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Effect of irrigation scheduling and live mulching of cowpea on root characteristics, consumptive use and water use efficiency of upland rice

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ABSTRACT

The field experiment was conducted in the farmer's field, Peringammala, Kalliyoor, Thiruvananthapuram during the Virippu 2017 to study the effect of irrigation scheduling and live mulching with cowpea on root and soil moisture characteristics of upland rice. The results revealed that root characters like root volume, root dry weight and root shoot ratio significantly increased under the irrigation treatment I_1 [irrigation at 3 cm depth at 10 mm cumulative pan evaporation (CPE)]. The root length was the highest for rain fed control (I_7). Among the mulches, live mulching with cowpea (M_2) recorded the highest root length and root shoot ratio. The treatments and their interaction had a significant influence on soil moisture. Irrigation at 3 cm depth at 10 mm CPE, live mulching with cowpea and their interaction recorded the highest consumptive use. The highest water use efficiency was recorded by the treatment irrigation at 2 cm depth at 20 mm CPE (I5) and live mulching with cowpea (M_2).

Key words: *Upland rice, irrigation scheduling, live mulching, root length, root weight, root volume, consumptive use and water use efficiency*

INTRODUCTION

Rice (*Oryza sativa* L.), the major staple food of the global population is cultivated in a wide range of ecosystems. In India, out of 42.7 m ha of land under rice, about 21.9 % of the area is exposed to risk prone upland ecology (Mishra, 1999). The total area under rice cultivation decreased from 8.50 lakh ha to 1.99 lakh ha over the last three decades (FIB, 2017). For upland rice production, inadequate water supply is the major constraint to yield (Yoshida, 1975).

Yadav et al. (2011) reported that the estimated water availability for agriculture which is 83.3 % of total water used today will shrink to 71.6 % in 2025 and to 64.6 % 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. The potential water savings at the field level when rice can be grown as an upland crop are large, especially on soils with high seepage and percolation rates (Bouman, 2001). Balasubramanian et al. (2001) reported that water use efficiency was better with continuous submergence of 2.5 cm depth throughout the crop period of direct seeded rice.

Mulching is a potential method for efficient water use in upland rice cultivation. *In situ* green manuring with cowpea and its subsequent incorporation 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 and there by improves the sustainability and water productivity of upland rice ecosystem. The present study was planned with the objective, to study the effect of irrigation scheduling and live mulching with cowpea on root and consumptive use of water in upland rice.

MATERIALS AND METHODS

The field experiment was carried out in the farmer's field, Peringammala, Kalliyoor, Thiruvananthapuram during the *Virippu* 2017 to study the effect of irrigation scheduling and live mulching with cowpea on root and soil moisture characteristics of upland rice. Prathyasa (MO 21), released from Rice Research Station (RRS) Moncompu was used for the study. Aiswarya, released from Kerala Agricultural University was used as cowpea 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. 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 soil of the experimental site 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 % respectively.

A total rainfall of 679 mm was recorded during the cropping period. Irrigation was scheduled as per irrigation treatments and the required quantity of water was measured using water meter. 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 pan 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 un mulched 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 root characteristics like root length, root weight, root volume and root shoot ratio were recorded. At the harvest stage, the five sample plants were uprooted carefully, root portion was separated, cleaned and root length was measured. The mean value was calculated and expressed in cm. Root volume plant^{-1} was found out by displacement method (Misra and Ahmed, 1989) and expressed in cm^3 plant^{-1}. 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. Root and shoot dry weights were recorded separately and root to shoot ratio was worked out.

Moisture parameters like consumptive use and water use efficiency were worked out. 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.Then consumptive use was worked out from the data on soil moisture depletion suggested by Dastane (1972).

Consumptive use (CU) =

$$\sum_{i-1}^{n} \frac{M1i - M2i}{100} \text{ x } D_b \text{ x depth of soil } (cm)$$

Where,

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

M1i - soil moisture percentage at first sampling in ith layer

M2i - soil moisture percentage at second sampling in the ith layer

D_b - bulk density

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}.

