

DRIP IRRIGATION TECHNOLOGY FOR RICE CULTIVATION FOR ENHANCING RICE PRODUCTIVITY AND REDUCING WATER CONSUMPTION

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ABSTRACT

The future of rice production which consumes a lion's share of water (85% in India) used in irrigated agriculture will therefore depend heavily on developing and adopting technologies and practices which will use less water with highest use efficiency. Rice is cultivated usually in a puddled soil condition with large volumes of water and grown in standing water. The water productivity is hardly 0.15 kg/m³ of water which is very low. Way back in 2008 we began introducing drip irrigation (both surface drip and sub surface drip systems) and fertigation for rice cultivation. During the last 10 years, this input management method is tried over several rice ecologies in India and over several rice varieties spanning both Dry seeded (DSR) and Transplanted rice (TPR) growing systems (sole rice or rotation with other crops).

Under drip –fertigation, the water productivity rose to 0.46 to 0.67 kg/m³ across varieties and locations. Rice yields were higher (13-28%) across varieties compared to the yields recorded in the respective conventional methods. Panicle number, grain number and test weights (grain) were found to be superior under water and fertilizer management through drip systems. Similarly, higher N, P and K efficiencies were also recorded under drip –fertigation. A standard rice growing package with drip fertigation is made available to farmers.

Keywords: drip irrigation, fertigation, water productivity, farmer field, yield

1. INTRODUCTION

Rice is the second important crop globally, producing 715MT paddy (482 MT milled rice). China is the largest producer with 210.1MT from an area of 29.5 Mha followed by India producing 165.3 MT from an area of 44.1 Mha. It is an important staple food for more than 50 % of world population (Anon, 2016). More than 90 % of global rice is produced from conventional lowland irrigated system, i.e. seedlings transplanted on puddled soil, with standing water 5-10 cm, throughout its growth period, till just few days before harvest. Also lowland rice is common in coastal areas under rain-fed conditions, using puddling to prepare the soil for transplanting/direct sowing. While upland direct seeded rice is produced during wet season under dryland aerobic conditions, without puddling or standing water, supported by supplementary irrigation. In recent times specially evolved aerobic rice varieties, tolerant to drought high yielding are used under aerobic (dry seeded) conditions.

Approximately 80 % of fresh water is used for irrigation of agricultural crops. Thirty percent of irrigation water is used for cultivation of rice under conventional lowland rice system. On an average, rice fields use 1400 L of water by evaporation and transpiration to produce one kg rice (Kijne et al, 2003; Bas Bouman, 2013, Maina et al, 2014). Exploitation of surface and ground water has reached its maximum in many States in India, requiring water saving technologies are used, otherwise it will be impossible to practice, sustainable rice cropping in coming years.

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2. CULTIVATION PROCEEDURE

Jain Irrigation systems whose motto is “more crop per Drop’ has carried out extensive field trials using drip irrigation and fertigation technology on important economic crops. Under this system moisture availability in soil is kept close to crop water requirement and the performance of crops are optimal, increased yields and improvement in quality of the produce could be achieved. Realizing that more than 90 % of rice is produced under inundated lowland system, extensive field trials were carried out using specially evolved aerobic rice varieties and genotypes under upland aerobic conditions using drip system to maximize yield and water productivity.

The paper focusses on the results of the trials, evaluating the performance of ADT-45,an aerobic rice hybrid in 2010 and five aerobic genotypes viz.27-p-31,27-p-63,27-p-71,Arize-6129, Arize-6444 in 2011 in the Experimental farm, Udumalpet, Tamil Nadu, India. It discusses the possible opportunity for transforming inundated low land rice cultivation to upland aerobic conditions using drip system to suit with the changing conditions of water availability.

