results revealed significant difference between irrigation (I), mulching (M) and their interaction. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest weed dry weight (26.77g m^{-2}) and was on par with I_4. I_7 (rainfed control) recorded the lowest value of 19.71 g m^{-2}.

Table 15. Effect of irrigation and mulching on weed dry weight

Treatments	Weed dry weight
Irrigation (I)	
I_1	26.77
I_2	25.45
I_3	22.95
I_4	26.21
I_5	22.10
I_6	20.85
I_7	19.71
SEm(±)	0.06
CD (0.05)	0.601
Live Mulching (M)	
M_1	30.14
M_2	16.73
SEm(±)	0.02
CD (0.05)	0.329
Interaction (I x M)	
i_1m_1	35.56
i_1m_2	17.98
i_2m_1	34.02
i_2m_2	16.88
i_3m_1	29.10
i_3m_2	16.81
i_4m_1	35.02
i_4m_2	17.42
i_5m_1	28.04
i_5m_2	16.15
i_6m_1	26.17
i_6m_2	15.53
i_7m_1	23.12
i_7m_2	16.32
SEm(±)	0.30
CD (0.05)	0.851

Among the mulching treatments, non mulched treatment (M_2) recorded the highest weed dry weight (30.14 g m^{-2}).

The interaction i_1m_1 (irrigation at 3 cm depth at 10 mm CPE and no live mulching) recorded the highest value of 35.56 g m^{-2} and was on par with i_4m_1. The lowest value of 15.53 was recorded by I_6m_2 (irrigation at 2 cm depth at 30 mm CPE and live mulching with cowpea).

4.8 PEST AND DISEASE INCIDENCE

The major pests observed in the field were leaf roller and earhead bug. The important diseases observed were sheath blight and blast. The incidence of pest and diseases never reached the threshold level and hence uniform score was given to all plots.

4.9 ECONOMIC ANALYSIS

The data on economics of cultivation are presented in Table 16a and 16b. The results revealed significant difference between irrigation (I), mulching (M) and their interaction.

The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest net income (₹22025 ha^{-1}) and was on par with I_2 and I_4 .The treatment I_7 (rainfed control) recorded the lowest value of ₹1151 ha^{-1}.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest net income (₹17105 ha^{-1}) and was superior to the non mulched treatment (M_1).

The interaction i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest value of ₹ 25195 ha^{-1} and was on par with i_4m_2 (₹ 23274 ha^{-1}) suggesting that i_4m_2 is as good as i_1m_2 for net income. The lowest value of ₹ 666 ha^{-1} was recorded by i_7m_1 (rainfed control and no live mulching).

With regard to benefit-cost ratio, the treatment I_2 (irrigation at 3 cm depth at 20mm CPE) registered the highest value (1.44) and was on par with I_4 and I_1.The treatment I_7 (rainfed control) recorded the lowest value of 1.03.

Among the mulching treatments, M_2 (live mulching with cowpea) recorded the highest value (1.35) and was superior to the non mulched treatment (M_1).

The interaction i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest value of 1.46 and was on par with i_2m_1,i_2m_2 i_4m_2 and i_5m_2 suggesting that irrigation at 2 cm depth at 20 mm CPE with live mulching of cowpea is as good as i_1m_2. The lowest value of 1.01 was recorded by i_7m_1 (rainfed control and no live mulching).

Table 16a. Effect of irrigation and mulching on net income and benefit cost ratio

Treatments	Net income (₹)	BCR
Irrigation (I)		
I_1	22025	1.41
I_2	20979	1.44
I_3	15257	1.34
I_4	21807	1.42
I_5	18207	1.39
I_6	10594	1.23
I_7	1151	1.03
SEm(±)	473.05	0.02
CD (0.05)	1375.461	0.031
Live Mulching (M)		
M_1	14329	1.29
M_2	17105	1.35
SEm(±)	252.86	0.01
CD (0.05)	735.214	0.011

Table 16b. Interaction effect of irrigation and mulching on net income and benefit cost ratio

Treatments	Cost of cultivation (₹)	Gross income (₹)	Net income (₹)	BCR
i_1m_1	54511	73365	18854	1.35
i_1m_2	54889	80084	25195	1.46
i_2m_1	47708	68348	20640	1.45
i_2m_2	48086	69403	21317	1.44
i_3m_1	44684	59310	14520	1.33
i_3m_2	45062	61056	15994	1.35
i_4m_1	51298	71638	20340	1.39
i_4m_2	51676	74950	23274	1.45
i_5m_1	46196	62509	16313	1.36
i_5m_2	46574	66676	20102	1.43
i_6m_1	43929	52898	8969	1.20
I_6m_2	44307	56525	12218	1.27
I_7m_1	40861	41527	666	1.01
I_7m_2	42039	43675	1636	1.04
SEm(±)			669.00	0.04
CD (0.05)			1945.200	0.046

DISCUSSION

5. DISCUSSION

The results from the study on "Irrigation scheduling and live mulching in upland rice (*Oryza sativa* L.)" as presented in the previous chapter are briefly discussed here under.

5.1 GROWTH CHARACTERS

Statistical analysis of data (Tables 3a, 3b, 4a and 4b) revealed that plant height at 30 DAS, 60 DAS and harvest, tiller number m^{-2} at 60 DAS, LAI at 60 DAS and DMP at harvest were favourably influenced by the treatments.

Irrigation treatments significantly influenced the growth characters, viz., plant height, tiller number m^{-2}, LAI and DMP. The profound influence of irrigation on growth parameters was observed in a period of 15 days from the date of application of irrigation treatments which coincided with the period of active vegetative growth in upland rice.

Water is the most important natural resource influencing the growth and yield of upland rice. It is a scarce resource which has to be judiciously used for crop production. It is a universal solvent and a major constituent of protoplasm (75-80 per cent) which is regarded as the "physiological basis of life". Plant growth is a function of increased turgidity of cells due to high soil moisture availability leading to cell expansion and cell division - the two vital processes. Low available soil moisture or water stress adversely affected the above processes and retarded plant growth. Under stress, reduction in turgor pressure caused severely impaired cell growth and adversely affected elongation as well as expansion (Shao *et al.*, 2008) and inhibited cell enlargement more than cell division (Jaleel *et al.*, 2009). Decrease in plant height in treatments receiving irrigations at wider intervals could be attributed to the adverse effect of water stress. Plant height increased progressively in all treatments with advancement in growth stage. This is in agreement with the findings of Jolly (2016) in upland rice. At 60 DAS, I_1 (irrigation at 3 cm depth at 10 mm CPE) produced the tallest