RESULT AND DISCUSSION

Root studies

Irrigation treatment had a significant influence on root characteristics. 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 an 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 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 root volume, root weight and root shoot ratio (Table 1). 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 (Table 1). Similar results were reported by Thomas (2000). Mulching had a significant influence on root length and root shoot ratio. The mulched treatment recorded the highest value for root characters.

Table 1. Effect of irrigation and mulching on root length, root volume, root weight and root shoot ratio.

Treatments	Root length (cm)	Root volume (cm3)	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

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.

Table 2. Details of water requirement, mm.

Treatments	Quantity of water	Pre sowing applied	Common irrigation 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

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.

Soil moisture content

Irrigation had a significant influence on soil moisture estimation. Frequent irrigation recorded the highest consumptive use. The irrigation treatment I_1 (irrigation

Table 3. 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

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.

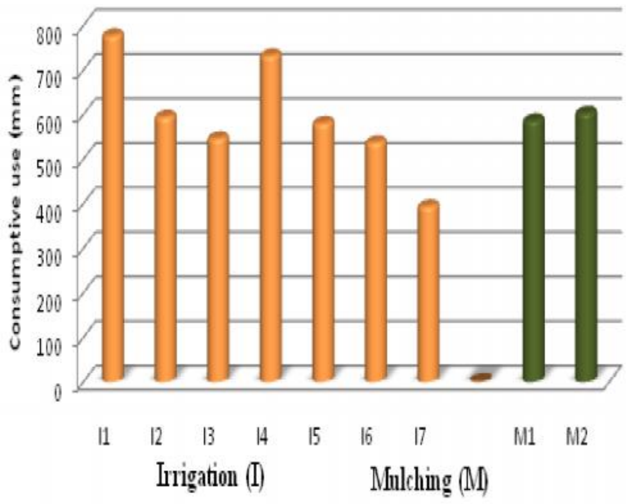

Fig. 1. Effect of irrigation and mulching on consumptive use.

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.

at 3 cm depth at 10 mm CPE) recorded the highest value (Fig. 1 and Table 3). 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

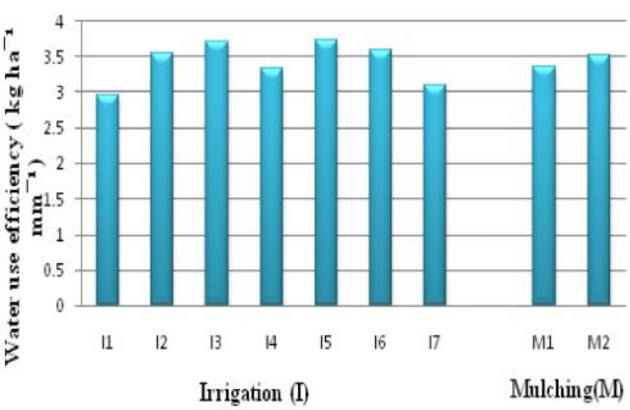

Fig. 2. Effect of irrigation and mulching on water use efficiency.

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.

Table 4. 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

Treatments: i_1m_1 -irrigation at 3 cm depth at 10 mm CPE and no live mulching with cowpea, i_1m_2- irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea, i_2m_1 - irrigation at 3 cm depth at 20 mm CPE and no live mulching with cowpea, i_2m_2- irrigation at 3 cm depth at 20 mm CPE and live mulching with cowpea, i_3m_1- irrigation at 3 cm depth at 30 mm CPE and no live mulching with cowpea, i_3m_2 - irrigation at 3 cm depth at 30 mm CPE and live mulching with cowpea, i_4m_1 - irrigation at 2 cm depth at 10 mm CPE and no live mulching with cowpea, i_4m_2 - irrigation at 2 cm depth at 10 mm CPE and live mulching with cowpea, i_5m_1 - irrigation at 2 cm depth at 20 mm CPE and no live mulching with cowpea, i_5m_2 - irrigation at 2 cm depth at 20 mm CPE and live mulching with cowpea, i_6m_1 - irrigation at 2 cm depth at 30 mm CPE and no live mulching with cowpea, i_6m_2 - irrigation at 2 cm depth at 30 mm CPE and live mulching with cowpea, i_7m_1 - rainfed control and no live mulching with cowpea, i_7m_2 - rainfed control and no live mulching with cowpea.