First set of field studies were carried out during monsoon season of 2010 and 2011 in sandy clay soil with good drainage,pH-7.66,E.C 0.21 dsm-1, in Udumalpet, Tamil Nadu (geographical coordinates10-36’N and77-14’ EL).The experimental fields were dry ploughed and harrowed, raised beds of 15 cm height,120 cm width were formed. A basal dose of fertilizers at 345 kg SSP, Zinc Sulphate 50 kg, Ferrous sulphate50 kg/ha were incorporated. The guard space around the plots were 1 m wide and between drip and flood plots was 4 m wide. Only one rice hybrid ADT-45,110 days of duration, semi-dwarf, erect, (medium slender, white grain) was planted.

Drip system: Two 16 mm drip line with 4 lph emitter spaced at 50 cm were laid at an interval of 40cm in each bed. Rice seeds were planted 20 X 15cm (Row-row X plant-plant) and the beds wetted before two germinated seeds were dibbled at 2 cm depth in each planting hole. Before sowing the wet seeds were treated with mono-chrotophos at 3 ml/L water for 20 minutes. A pre-emergence herbicide of pendimethal in at 1.25 kg a.i./ ha was applied 3 days after first irrigation. Irrigation was given daily, based on previous day’s crop ET. (as given in Table 1).

Table1. Drip irrigation schedule followed in different fields (an example is given below)

Duration	Evaporation per day	Water requirement
	mm	l/ha/day
Feb 16-28	6.68	18704
Mar 1-15	6.73	40044
Mar 16-31	6.82	47740
Apr 1-15	6.09	56840
Apr 16-30	6.53	60947
May 1-15	7.44	70019
May 16-31	7.57	58878

The fertigation schedule indicating the nutrients requirement at different phenological stage and quantities of recommended dose of nutrients applied at 150 kg N,55 kg P2O5 and 175 kg K2O/ha. The fertilizers in water soluble form in splits applied through drip at a frequency of two occasions in a week to mitigate the high pH of soil. The quantity of nutrients determined based on initial soil nutrients status. Fertigation schedule followed in the experiment.

Control plot with inundated water was prepared by conventional puddling and sowing was done in the same way, weeds growth was controlled using weedicide and manual weeding during the critical period of weed growth. Four sprays of quinalphos at 2ml/L were given against targeted pests –stem borer and leaf roller at critical period.

The data of yield per acre, water used in liters are presented in table 3. In table 4 the water productivity under flood and drip irrigation are reported for many rice varieties.

Table 2. Water and power use by rice crop under two different Irrigation methods (2009-2010) Elayamuthur farm, (10° 34' 48" N / 77° 14' 24" E), Coimbatore, Tamil Nadu (Rice variety, ADT 45)

Irrigation	Yield (t/ha)	Water use (million liter/ha)	Power use (units/ha)
Flood	7.75	23.75	1168
Drip	9.5	8.0	565
Difference (%)	22.5	66.3	52

Table 3: Water productivity in flooded and drip irrigated rice (kg/m³)

Rice Variety	Flood irrigated	Drip Irrigated
SBH-999	0.13	0.67
25P25	0.10	0.57
25P31	0.14	0.62
MAS- 946-1	0.14	0.52
Try (R)-2	0.13	0.53
BPT	0.10	0.46
PusaSugandha	0.12	0.70

3. FARMES' FIELD DEMONSTRATIONS

Encouraged by these promising results (Soman et al 2018), the technology is extended to farms covering seven different states, during two main seasons-Rainy (Kharif) and winter (Rabi) under varied ecosystems of the country were carried out using the drip irrigation and fertigation technology in Rice during 2009-2014 .About 15 rice genotypes/hybrids were used in these trials and the results are discussed.

Monsoon or “Kharif” June-July sowing, as also Winter or “Rabi” Oct-December sowing was done. Some farmers raised Direct seeded rice (DSR) crop while others raised seedling transplanted rice crops (Not clear). Details such as name of the farmer, rice varieties used for direct sowing or transplanted crop, and the season of sowing, harvest data etc. are given in Table 5. The soil type varied from sandy loam to clayey loam.