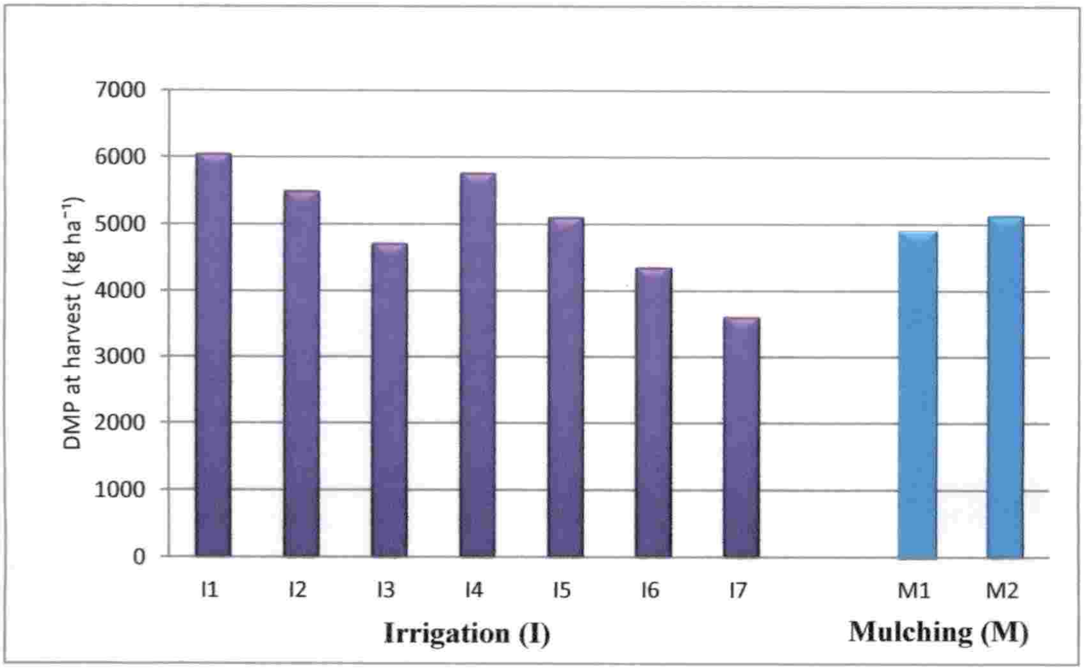


Fig.3 Effect of irrigation and mulching on dry matter production at harvest

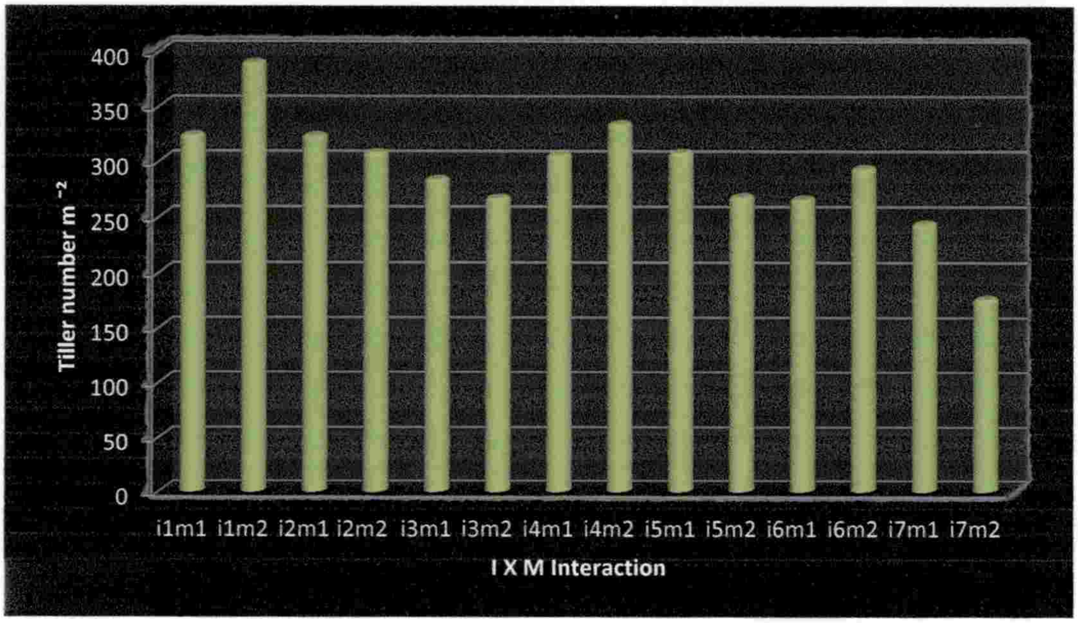


Fig.4 Interaction effect of irrigation and mulching on tiller number m^{-2}

plants compared to rainfed control. At harvest. I_4 (irrigation at 2 cm depth at 10 mm CPE) produced taller plants compared to rainfed control, the percentage increase being 28.90. It is clear from table 3a that at 60 DAS, M_1 (non mulched treatment) produced taller plants and at harvest there was no significant difference between treatments on plant height. At later stages of growth (after 30 DAS) cowpea was growing faster than upland rice and might have produced shorter plants of upland rice.

Irrigation treatments had a significant effect on tiller production at 60 DAS. Irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) produced the highest tiller number. Frequent irrigations were found to produce more tillers as compared to wider irrigation interval. The favourable influence of irrigation might be due to the continuous and uniform availability of soil moisture which increased cell turgidity and cell division (Begg and Turner, 1976). Moisture stress during vegetative phase resulted in reduced tiller number and this might be attributed to the higher physiological activity during this period as reported by Sheela (1993) and Thomas (2000). Mulched treatments did not exert any significant influence on tiller number. The interaction effect due to irrigation and mulching was significant on tiller production. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) produced the highest tiller number indicating the positive effect of irrigation and mulching on tiller production. Higher moisture content of soil due to frequent irrigation coupled with improved physical and chemical properties of the soil, higher water holding capacity and organic matter content of the soil due to mulching might have promoted tiller production. Similar findings were reported by Thomas (2000), Ranjini (2002) and Kumar (2016).

Irrigation levels were found to have significant influence on the LAI at 60 DAS. Irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) produced the highest LAI as compared to wider irrigation intervals. The increase in LAI at 60 DAS due to frequent irrigation could be attributed to the marked increase in leaf area through its favourable influence on leaf size and leaf number. This is in agreement with the findings of Sheela (1993) and Thomas (2000). Mulching did not exert a significant influence on leaf area index.

Dry matter accumulation is an important character which expresses the photosynthetic efficiency of plants and influences the yield of a crop. It is a direct index of plant proliferation. In rice, water uptake and dry matter production in shoot were largely suppressed under severe water stress compared with mild stress. Crop canopy decreased with increased soil moisture stress. The irrigation treatment 3 cm depth at 10 mm CPE (I_1) produced the highest dry matter production. It decreased with decreasing the amount of water applied. The dry matter production is influenced more by moisture supply than by nutrients and is considered to be the most sensitive index for water supply. There was severe reduction in growth characters under water stress situation especially under rainfed condition which inturn reduced the DMP. Higher source production due to frequent irrigation enhanced the photosynthetic efficiency of the crop leading to more photosynthate production and its subsequent translocation from source to the sink resulting in increased DMP. Similar findings were reported by Sheela (1993), Geetha (1999) and Thomas (2000). Mulching had a significant influence on dry matter production. Live mulching with cowpea (M_2) resulted in higher DMP at harvest and this could be attributed to increased soil moisture which was utilized for tiller production coupled with improved photosynthesis.

5.2 YIELD ATTRIBUTES AND YIELD

Statistical analysis of data (Tables 5a, 5b, 6a, 6b, 7a and 7b) revealed that number of productive tillers m^{-2}, length of panicle, weight of panicle, number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, thousand grain weight, grain yield, straw yield, harvest index and sterility percentage were favourably influenced by the treatments.

Irrigation had a significant influence on yield attributing characters like number of productive tillers m^{-2}, length of panicle, weight of panicle, number of spikelets

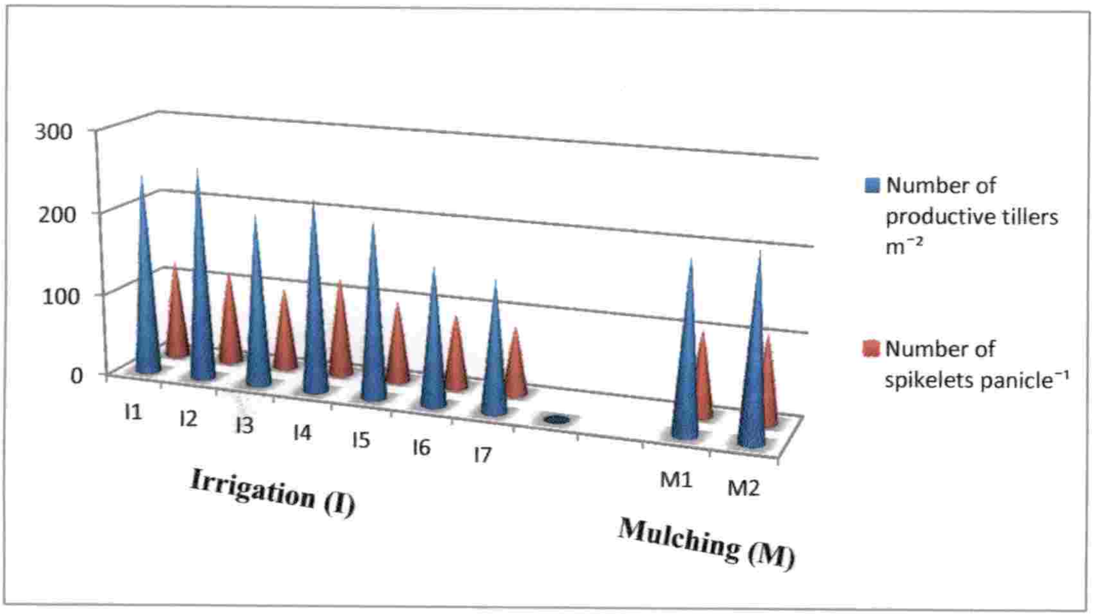


Fig. 5 Effect of irrigation and mulching on number of productive tillers m^{-2} and number spikelets $panicle^{-1}$