treatments exerted a positive influence on consumptive use. The treatment M_2 (live mulching with cowpea) recorded the highest consumptive use (Fig. 1 and Table 3). The treatment combination i1m^2 (irrigation at 3 cm depth at 10 mm CPE and live mulching with cowpea) recorded the highest value for consumptive use (Table 4). 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 (Fig. 2 and Table 3). 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). Decreasing WUE with increase in levels of irrigation is also reported by Toung et al. (2004) and Belder et al. (2005). Mulched treatment exerted a significant influence on WUE. The treatment M_2 (live mulching with cowpea) registered the highest value (Fig. 2 and Table 3). The high consumptive use of water in M_2 lowered the water use efficiency in that treatment.

CONCLUSION

The irrigation treatments had a significant influence on root characters. Irrigation at 3 cm depth at 10 mm CPE recorded the highest root volume, root dry weight and root shoot ratio. Live mulching with cow pea recorded the highest root length and root shoot ratio. Irrigation at 3 cm depth at 10 mm CPE, live mulching with cowpea and their interaction recorded the highest consumptive use. For higher water use, irrigation at 2 cm depth at 20 mm CPE (I5) and live mulching of cowpea (M_2) can be recommended.

REFERENCES

Araki H and Iijima M (2005). Stable isotope analysis of water extraction from subsoil in upland rice as affected by drought and soil compaction. Plant Soil 270: 147-157

Balasubramanian R and Krishnarajan J (2001). Yield and correlation studies in direct seeded rice as influenced by irrigation levels. Indian J. Agric. Res. 35: 194-197

Belder P, Bouman BAM, Spiertz S, Peng AR, Castaneda AR and Visperas RM (2005). Crop performance, nitrogen and water use in flooded and aerobic rice. Plant Soil 273: 167-182

Bouman BAM and Tuong TP (2001). Field water management to save water and increase its productivity in irrigated rice. Agric. Water Manag. 49: 11-30

Bouman BAM (2001). Water-efficient management strategies in rice production. International Rice Research Notes 16.2, IRRI, Los Banos, Philippines pp. 17-22

Dastane NG (1972). A practical manual for water use research in Agriculture. 2nd edition, Navabharat Prakasan pp. 120

Jolly GE (2016). Response of upland irrigated rice varieties to irrigations. M. Sc. (Ag) thesis, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola pp. 42

Kulandaivelu R (1990). Soil and climate based irrigation schedules for rice. Indian J. Agron. 35(2): 82-84

Mishra GN (1999). Strategic approaches for boosting upland rice yield. Indian Farming 48(2): 9

Thomas UC (2000). Response of seed priming, nutrient management and irrigation on upland rice (*Oryza sativa* L.). M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur pp. 117

Tuong TP, Bouman BAM and Mortimer M (2004). More rice, less water integrated approaches for increasing water productivity in irrigated rice based systems in Asia. In: Proceedings of the fourth International Crop Science Congress, 26 September to 1st October 2004, Brisbane, Australia pp. 1-13

Yadav S, Gill G, Humphreys E, Kukal SS and Walia US (2011). Effect of water management on dry direct seeded rice and puddled transplanted rice Part 2: Water balance and water productivity. Field Crops Res. 120: 123-132

Yoshida S (1975). Factors that limit the growth and yields of upland rice. In: Major Research in Upland Rice, International Rice Research Institute, Los Banos, Laguna pp. 46-71