The demonstration trials were carried out in farmers' field in seven States 1. Andhra Pradesh (AP) covering Vizag, Kadapa, Kurnool, East Godavari and Vijayanagaram districts 2.Telengana covering Medak, Karimnagar, Nalgonda districts 3. Chhatisgarh, Durg district, 4. Rajasthan, Kota district 5. Punjab Patiala, and Ludhiana districts, 6. Tamil Nadu Cuddalore, Tiruvannamalai, Madurai districts, and 7. Maharashtra, Raigarh district, during 2009 to 2014.

The main objectives were, 1. to determine yield stability and pattern of response of genotypes to drip irrigation and fertigation treatments across varied ecosystems and 2. To demonstrate the efficacy of drip and fertigation technology in increasing yield and

water productivity to wide spectrum of farmers in the country and motivate them to use water and fertilizer saving technologies.

The quantum of irrigation given varied from location to location based on the evapotranspiration (ET) and the season of the crop (Table 4). Fertilizers were injected through a ventury system. The fertigation schedule (Tables 5a and 5 b)) indicating the nutrients supplied at different stages of growth and quantities of recommended dose of nutrients applied. The fertilizers in water soluble form in splits applied through drip at a frequency of two occasions per week to mitigate the high pH of the soil.

Table 4. Irrigation schedule for Drip Method \$

S. No.	Period	Mean Daily Evaporation (mm/day)	Crop Water Requirement (l/ha/day)
1	June 1 fortnight (fn)	5.53	12289
2	June 2 fn	5.53	55300
3	July 1 fn	5.42	60222
4	July 2 fn	5.35	59444
5	Aug 1 fn	5.23	69733
6	Aug 2 fn	4.91	65466
7	Sept 1 fn	4.87	54111

\$ This table (used for Andhra Pradesh for June planting, Kharif) is an example for the different schedules followed in different locations mentioned in the paper.

Table 5 a. Fertilizer recommendations for each state (basis for fertigation schedules)

FERTILIZER (NPK)				
State of India	N	P	K	kg/ha
Andhra Pradesh (&Telengana)	180	62.5	75	
Chattisgarh	220	55	125	
Maharashtra	100	50	50	
Punjab	150	60	45	
Tamil Nadu	150	50	50	

Table 5 b. Ratios of N and K used to prepare Fertigation schedule in each of the farmer fields

FERTIGATION SCHEDULE	
Stage of Crop	N: K ratio
till 10 DAP#	01:00
11-35 DAP	03:01
36-55 DAP	01:01
55-65 DAP	01:03
71-85 DAP	00:01

All P fertilizer is applied as basal during field preparation along with FYM (manure), Zn, and Fe. DAP= Days after germination in Direct seeded or plant establishment in Transplanted rice.

Weeds were controlled by application of Pendimethalin at 1.25 l/ha 3 days after sowing, plus manual weeding at critical stage of growth 45 days after sowing. Routine observation for stem borer and leaf roller were made and appropriate treatment given.

Table 6. Farmer name, location, rice planting type, rice variety and yield performance