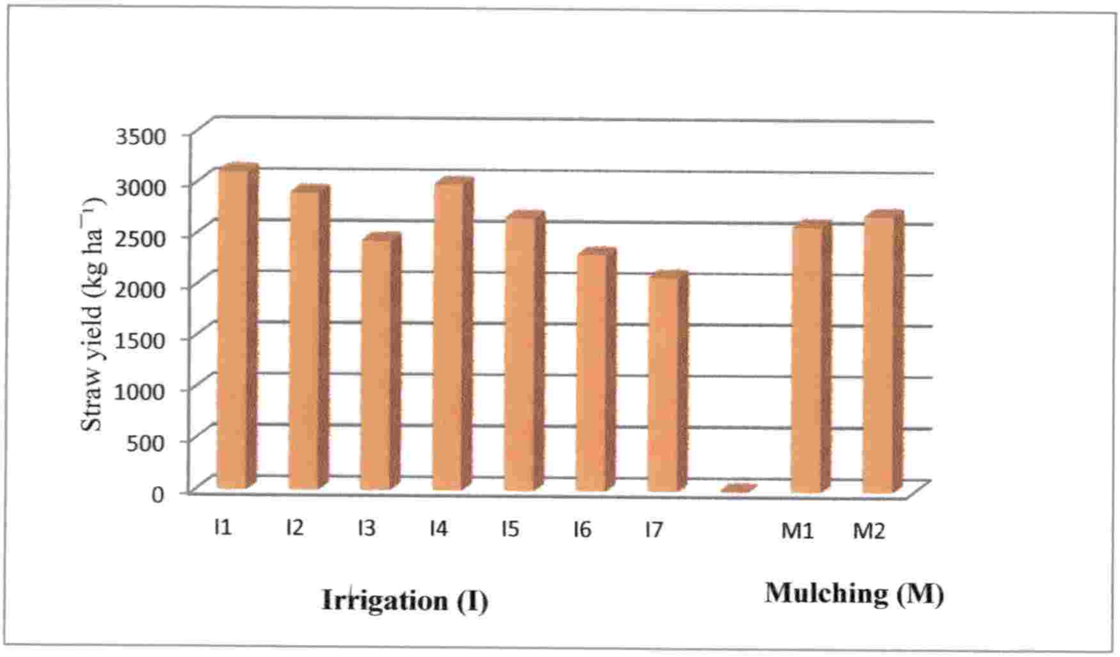


Fig.6 Effect of irrigation and mulching on straw yield

panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight. Frequent irrigation treatments recorded the highest value for all the yield attributing characters. There was a significant reduction in all these characters for wider irrigation treatments. This might be due to higher soil moisture stress for wider irrigation treatments. Soil moisture stress during tilleing stages resulted in significant reduction in panicle number, while stress during panicle development stage reduced the percentage of filled grains (Sudhakar *et al.*, 1989). Moisture stress showed an inhibitory effect on panicle emergence and development of yield components. Grain sterility is directly related to stress during flowering to ripening stages (Lenka and Garnayak, 1991). The number of productive tillers m^{-2} was higher for the treatment I_2 (irrigation at 3 cm depth at 20 mm CPE). The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest values for length of panicle, weight of panicle, number of filled grains panicle^{-1} and thousand grain weight, while the treatment I_4 (irrigation at 2 cm depth at 10 mm CPE) produced the highest number of spikelets panicle^{-1} indicating that frequent and deeper irrigations favourably influenced the yield attributes. Water stress retarded carbohydrate synthesis and weakened the sink strength at reproductive stages and abortion of fertilized ovaries (Rahman *et al.*, 2002).Water stress at flowering resulted in flower abortion, grain abscission and increasing of percentage of unfilled grain (Hsiao *et al.*, 1976). The production of more photosynthates at frequent irrigation and their subsequent translocation from source to sink might have resulted in the development of favourable yield attributes. Kumar *et al.* (2006) and Shekara *et al.* (2010) expressed similar views in rice. Mulching treatments exerted a positive influence on yield attributes. The treatment M_2 (live mulching with cowpea) recorded the highest value for number of productive tillers m^{-2}. Mulching enhanced the soil physical, chemical and biological properties, increased soil water holding capacity, increased soil organic matter status, lowered soil bulk density and increased the nutrient uptake and there by favourably influenced the yield attributes. Similar reports were published by Ranjini (2002) and Kumar (2016).

