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Drip Irrigation : A Climate Smart Irrigation Practice for Sustaining Crop Productivity, Water Saving and Mitigating Green House Gases (GHG's) in Rice

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Abstract

Over the past decade, we have witnessed a growing scarcity and competition for water around the world. Rice being a moisture loving crop, commonly grown in puddled condition which consumes 50 per cent of irrigation water in the world besides leading destruction of soil aggregates, reduced water and nutrient use efficiency and emission of green house gases like methane and nitrous oxide. Hence, drip irrigation in aerobic rice could be a good choice as an alternative rice growing method with higher water productivity, boosted yields and reduced green house gases emission. The objective of this paper is to review the climate smart irrigation system with sustained production with efficient use of resources. Under drip irrigation, aerobic method of rice cultivation showed better performance with 15 to 20 per cent higher grain yield, 40 to 50 per cent water saving, besides reduced pollution risk to the environment by minimizing emission of methane and nitrous oxide, which is clearly noticed from the results of experiments reviewed in this literature.

Rice (*Oryza sativa* L.) is one of the most important food crops in the world for more than half of its population which is mainly grown in Eastern and Southern Asia. It is grown in a wide range of environments and productive in many situations where other crops would fail. Rice-growing environments are based on their hydrological characteristics which include irrigated, rainfed lowland and upland. Water - nature's gift to mankind is not unlimited and free forever. The amount of water present in the universe is only about 1520 million cubic kilometers, 97 per cent is ocean and sea water, 2 per cent is frozen arctic waters and only 1 per cent is water in lakes, rivers and underground water, which is portable water for direct use to humans (Shaker, 2004).

In India, rice is grown in an area of 44.5 m ha with an annual production of 106.5 m t. More than 50 per cent of the irrigation water in the world is used for rice (Fan, 1996; Anon., 2010; Anon., 2010b) which is not different in the State of Karnataka, where rice is the largest consumer of irrigation water and accounting for more than 47 per cent. Conventional puddled transplanted rice cultivation uses more than 2000 mm water in many command areas of India.

The traditional rice production system not only leads to water wastage but also causes destruction of soil aggregates, reduction in micro pores and reduces fertilizer use efficiency (Soman, 2012a). The increasing scarcity of water threatens the sustainability of irrigated rice production system. The conventional practice of rice production keeps the soil flooded and therefore anaerobic almost throughout the rice season. Wetland rice system emit large quantities of green house gases like methane (CH_4) and nitrous oxide (N_2O) which account for 8.7 to 28 per cent of total anthropogenic emissions (Moiser *et al.,* 1998).

Therefore, a more efficient climate smart method of rice cultivation with higher water productivity is the need of hour. Looking into problems associated with traditional flood method of rice cultivation, a novel and eco-friendly practice of growing aerobic rice under drip irrigation along with fertigation seems to be satisfying from the results of studies discussed in this literature.

Performance of aerobic rice under drip irrigation

Demand for rice in India is increasing every year and it is estimated that by 2025 AD, the increasing requirement would be 140 m t. To sustain present self-sufficiency in food production and to meet future food requirements, India has to increase its rice productivity by 3 per cent per annum against the backdrop of diminishing natural resources mainly water that pose a real challenge for scientific community.

The growth attributes varied significantly due to different methods of crop establishment and cultivation (Anusha *et al*., 2015; Soman, 2012b). Significantly higher growth parameters like plant height, total tillers and leaf area lead to more accumulation of dry matter in plant parts (Gururaj *et al*., 2016; Sundrapandiyan, 2012). Aerobic rice with drip irrigation registered significantly higher number of productive tillers hill^{-1} (26.9) and 20 per cent higher grain yield (7803 kg ha^{-1}) as compared to puddled (15.7 and 6573 t ha^{-1}, respectively) transplanted rice (Table I). Though the extent of increment in yield varied in different establishment methods at different places, the results are in accordance (Table II).