	FARMER NAME	LOCATION	PLANTING TYPE	SEASON	RICE VARIETY	YIELD t/ha		% YIELD INCREASE OVER FLOOD
						DRIP	FLOOD	
1	V.Ranga Rao	MedakTelengana (TGA)	DSR (direct seeded)	July, 2009	US311	9.38	7.41	26.7
2	G.Srinivas	MedakTGA	Transplanted (TRP)	Jan, 2011	MTU1010	8.15	6.42	26.9
3	G.Srinivas	Medak,TGA	TRP	July 2011	MTU1010	8.4	7.5	14.7
4	D.Chandra Appa Rao	Vizag,Andhra Pradesh (AP)	TRP	Jan-2011	MTU-3626	7.41	5.92	25.0
5	Siva Reddy	Kadapa,AP	TRP	Jul 2011	MTU 4870	9.38	7.41	26.7
6	Mahipal Yadav	Kareemnagar, TGA	TRP	Jun 2013	MTU1010	8.89	7.16	24.1
7	Repeated	KareemnagarTGA	TRP	Oct, 2013	MTU1010	6.42	4.94	29.9
8	Shankar Reddy	KurnoolAP	DSR	Jun 2013	MTU 1010	7.9	6.17	27.9
9	VeerarajuChaudary	East Godavari, AP	TRP	Jun 2013	BPT5204	8.58	6.66	28.7
10	MVV Satyanarayana	East Godavari, AP	TRP	Jun 2013	MTU-7029 Swarna	8.89	6.91	28.6
11	Mrs.Kranti	Vijayanagaram AP	TRP	Jun-2013	Arize-6449	7.16	5.68	26
12	Nanda kumar varma	Durg, Chhattisgarh	TRP	Mar,2010	MTU-1010	7.41	6.17	20
13	R.Vijay	Kota,Rajasthan	TRP	July,2009	Pusa-1121	8.39	7.16	17.2
14	S.Tapia	Kota,Rajasthan	TRP	July,2010	pusa1121	8.4	6.91	21.4
15	Govt.seed farm	Patiala,Punjab	DSR	Jul-11	PR115	6.36	5.43	17.2
16			DSR	Jul-11		5.82	6.36	7.34
17	Diddar singh	SBS nagar,Punjab	DSR	Jun-10	Arize 6129	8.01	6.91	15.8
18	V.Annamalai	Tiruvannamala Tamil Nad (TN)	DSR	Feb-12	ADT-45	9.63	7.65	25.8
19	Solamalai	Madurai, TN	DSR	Aug-13	JGL-1798	11.61	9.13	27
20	SekharBad savale	Raigarh, Maharashtra	DSR	Dec-09	Pusasugandh	5.92	4.69	26.3

The conventional flood system plot was prepared by puddling, seedlings transplanted and the same rate of fertilizers was applied in four splits. Other practices were according to conventional system.

4. DISCUSSION

A critical evaluation of the results of two year trial result show that: The drip system with fertigation through drip not only saved 50-61 % water but also increased yield and water productivity in all the genotypes both the years over flood system (Table 6) While the water productivity in flood irrigated control ranged between 0.097 and 0.224 kg/m³ for all the varieties/genotypes during 2010 and 2011, the same WP was close to three to five times higher under drip plus mulch plots ranging from 0.365 kg/m³ to 0.714 kg/m³ maximum recorded by 27p31 (Table 2 and 3). Most of these varieties are of 110--135 days duration, (Medium slender/bold grain), produced yields ranging from 4.5 t to 8.19 t per ha under drip plus poly/paddy husk mulch recording more than 17.7 to 22.2 % over flood irrigated and the water productivity highest 0.713 kg/m³ indicating that genotypes such as 27p31 have used barely around 1400 L water to produce one kg of rice which is approximately the crop loses by way of evapotranspiration only, to produce one kg grain, indicating water use efficiency more than 95 % (WUE) under aerobic drip irrigated using plastic mulch conditions.

The studies thus showed that drip irrigation and fertigation with mulching (paddy husk/polythene) have an explicit role in increasing yield and water productivity of the varieties tried. Similar results were observed by Medonalt et al, 2014, Ramadass and Ramanathan, 2017., Soman, 2012. Rachel Predeepa's (2012) observation that aerobic rice is the next generation innovation in rice cultivation Technology.