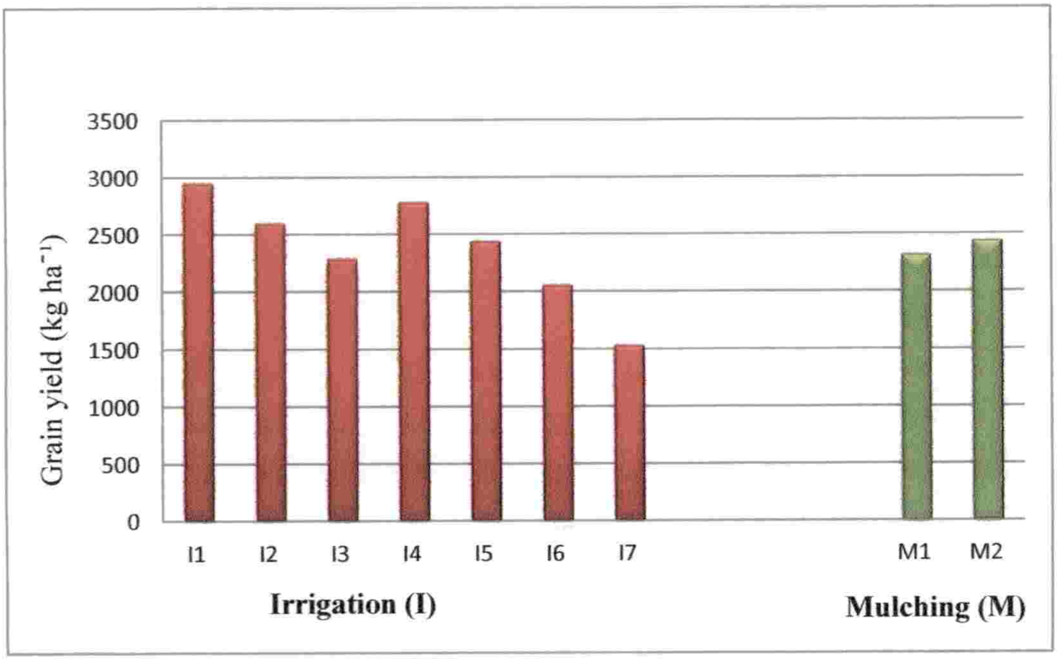


Fig.7 Effect of irrigation and mulching on grain yield

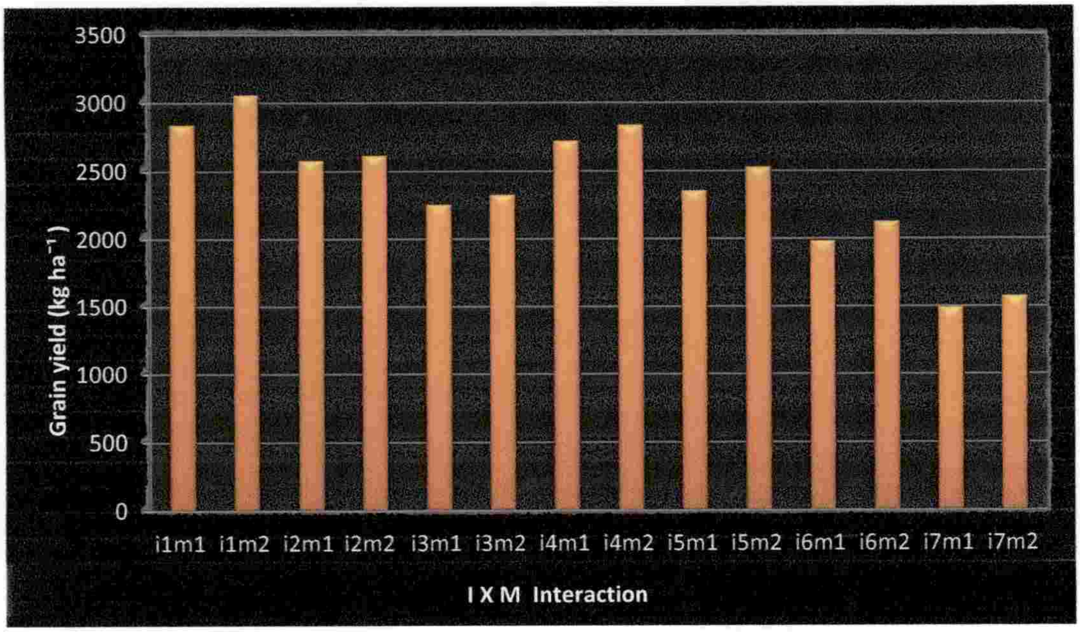


Fig.8 Interaction effect of irrigation and mulching on grain yield

Irrigation treatments had a significant influence on the grain and straw yield. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) produced the highest grain and straw yields which were significantly superior to other irrigation treatments. The treatment I_1 resulted in 92.4 per cent increase in grain yield compared to rainfed control (I_7). The reduction in yield at wider irrigation treatment might be due to the severe moisture stress experienced especially during tillering and panicle initiation stage. The marked influence of frequent and deep irrigation on yield attributes like number of length of panicle, weight of panicle, number of filled grains panicle^{-1} and thousand grain weight resulted in higher grain yield. It was reported that yield reduction under moisture stress was mainly attributable to the higher number of unfilled grains. Yield is the ultimate manifestation of the yield attributes. Soil wetness favourably influenced the yield attributes and there by yield. Grain yield is influenced by higher photosynthates production in the source, increased translocation of photosynthates from source to the sink and increased capacity of the sink to accept the photosynthates. This is in agreement with the findings of Sheela (1993) and Thomas (2000). Grain and straw yield were favourably influenced by M_2 (live mulching with cowpea) .Yield increase by mulching was due to high moisture content, increased microbial activity, higher organic matter status and nutrients mobility (Chonbeck and Evanylo, 1998). Combined application of irrigation and mulching favourably influenced the grain yield. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest grain yield. The increased soil moisture content due to deeper and frequent irrigation combined with high water holding capacity of the mulches helped in maintaining uniform moisture supply throughout the crop period and resulted in high nutrient uptake and dry matter production and this could have manifested in higher grain yield.

The maximum harvest index of 0.49 was reported by the treatment I_1 (irrigation at 3 cm depth at 10 mm CPE). Mulching did not have a significant influence on harvest index.

5.3 PHYSIOLOGICAL AND CHEMICAL ESTIMATION

Statistical analysis of data (Tables 8a, 8b, 9a and 9b) revealed that relative leaf water content, proline content, chlorophyll content and NPK uptake were favourably influenced by the treatments. Irrigation had a favourable influence on physiological characters like RLWC and proline content.

The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) produced the highest RLWC. RLWC is an expression of internal water status in plant tissues. High moisture content in the soil due to frequent irrigation resulted in greater absorption of water by roots and thereby maintained high water content in the plant tissues. This is in conformity with the findings of Sheela (1993). Though not significant, mulching with cowpea maintained high RLWC. The higher water holding capacity in the soil due to mulching coupled with improved physical properties of the soil helped the plant to extract more water in the soil leading to high RLWC. This is in agreement with the findings of Kumar (2016) and Ranjini (2002).

The rainfed treatment recorded the highest proline content. Proline accumulation in the leaves of water stressed plants may play a role as stress indicator. It is one of the most important osmolytes that accumulate in plants experiencing drought stress (Yoshiba *et al.,* 1997). Proline accumulation under stress supplied energy for survival and growth and thereby helped the plants to tolerate stress condition (Kumar *et al.*, 2011). Besides acting as an excellent osmolyte, proline plays three major roles during stress, i.e., as a metal chelator, an antioxidative defence molecule and a signaling molecule (Hayat *et al.*, 2012).

There was no effect of irrigation, mulching and their interaction on chlorophyll content. Though not significant, the irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE), M_2 (live mulching with cowpea), i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) registered the highest chlorophyll content.

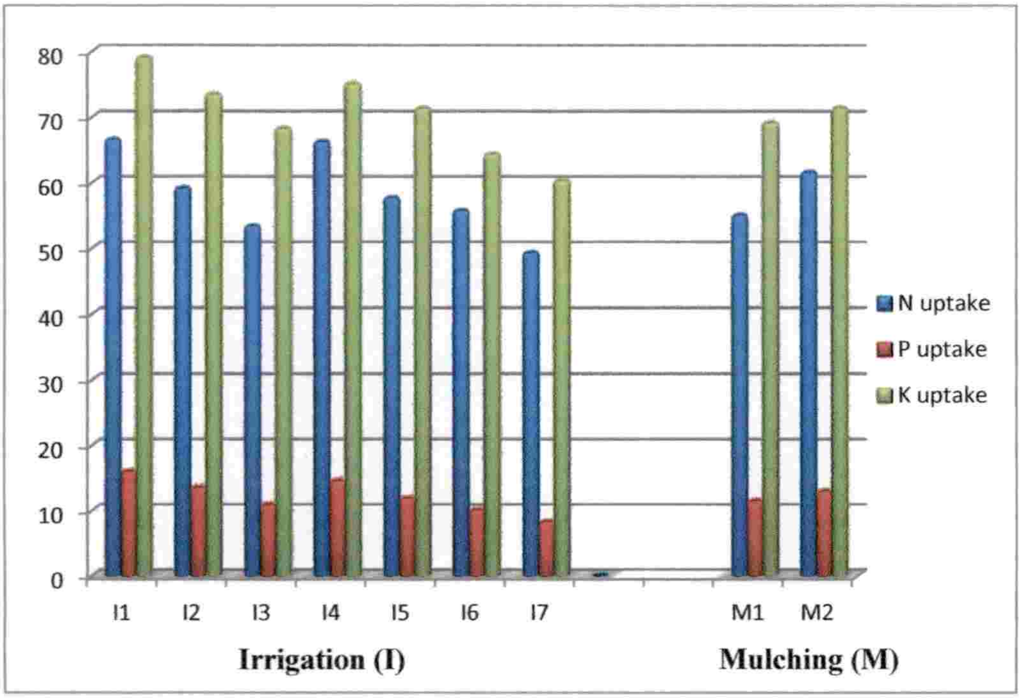


Fig.9 Effect of irrigation and mulching on NPK uptake

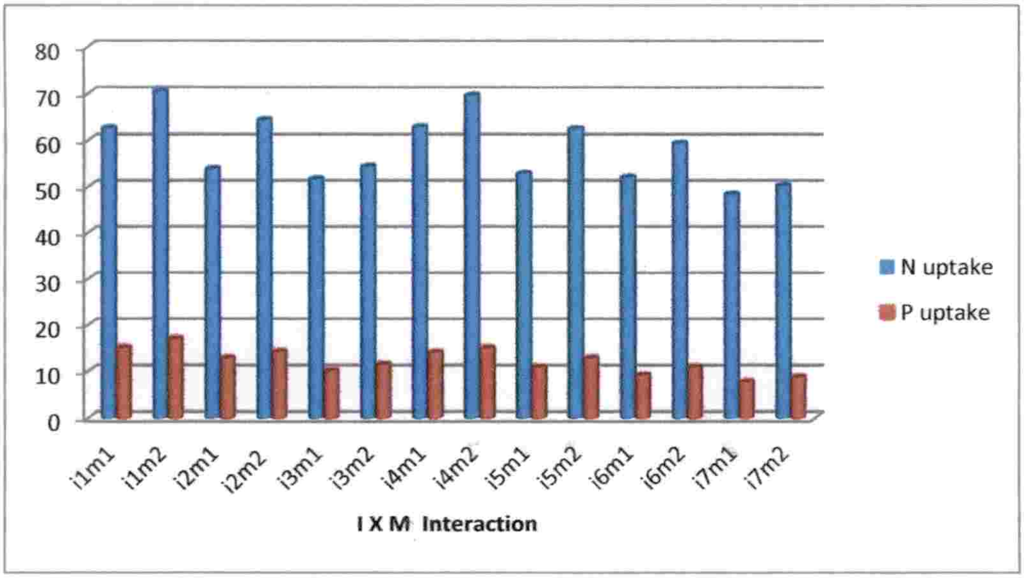


Fig.10 interaction effect of irrigation and mulching on N and P uptake

Irrigation had a significant influence on NPK uptake. Frequent irrigation recorded the highest value for NPK uptake. The irrigation I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest NPK uptake. Higher nutrient uptake in frequent irrigation schedule might have resulted in higher DMP, grain and straw yield and yield attributes. Frequent irrigation increases the wetness of the soil and rendered the nutrients more available and stimulated growth. So the availability of water in the root zone depth of soil is the great significance for the roots to absorb nutrient and the soil to supply them. High root volume and root weight in frequently irrigated treatments helped the plant to absorb more nutrients. Similar findings were reported by Sheela (1993) and Thomas (2000). Mulching had a significant influence on NPK uptake. The treatment M_2 (live mulching with cowpea) recorded highest NPK uptake. The enhanced nutrient availability coupled with high DMP and soil moisture due to mulching resulted in high uptake of NPK. This is in conformity with the findings of Ranjini (2002) and Kumar (2016). The combined effect of irrigation and mulching favourably influenced the nutrient uptake. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest N and P uptake. The prevalence of high moisture content in the soil due to irrigation and mulching combined with high DMP resulted in high nutrient uptake.