The higher yield in drip irrigation may be the resultant of higher nutrient uptake (Rekha *et al.*,2015) wherein soil moisture was held at field capacity (Geethalakshmi *et al*., 2011) due to uninterrupted and continuous moisture supply meeting the crop requirement (Vanitha *et al*., 2012; Vijaykumar, 2009).

TABLE I

Influence of different establishment methods on tiller production and grain yield of rice

Method of establishment	Productive tillers hill^{-1}			Grain yield (kg ha^{-1})		
	2013	2014	Pooled	2013	2014	Pooled
Aerobic rice with surface irrigation	18.8	18.1	18.4	6238	5965	6101
Aerobic rice with drip irrigation	27.2	26.7	26.9	7934	7672	7803
Puddled transplanted rice	16.1	15.4	15.7	6659	6487	6573
CD @ 5%	0.98	1.24	1.09	425	338	280

TABLE II

Representative yield increment in drip irrigated rice in different places

Location	Yield achievement (t ha^{-1})	% Increment over conventional method	Reference
Madhurai, TN (India)	6.20	24	Vijaykumar, 2009
Andhra Pradesh (India)	9.38		
Maharashtra (India)	7.56		
Punjab (India)	8.20		
Rajasthan (India)	9.20	40-200	Soman, 2012b
Tamil Nadu (India)	8.50		
Uttar Pradesh (India)	5.50		
Bangalore, KA (India)	6.59	90	Gururaj *et al*., 2015
Coimbatore, TN (India)	4.29	21	Parthasarathi *et al.*, 2013
Shanghai (China)	8.38	16	Modinat *et al.*, 2014
Mandya, KA (India)	4.96	28	Balaji Naik *et al.*, 2015
Bangalore, KA (India)	7.80	18	Anusha *et al*., 2015

Water use and water saving in aerobic rice under drip irrigation

Rice being a moisture hungry crop and prolific user of water, requires 3000-5000 litres of water to produce one kg of grain which is almost 2 to 3 times higher than any other cereal crops such as wheat and maize (Anon., 2009). The water supply- demand gap in India is projected to be 25 per cent by the year 2020 (Sunder Singh *et al*., 1996).

Reducing water input in rice production can have a high societal and environmental impact, if the water saved can be diverted to areas where competition is high. A reduction of 10 per cent in water used in irrigated rice would free 150,000 million m^3, corresponding to about 25 per cent of the total fresh water used globally for non-agricultural purposes (Klemm, 1999). Therefore efficient irrigation system is necessary to reduce the use of water for rice cultivation without impacting on its yield level. Although various types of irrigation techniques differs in how the water obtained from the source is distributed within the field, generally, the ultimate goal is to supply the entire field uniformly with water, so that each plant has the right amount of water it needs, neither too much nor too little (Andreas and Karen, 2002).

Drip irrigation system for cultivation of rice under aerobic condition seems to be promising in reduced use of water with boosted yield levels (Nagaraju, 2014). Among different methods evaluated (Table III), drip irrigation has recorded least water use (77.7 cm) with higher water use efficiency (103.0 kg ha-cm^{-1}) as compared to puddled transplanted rice (150.9 cm and 43.7 kg ha-cm^{-1}, respectively).

Drip irrigation is the most energy and water efficient of all the irrigation systems. Water savings of up to 50 per cent as compared to conventional puddled rice (Anusha *et al.,* 2015; Gururaj *et al.,* 2016). Ideally, water is applied in the proper amount to the root ball of the plant, minimizing water leaching from the root zone. The higher water use efficiency with drip system was attributed to reduced water loss and efficient water use by the plants resulting in higher yield (Parthasarathi *et al*., 2013). Similar results were noticed by several authors from studies indicated (Table IV).