The technology has been demonstrated in farmers' field of Punjab, Rajasthan, Chattisgarh, Andhra-Pradesh and its profitability over conventional flood system has been well established. The value of water saved should be considered in the context of acute drought experienced in some years. Most of the districts in Karnataka and Tamil Nadu in the Cauvery basin experience unprecedented drought in the last so many years (Sashidhar, 2009), where three paddy crops used to be raised in a year, it has now become impossible even to harvest single normal crop, allowing the fields to fallow during major part of the year due to non-availability of water. Especially in such situations, aerobic rice cultivation with precision farming package, using drip and fertigation with mulch technology offer scope, will enable rice farmers who account for more than 65 % of population in the rice growing districts, to get better returns by saving water, labor and other inputs. Experience so far have shown that farmers do not adopt technology for the sake of water or power or other resource saving alone. In India water is not metered, power is highly subsidized. New technologies are accepted by the farming community, if it gives more profit, supported by government's farmer-friendly policies, offering subsidy and other incentives.

A critical examination of the performance of 15 genotypes in over 20 farmers' field covering seven States under different ecosystems shows that almost all genotypes performed as per their ascribed attributes. Under drip fertigation, the maximum grain yield of 11.61 t/ha was from genotype JGL1798, in Madurai, Tamil Nadu and the minimum was from PR-115, 6.363 t/ha and 5.829 t/ha under sprinkler system, in the Government Seed Farm, Patiala, Punjab. All these genotypes recorded yield between 9.139 t/ha (JGL1798) and 4.94 t/ha (MTU1010) under flood irrigated conventional system (control). The increase in yield in drip irrigated rice fields over those of flood irrigated ones, irrespective of genotypes varied from 14.7 % (MTU-1010, Kharif crop) to 29.9 % (MTU 1010, transplanted, Rabi crop). The minimum yield obtained in this variety under flood could also be due to hail storm damage. However, the overall performance of the genotypes show that drip irrigation coupled with fertigation with appropriate dose and proportion of water soluble fertilizer, given twice a week, enabled the crop to perform to its optimum potential. The savings in water in drip irrigated rice fields and increased water productivity and grain yields under aerobic rice systems have been reported by Soman et al (2018), Hemalata (2015) Gururaj Kombali (2013), Parthasarathi et al, (2013), Anusha and Nagaraj (2015).

The results have explicitly demonstrated that drip irrigation and fertigation technology with appropriate proportion of nutrient fertilizers in dissolved form when injected in irrigation water at twice a week interval had resulted in maximum fertilizer-use efficiency and optimum yield response and saving in water (not measured in the farmers field) and recorded enhanced yield in drip irrigated farms from 17.2 to 29.9 % over the flood irrigated fields, thus establishing the efficacy of drip irrigation and fertigation technology in increasing the yield of grains over conventional flood irrigated system.

Generally, the farmers' response to new technologies is slow, even when there is yield advantage. As the majority of farmers are small/marginal (holding <2.0 ha), cash incentives like subsidized rate for drip system is expected from the government which is presently not available for rice cultivation using drip. Considering that millions of hectares of rice are cultivated using conventional, puddled, flood system, and the huge water saving, yield advantage and ease in cultivation involved in using drip system, the government and the farmers should jointly make efforts to spread the area under such water saving technologies so as to avert impending water crisis in the country.

There is further progress in the adoption of this technology as the State Government of Andhra Pradesh has started providing special financial support to farmers to grow rice crop with drip irrigation. There is acceptance of the water saving and yield enhancing technology.

5. CONCLUSION

Under drip –fertigation, the water productivity of rice crop rose to 0.46 to 0.67 kg/m³ across varieties and locations. Rice yields were higher (13-28%) across varieties compared to the yields recorded in the conventional flood method. A standard rice growing package with drip fertigation is made available to farmers. Considering the direct water, power and yield benefits, the state governments in India are slowly warming up to the idea of subsidising the investment cost of the irrigation system to rice farmers; in Andhra Pradesh, Tamil nadu and Haryana states of India in this financial year.

This work also generated a number researchable issues: (1) drip -water management effect on methane gas emission from rice fields and its impact. (2) Are there any specific adaptation traits among rice to drip method of soil wetting (3) Can fertigation help in reducing excess nitrogen entry to surface water in rice ecosystems (4) Can drip method, and associated micro climate influence the disease and pest spectrum affecting rice crop/alternate follower crop etc.

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