5.4 ROOT STUDIES AT HARVEST

Statistical analysis of data (Table 10a and 10b) revealed that root length, root volume, root weight and root shoot ratio were favourably influenced by the treatments.

The irrigation treatment I_7 (rainfed control) recorded the highest root length. Root length increased with treatments receiving irrigation at wider intervals. A decrease in available soil moisture resulted in longer roots and plant themselves play a important role in influencing the availability of soil moisture through their capability to extend roots downward into the soil. The ability of rice plants to tolerate drought stress is associated with root characteristics. Deep roots are a key trait for improving

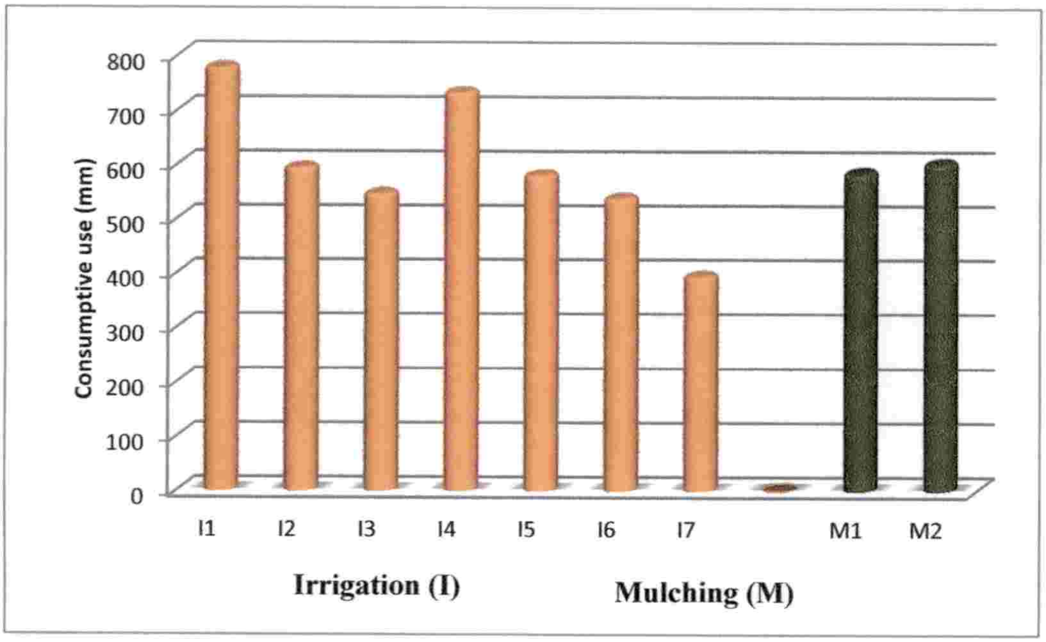


Fig. 11 Effect of irrigation and mulching on consumptive use

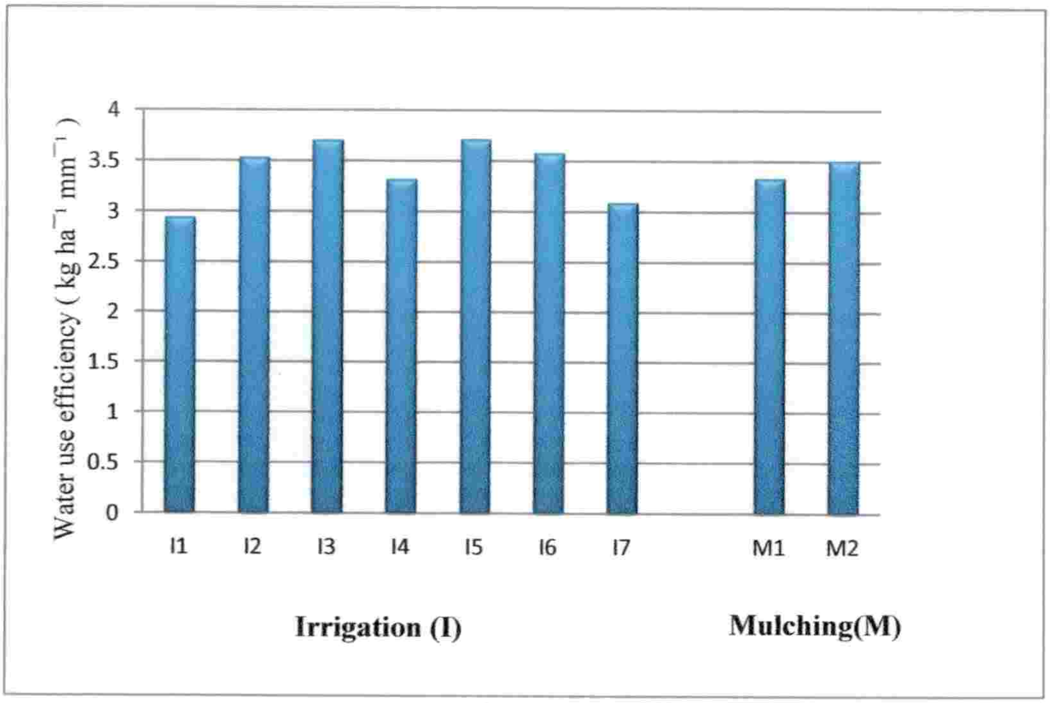


Fig. 12 Effect of irrigation and mulching on water use efficiency

drought resistance in upland rice as they contribute to water uptake from deeper soil layers during drought (Araki and Iijima, 2005). The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest value for root volume, root weight and root shoot ratio. With increase in soil dryness and soil moisture tension the soil offered high degree of resistance that might have resulted in reduced root volume, root weight and root shoot ratio. Similar results were reported by Thomas (2000). Mulching had a significant influence on root length and root shoot ratio. The mulched treatment M_2 recorded the highest value for root characters.

5.5 SOIL MOISTURE ESTIMATION

Statistical analysis of data (Table11a and 11b) revealed that consumptive use and water use efficiency were favourably influenced by the treatments.

Irrigation had a significant influence on soil moisture estimation. Frequent irrigation recorded the highest consumptive use. The irrigation treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest value. The higher values for consumptive use in treatments receiving frequent irrigations might be due to the higher amount of irrigation water provided in the treatment. This is in conformity with the findings of Jolly (2016). In upland rice mulching treatments exerted a positive influence on consumptive use. The treatment M_2 (live mulching with cowpea) recorded the highest consumptive use. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest value for consumptive use. The prevalence of high moisture in the soil due to frequent irrigation and mulching might have contributed to the more water uptake by the crop and hence higher consumptive use. Similar findings were reported by Thomas (2000) and Jolly (2016).

The irrigation treatment I_5 (irrigation at 2 cm depth at 20 mm CPE) recorded the highest water use efficiency. The higher water use efficiency in I_5 might be due to the comparatively higher grain yield and lower quantity of water used compared to other treatments. In wider irrigation treatments, there was low soil moisture content and low leaf area which might have contributed to lower rate of transpiration and higher water use efficiency. Hence lower water use efficiency in frequently irrigated treatments could be attributed to a higher consumptive use of water. This is in conformity with the findings of Kulandaivelu (1990) and Thomas (2000). Mulched treatment exerted a significant influence on WUE. The treatment M_2 (live mulching with cowpea) registered the highest value. The high consumptive use of water in M_2 lowered the water use efficiency in that treatment.