TABLE III

Water use and water use efficiency (WUE) of aerobic rice in different methods

Method of establishment	Water use (cm)			WUE (kg ha-cm^{-1})		
	2013	2014	Pooled	2013	2014	Pooled
Aerobic rice with surface irrigation	101.16	119.25	110.20	61.6	49.8	55.7
Aerobic rice with drip irrigation	66.16	89.25	77.70	120.2	85.9	103.0
Puddled transplanted rice	142.05	159.80	150.93	46.7	40.8	43.7

TABLE IV

Comparison of different rice growing methods for their water use

Location	Water use in drip irrigation (cm)	% water save over flooding	Reference
Coimbatore, TN (India)	64.7	44.0	Parthasarathi *et al.,* 2013
Bangalore, KA (India)	77.0	30.8	Anusha *et al.,* 2015
Bangalore, KA (India)	70.6	39.0	Gururaj *et al.,* 2016
Madhurai, TN (India)	67.4	42.0	Vijaykumar, 2009
Farmers field trials (India)	80.0	40.0	Soman, 2012b

Effect of irrigation practices on emission of green house gases

Methane is one of the major green house gases (GHG) contributing to global warming. The annual methane emissions from rice fields are 3 -10 per cent of global emissions of about 600 Tg. Estimates of annual methane emissions from the principal rice producers, China and India, are in the range of 10-3 Tg (Bouman *et al*., 2007). The total methane emissions from a paddy field are determined by methane *production, oxidation* and *transport* (Frenzel *et al*., 1999). These in turn are affected by the physical, chemical and biological properties of the soil, quantity of organic residues, temperature, plant physiology and water regime (Minami, 1995). Emission of methane from rice fields is very sensitive to management practices (including water management), so improved management of rice to reduce GHG is an important target (Wassmann *et al*., 2004).

Emissions of CH_4 from SRI method are hard to pin down. In an aerobic system, there would be a net sequestration of methane, but in a partially anaerobic system we would still expect methane production, but at a lower level than in fully anaerobic systems. Controlled irrigation trials can be used as a surrogate. These do not include the other aspects of SRI techniques such as wider spacing and earlier transplanting, but methane emissions are dominated by the water regime, so these are likely to be less important. From these studies (Peng *et al*., 2011a; Peng *et al*., 2011b; Hou *et al.,* 2012 and Suryavanshi *et al*., 2013) there is a considerable range in methane emissions compared to conventional irrigation, but with a mean proportion of 0.58 methane emitted per area.

Drip irrigation could be a good choice as an alternative rice cropping system since it reduced greenhouse gas emission greatly and with comparable yield as in paddy field condition. One of the factors resulting in methane gas emission from rice fields is the standing water and the anaerobic decomposition of organic matter (Modinat *et al*., 2014). In this study, methane gas emission from the drip irrigation field basically maintained a lower level, equivalent to that of the open air, less than 5 ppm, while the paddy field produced significantly higher methane gas emission, higher than 20 ppm. In this experiment, the result showed that drip irrigation could effectively prevent or greatly reduce this gas emission from rice fields. Jayadeva (2007) also reported higher methane flux from puddled transplanted rice as compared to SRI and aerobic method of rice cultivation from his experiments. Similar results (Table V) were obtained from studies conducted at NICRA in different rice establishment techniques with drip irrigation.

TABLE V

Impact of different water saving technologies on greenhouse gas emissions in rice

Irrigation practice	CH_4 (kg ha^{-1})	GWP (kg CO_2 eq. ha^{-1})
DSR - Drip irrigation	0.04	797
DSR - Conventional irrigation	0.14	847
SRI - Drip irrigation	7.52	715
SRI - Conventional irrigation	22.42	1100
Conventional transplanted rice	56.97	1688

DSR - Direct seeded rice; SRI - System of rice intensification

Drip irrigation has the highest water use efficiency with water saving of 40 to 50 per cent besides increasing the yield to the extent of 15 to 20 per cent as compared to traditional method of rice cultivation. The merit of environmental friendliness of drip irrigation was achieved from the experiments, especially with the methane gas emission which was obviously decreased in the drip irrigation system.

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