5.6 SOIL PROPERTIES

Statistical analysis of data (Tables13a, 13b, 14a and 14b) revealed that bulk density, water holding capacity and organic carbon content of the soil were not significantly influenced by the treatments. The available NPK contents of the soil were favourably influenced by the treatments.

The irrigation treatments had a significant effect on soil available NPK. The rainfed control (I_7) registered the highest values for available NPK. Due to the lack of sufficient moisture in the rainfed treatment, solubilization of nutrients in the soil was reduced leading to lower nutrient uptake and higher available NPK in the soil. In frequently irrigated treatments like I_1 soil wetness was more leading to more uptake of NPK and low available NPK status of soil. The content of available nutrients in the soil decreased with increasing number of irrigation and moisture availability, which was mainly due to dilution effect as a consequence of increased dry matter production. This is in conformity with the findings of Thomas (2000) in upland rice and Maurya *et al.* (2017) in ground nut. Live mulching with cowpea (M_2) recorded the highest available N and K. Legume based mulches released trapped atmospheric nitrogen and made it available as a biological source of nitrogen in a mulched plot, conserved soil moisture, increased soil organic matter status and improved soil properties and microbial activity thereby supporting mineralization rate and release of nutrient into the soil. This could be the rationale behind the increased nutrient content in the mulched treated plots thereby contributing to better growth, biomass and yield of upland rice. This corroborates with the findings of Awopegba *et al.* (2017) in maize. The treatment combination i_7m_2 (rainfed control and live mulching with cowpea) recorded the highest values for available N and K. The decreased moisture availability in the soil in rainfed control treatment coupled with live mulching of cowpea increased the available nutrients.

5.7 MAJOR WEEDS

Statistical analysis of data (Table15) revealed that weed dry weight was favourably influenced by the treatments. The major weed species were *Setaria barbata, Borreria hispida, Phyllanthus niruri* and *Urena lobata*. The treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) registered the highest weed dry weight. Increased soil moisture supply in I_1 favoured weed growth and hence dry weight. 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 % CPE. Mulching had a significant influence on weed dry weight. Mulching is one of the important methods used to control weeds. The non mulched treatment M_1 recorded the highest weed dry weight indicating that mulching had a smothering effect on weeds. Mulching decreased the occurrence of weeds by blocking light and release of allelopathic substance. Similar findings were reported by Wayayok *et al.* (2014). The treatment combination i_1m_1 (irrigation at 3 cm depth at 10 mm CPE and no live mulching) recorded the highest weed dry weight. High soil wetness and no mulching registered the highest weed growth and dry weight and are in conformity with the findings of Thomas (2000) in upland rice.

5.8 ECONOMIC ANALYSIS

Statistical analysis of data (Table16a and 16b) revealed that net income and benefit cost ratio were favourably influenced by the treatments. The irrigation

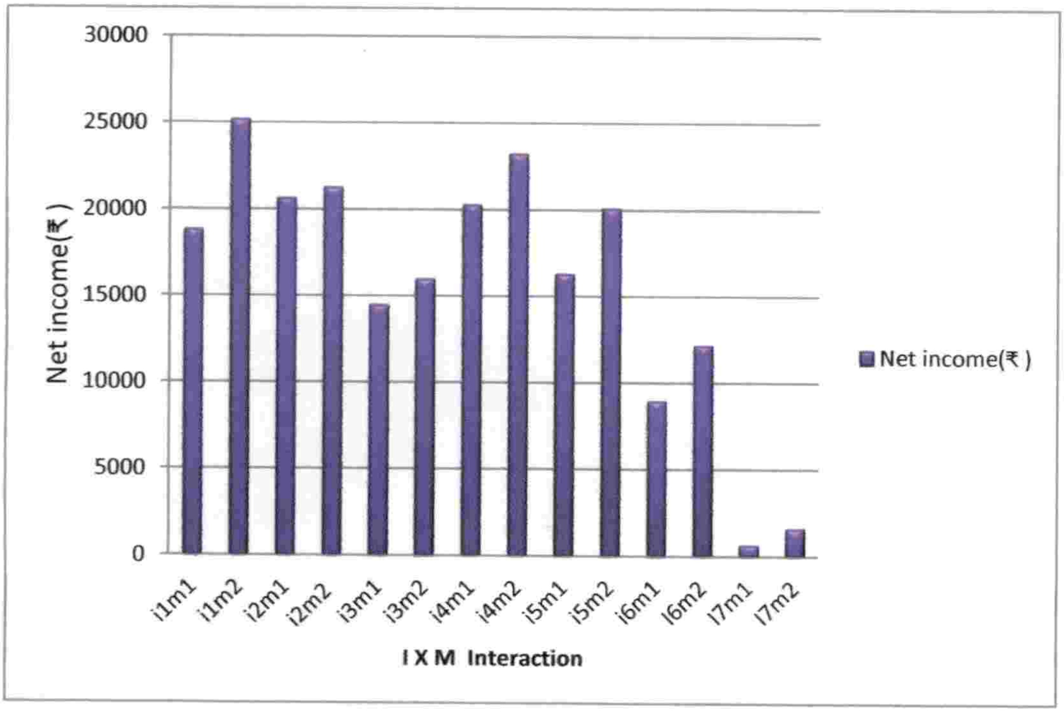


Fig. 13 Interaction effect of irrigation and mulching on net income

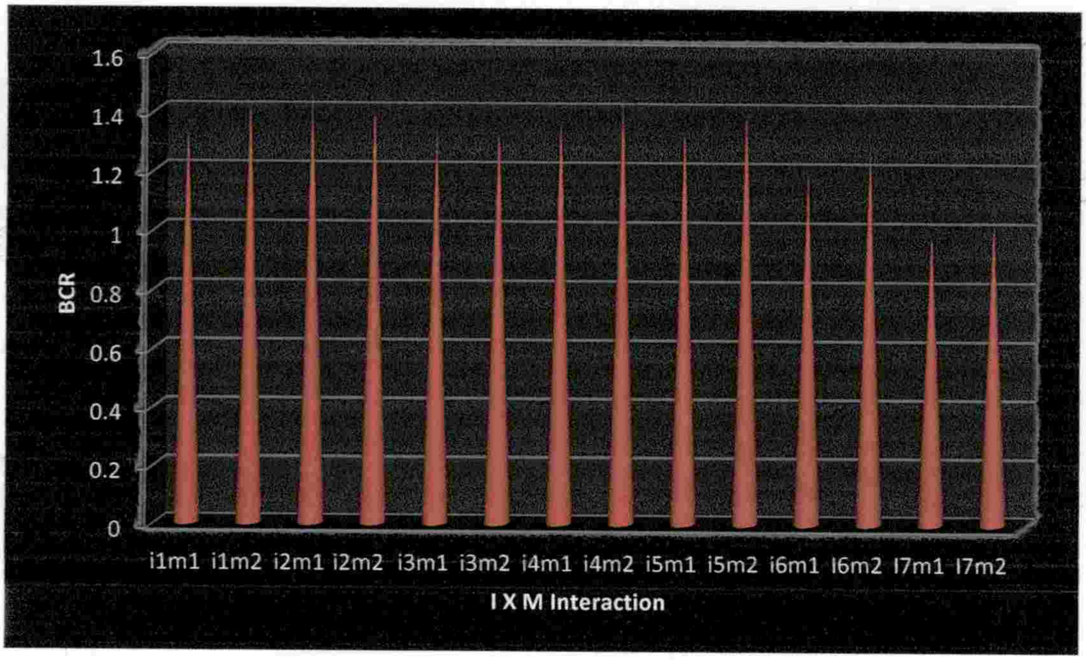


Fig. 14 Interaction effect of irrigation and mulching on benefit cost ratio

treatment I_1 (irrigation at 3 cm depth at 10 mm CPE) recorded the highest value for net income while benefit cost ratio was higher for I_2 (irrigation at 3 cm depth at 20 mm CPE) and was on par with I_1 (irrigation at 3 cm depth at 10 mm CPE) and I_4 (irrigation at 2 cm depth at 10 mm CPE).The higher grain and straw yield recorded in I_1 was mainly attributable for the higher economic returns. Mulched treatment exerted a significant influence on economic returns. The treatment M_2 (Live mulching with green manure cowpea) registered the highest economic return. The treatment combination i_1m_2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest economic return. The additional grain and straw yield obtained in i_1m_2 resulted in high net returns and BCR. This is in conformity with the findings of Kumar (2016) in upland rice.

SUMMARY

6. SUMMARY

The field experiment was conducted in the farmer's field of Sri. Madhusoodhanan Nair, M.S. Sadhanam, Peringammala, Kalliyoor, Thiruvananthapuram during the *Virippu* 2017 to standardize irrigation schedule for economising water use and study the effect of live mulching with cowpea on growth and yield of upland rice. The soil was sandy clay loam, strongly acidic, medium in organic carbon, low in available N and high in available P and K. The values of field capacity and permanent wilting point of the soil were 16 and 10 per cent respectively. The experiment was laid out in randomized block design with seven irrigation treatments and two mulching treatments. The irrigation treatments were I_1 -irrigation at 3 cm depth at 10 mm CPE, I_2 - irrigation at 3 cm depth at 20 mm CPE, I_3 - irrigation at 3 cm depth at 30 mm CPE, I_4 - irrigation at 2 cm depth at 10 mm CPE, I_5 - irrigation at 2 cm depth at 20 mm CPE, I_6 - irrigation at 2 cm depth at 30 mm CPE, I_7 – rainfed control. Two mulching treatments were M_1 - no live mulching and M_2 - live mulching with cowpea. There were fourteen interaction treatments i_1m_1, i_1m_2, i_2m_1, i_2m_2, i_3m_1, i_3m_2, i_4m_1, i_4m_2, i_5m_1, i_5m_2, i_6m_1, i_6m_2, i_7m_1 and i_7m_2. The fertilizer recommendation of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} were followed in all plots. Nitrogen was applied in three equal split doses, first as basal dressing, second at active tillering stage and third at panicle initiation stage. The entire dose of phosphorus was applied as basal. Potassium was applied as two split doses, half as basal and half at panicle initiation stage. One pre sowing irrigation was given to the field on the day before sowing with 10 mm depth of water and rice seeds were dibbled on 26th May, 2017. A common irrigation was also given to all plots on 15th June, 2017 with 10 mm depth of water to ensure uniform establishment of seedlings. The differential irrigation according to treatments was started only after 15th June 2017. The evaporation readings from a USWB Class A open evaporimeter were recorded daily and whenever the cumulative pan evaporation values attained the treatment values, irrigation was given to the concerned plots with 20 mm and 30 mm depth of water as per treatments. Seeds of upland rice variety Prathyasa were dibbled at 85 kg ha^{-1} at a spacing of 20 cm x 10 cm and one row of cowpea variety Aiswarya was sown between two rows of rice in mulched treatment plots. In unmulched treatment cowpea seeds were not sown. In mulched plots cowpea was incorporated in to the field at six weeks active growth stage. The observations on growth parameters like plant height, tiller number m^{-2}, LAI, dry matter production were recorded. The data on yield attributes like number of productive tillers m^{-2}, length of panicle, weight of panicle, number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight were recorded. Grain yield, straw yield and harvest index were recorded. Physiological and chemicals parameters like relative leaf water content, proline content, chlorophyll content and NPK uptake were recorded. The root characters like root length, root volume, root weight and root shoot ratio were recorded. Soil moisture data like consumptive use and water use efficiency were worked out. Soil properties like bulk density, water holding capacity, organic carbon and available NPK were studied. Observation on major weeds was done and their dry weight was worked out. Economics of cultivation and benefit cost ratio were tabulated. The data were statistically analyzed and interpretations drawn were briefly presented below.

The treatments had a significant influence on growth characters. Among the irrigation treatments, I_1 recorded the highest growth characters viz., plant height at 60 DAS, tiller number m^{-2} at 60 DAS, LAI at 60 DAS and DMP at harvest. At harvest the tallest plants were produced by I_4. Among the mulched treatment, M_2 registered the highest value for dry matter production at harvest. M_1 produced taller plants at 60 DAS and was not influenced by mulching at harvest. The combined application of irrigation at 3 cm depth at 10 mm CPE and live mulching of cowpea recorded the highest tiller number m^{-2}.

It was observed that irrigation treatments had a significant effect on yield attributes and yield. The treatment I_1 recorded the highest length of panicle, weight of panicle, number of filled grains panicle^{-1} and thousand grain weight. The treatment I_2 and M_2 produced the highest productive tillers m^{-2}.The treatment combination had no significant effect on yield attributes. The irrigation treatment I_1 registered the highest grain yield, straw yield and harvest index. The grain and straw yields were the highest for M_2. The grain yield was the highest for combined application of irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea (i_1m_2).

The irrigation treatments had a significant influence on physiological and chemical estimation. It was noticed that I_1 recorded the highest relative leaf water content. The treatment I_7 produced plants with higher proline content. Neither irrigation and mulching nor their interaction had a significant effect on chlorophyll content. The uptake of N, P and K differed significantly. The treatment I_1 and M_2 recorded the highest value for NPK uptake. The treatment combination irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea (i_1m_2) recorded the highest N and P uptake.

The root characters like root volume, root dry weight and root shoot ratio significantly increased under the irrigation treatment I_1. The root length was the highest for I_7. Among the mulches, M_2 recorded the highest root length and root shoot ratio. Mulches did not exert a significant effect on root characters except root length and root shoot ratio. The interaction effect was not significant on the root characters.

The treatments and their interaction had a significant influence on soil moisture estimation. The treatment I_1, M_2 and their interaction effect i_1m_2 recorded the highest consumptive use. The highest water use efficiency was recorded by I_5 and M_2. The interaction effect was not significant on water use efficiency.

Neither irrigation and mulching nor their interaction had a significant effect on bulk density and water holding capacity.

Neither irrigation and mulching nor their interaction had a significant effect on organic carbon. The available N, P and K status were the highest for I_7. The available soil N and K were the highest for M_2. The interaction effect i_7m_2 registered the highest values for available soil N and K.

The treatment I_1, M_1 and their interaction i_1m_1 (irrigation at 3 cm depth at 10 mm CPE and no live mulching) recorded the highest weed dry weight.

The highest net income was obtained with I_1 and was on par with I_2 and I_4. The highest BCR was recorded by I_2 and was on par with I_4 and I_1. M_2 recorded the highest net income and BCR. The interaction i_1m_2 recorded the highest net income and was on par with i_4m_2. The interaction i_1m_2 registered the highest BCR and was on par with i_2m_1, i_2m_2, i_4m_2 and i_5m_2.

The present study revealed that irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea favourably influenced the growth, yield attributes, yield, physical, chemical properties of the soil and economics of cultivation. Although the highest grain yield was recorded by i_1m_2, it was found that i_1m_2 was on par with i_4m_2 for net income suggesting that irrigation at 2 cm depth at 10 mm CPE with live mulching of cowpea is as good as i_1m_2. For BCR, i_1m_2 was on par with i_2m_1, i_2m_2, i_4m_2 and i_5m_2 suggesting that irrigation at 2 cm depth at 20 mm CPE with live mulching of cowpea is as good as i_1m_2. For higher water use, irrigation at 2 cm depth at 20 mm CPE and live mulching of cowpea can be recommended.

Future line of work

The relative efficiency of different mulching materials on soil moisture conservation and growth of upland rice has to be studied. The efficacy of combined application of irrigation with different mulches on growth, yield attributes, yield and in situ moisture conservation has to be explored.

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IRRIGATION SCHEDULING AND LIVE MULCHING IN UPLAND RICE (*Oryza sativa* L.)

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ABSTRACT

IRRIGATION SCHEDULING AND LIVE MULCHING IN UPLAND RICE (*Oryza sativa* L.)

The experiment entitled 'Irrigation scheduling and live mulching in upland rice (*Oryza sativa* L.)' was undertaken at farmer's field at Peringammala, Kalliyoor, Thiruvananthapuram during *Virippu* 2017 to standardize irrigation schedule for economizing water use and study the effect of live mulching with cowpea on growth and yield of upland rice. Prathyasa (MO 21) was used as the variety. The experiment was laid out with 14 treatment combinations involving seven irrigation treatments (I_1 - irrigation at 3 cm depth at 10 mm CPE, I_2 - irrigation at 3 cm depth at 20 mm CPE, I_3 - irrigation at 3 cm depth at 30 mm CPE, I_4 - irrigation at 2 cm depth at 10 mm CPE, I_5 - irrigation at 2 cm depth at 20 mm CPE, I_6 - irrigation at 2 cm depth at 30 mm CPE and I_7 - rainfed control) and two mulching treatments (M_1 - no live mulching, M_2 – live mulching with cowpea) with three replications in randomized block design.

The results revealed that I_1 recorded the highest value for the growth characters viz., plant height at 60 DAS, tiller number m^{-2} at 60 DAS, LAI at 60 DAS and DMP at harvest. At harvest, the tallest plants were produced by I_4. M_2 registered the highest dry matter production at harvest. The interaction i_1m_2 recorded the highest tiller number m^{-2}.

The yield attributes and yield were significantly influenced by the irrigation treatments. The treatment I_1 recorded the highest length of panicle, weight of panicle, number of filled grains $panicle^{-1}$ and thousand grain weight. M_2 produced the highest productive tillers m^{-2}. I_1 registered the highest grain yield (2949 kg ha^{-1}), straw yield (3100 kg ha^{-1}) and harvest index (0.49). The grain and straw yields were the highest

for M_2. The grain yield (3057 kg ha^{-1}) was the highest for i_1m_2 and significantly superior to other treatments.

It was noticed that I_1 recorded the highest relative leaf water content and I_7 registered the highest proline content. The uptake of N, P and K differed significantly. I_1 and M_2 recorded the highest NPK uptake. The interaction effect i_1m_2 registered the highest values for N and P uptake.

The root characters viz., root volume, root dry weight and root shoot ratio were significantly increased due to irrigation and I_1 recorded the highest values. The root length was the highest for I_7. Among the mulches, M_2 recorded the highest root length and root shoot ratio.

The highest consumptive use was recorded by I_1, M_2 and their interaction i_1m_2. The highest water use efficiency (3.72 kg ha^{-1} mm^{-1}) was recorded by I_5 and was on par I_3 and superior to other treatments. M_2 registered the highest WUE (3.51 kg ha^{-1} mm^{-1}) and superior to M_1.

The available N, P and K status were the highest for I_7. The available soil N and K were the highest for M_2. The interaction effect i_7m_2 registered the highest values for available soil N and K.

The highest weed dry weight was recorded by I_1, M_1 and their interaction i_1m_1.

The highest net income was obtained with I_1 and was on par with I_2 and I_4. The highest BCR was recorded by I_2 and was on par with I_4 and I_1. M_2 recorded the highest net income and BCR. The interaction i_1m_2 recorded the highest net income and was on par with i_4m_2. The interaction i_1m_2 registered the highest BCR (1.46) and was on par with i_2m_1, i_2m_2, i_4m_2 and i_5m_2.

The results revealed that frequent irrigation especially at 3 cm depth at 10 mm CPE in combination with live mulching of cowpea favourably influenced most of the growth, yield attributes, yield, physical, chemical properties of the soil and economics of cultivation. Although the highest grain yield was recorded by i_1m_2, it was found that i_1m_2 was on par with i_4m_2 for net income suggesting that irrigation at 2 cm depth at 10 mm CPE with live mulching of cowpea is as good as i_1m_2. For BCR, i_1m_2 was on par with i_2m_1 , i_2m_2 , i_4m_2 and i_5m_2 suggesting that irrigation at 2 cm depth at 20 mm CPE with live mulching of cowpea is as good as i_1m_2. For higher water use, irrigation at 2 cm depth at 20 mm CPE (I_5) and live mulching of cowpea (M_2) can be recommended. From farmer's point of view, irrigation at 2 cm depth at 10 mm CPE with live mulching of cowpea is beneficial for higher economic returns in acute water deficit areas.

സംഗ്രഹം

കരനെൽകൃഷിയിലെ ജലസേചനാവൃത്തിയും ജൈവ പുതയിടലും എന്ന വിഷയതിൽ ഒരു പഠനം പെരിങ്ങമലയിലെ ഒരു കർഷകന്റെ കൃഷിയിടത്തിൽ നടത്തുകയുണ്ടായി. കരനെൽ കൃഷിക്ക് അനുയോജ്യമായ ജലസേചന രീതി കണ്ടെത്തുക, പയർ കൊണ്ടുള്ള ജൈവ പുതയിടൽ കര നെൽ കൃഷിയുടെ വളർച്ചയെയും വിളവിനെയും എങ്ങനെ സ്വാധീനിക്കുന്നു എന്നിവ കണ്ടു പിടിക്കുകയായിരുന്നു ഈ പഠനത്തിന്റെ ലക്ഷ്യം. മങ്കോമ്പ് നെല്ല് ഗവേഷണ കേന്ദ്രത്തിൽ നിന്നും വികസിപ്പിച്ചെടുത്ത പ്രത്യാശ എന്ന കര നെല്ലിനം ആണ് പഠനത്തിന് ഉപയോഗിച്ചത്.

ഏഴ് ജലസേചനാവൃത്തിയും (I_1 - 3 സെമി ആഴത്തിൽ 10 മില്ലി CPE, I_2 - 3 സെമി ആഴത്തിൽ 20 മില്ലി CPE, I_3 - 3 സെമി ആഴത്തിൽ 30 മില്ലി CPE, I_4 - 2 സെമി ആഴത്തിൽ 10 മില്ലി CPE, I_5 - 2 സെമി ആഴത്തിൽ 20 മില്ലി CPE, I_6 - 2 സെമി ആഴത്തിൽ 30 മില്ലി CPE, I_7 - മഴയെ ആശ്രയിച്ചിട്ടുള്ള കണ്ട്രോൾ) രണ്ടു പുതയിടൽ രീതിയും (M_1 - ജൈവ പുതയിടൽ നടത്താത്തത് M_2 - ജൈവ പുതയിടൽ നടത്തിയത്) ചേർത്ത് പതിനാല് ട്രീട്മെന്റുകളായി മൂന്ന് പ്രാവശ്യം ആവർത്തിച്ച് റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠനരീതി അവലംബിച്ച് പരീക്ഷണം നടത്തി.

പഠനത്തിന്റെ പ്രധാന കണ്ടെത്തലുകൾ ഇവയാണ്. 3 cm ആഴത്തിൽ രണ്ടു മൂന്ന് ദിവസത്തിൽ ഒരിക്കൽ ജലസേചനം ജൈവ പുതയിടലോടു കൂടി നടത്തുന്നത് നെല്ലിന്റെ വളർച്ചയ്ക്കും വിളവിനും അനുകൂലമാണെന്ന്

കണ്ടെത്തി. ഇതു കൂടാതെ 2 cm ആഴത്തിൽ രണ്ടു മൂന്ന് ദിവസത്തിൽ ഒരിക്കൽ ജലസേചനം ജൈവ പുതയിടലോടു കൂടി നടത്തുന്നത് കൂടുതൽ അറ്റാധായം തരുന്നതായി രേഖപെടുത്തി. 2 cm ആഴത്തിൽ നാല് ദിവസത്തിൽ ഒരിക്കൽ ജലസേചനം ജൈവ പുതയിടലോടു കൂടി നടത്തുന്നത് ചെലവിനു അനുപാതമായി കൂടുതൽ വരവ് നൽകുന്നതായി രേഖപെടുത്തി. 2 cm ആഴത്തിൽ നാല് ദിവസത്തിൽ ഒരിക്കൽ ജലസേചനം നടതുന്നതും ജൈവ പുതയിടലും ജല ഉപയോഗ ക്ഷമത വർദ്ധിപ്പിക്കുന്നതായി കണ്ടെത്തി.

APPENDIX

APPENDIX I

Weather parameters during the cropping period – 26th May to 25th September

Standard weeks	Minimum Temperature (^0C)	Maximum Temperature (^0C)	Rainfall (mm)	Maximum Relative Humidity (%)	Minimum Reative Humidity
22	23.9	31.9	187.9	96.8	96.8
23	24.6	30.8	31.7	92.9	92.9
24	25.2	31.7	11.3	91	91
25	24.4	32.2	18.9	89.7	89.7
26	23.7	31.1	140.2	95.9	95.9
27	24.6	31.7	10	91.5	91.5
28	24.5	31.2	10.3	91.7	91.7
29	24.6	31.2	17	89.9	89.9
30	25	32.2	3.1	89	89
31	25	32.3	7.2	90.9	90.9
32	24.5	31.3	18.5	92.3	92.3
33	24.7	31.1	21.4	92.9	92.9
34	24.6	30.5	37.7	91.7	91.7
35	24.4	31.5	17.9	91.6	91.6
36	24.6	32.3	22.9	91.4	91.4
37	24.2	31.5	30	92.1	92.1
38	24.4	30.4	92.7	94	94