International Journal of Water Resources and Arid Environments 10(2): 70-77, 2021
ISSN 2079-7079

Drip Irrigation and Fertigation Technology for Rice Production Leading to Higher Water Productivity

P. Soman

Senior Vice President and Chief Agronomist (Global), Jain Irrigation Systems Ltd., India

Abstract: Rice is in ever-increasing demand in India and in South, South East Asian and African countries. A hectare of rice consumes 1300-1600 mm per season as reported in literature. But farmers use much more, up to 2000 mm, in India. As the demand for water rises in the future, water availability for agriculture in India which is 83.3% of total water used today, will shrink to 78.2% in 2010, to 71.6% 2025 and to 64.6% in 2050. We are almost exhausting irrigation water to bring any more land under conventional irrigation. The future of rice production 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 and grown in continuous standing water. The water productivity is hardly 0.15 kg/m^3 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 12 years, this input management method is tried over several rice ecologies in India and over several rice varieties spanning both direct seeded (DSR) and transplanted rice (TPR) growing systems and in sole rice or rotation with other crops. Under drip –fertigation, the water productivity rose to 0.46 to 0.67 kg/m^3 across varieties and locations. Rice yields were higher (13-28%) across varieties compared to the yields recorded in the respective conventional methods. A standard rice growing package with drip fertigation is made available to farmers. The benefit – costs (BC) worked out in individual farms ranged from 1.4 to 2.1 across varieties. This work also generated a number research able 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) Could 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.

Key words: Rice・Water productivity・Drip irrigation・Fertigation

INTRODUCTION

Approximately 80 % of fresh water is used for irrigation of agricultural crops in India. Thirty percent of irrigation water is used for cultivation of rice under conventional lowland rice system. On an average, rice use 1400 liter water by evaporation and transpiration to produce one kg rice [1]. Exploitation of surface and ground water has reached its maximum in many States in India, that unless water saving technologies are used, it will be impossible to practice, sustainable agriculture in coming years.

The demand for water for domestic, municipal, industrial and environmental purposes rise in the future and less and less water would be available for irrigation. Water availability for agriculture in India which is 83.3% of total water used today, will shrink to 71.6% 2025 and to 64.6% in 2050 (Min. Agriculture, GOI). We are almost exhausting all of the irrigation water to bring any more land under irrigation.

Rice is the main grain that is in demand in India and South Asian countries. A hectare of rice in conventional puddle cultivation uses 1300-1600 mm per season as per the literature (i.e 13 to 16 million liter). But in actuality farmers use much more volume (up to 2000 mm) in many delta areas in India. In Asia, 17 million ha of irrigated rice will face “physical water scarcity” and 22 million ha may have “economic water scarcity” by 2025. The highest share of this inadequacy will occur in India, the largest rice producer of the region.

Corresponding Author: Dr. P. Soman, Senior Vice President and Chief Agronomist (Global), Jain Irrigation Systems Ltd., Jalgaon, Maharashtra, India.

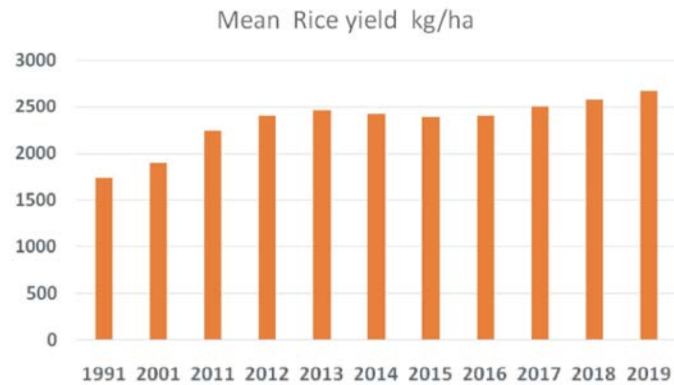

Fig. 1: Average rice yield in India under conventional water management systems (Source: Statista)

The future of rice production 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 puddle condition with large volumes of water and grown in standing water. The water productivity is hardly 0.15 kg/m^3 water, which is very low.

With all that water use, still the rice yields in India are not very high and seems to have stagnated (Fig. 1) in the last decade or so.

Indian average productivity of rice is very low (Fig. 1). Farmers use excess water and produce less!.

In the case of several other so called high water user crops - sugarcane, banana, vegetables, etc. we could find that actual water need is found to be 50 -60% less than what are thought of the water requirements. This is made possible by drip irrigation technology; moisture availability in soil is kept close to the crop water requirement on a continuous basis. In this method, the crop performs close to its genetic potential and yields are enhanced. Given that 45 per cent of the country's total irrigation water is used solely for rice cultivation, the need to improve farming methods is imperative.

Besides being wasteful, excessive use of water results in lower yields and adverse environmental effects such as soil salinity and waterlogging. Paddy yields in irrigated regions of Tamil Nadu, Punjab and Haryana range from five to six t/ha, whereas in the high-rainfall areas of eastern UP, Bihar, West Bengal and Orissa, the yields are about 1.8 t/ha. The main reasons for the poor yields are improper irrigation management and waterlogging. Economic analysis of this issue is reported by Asok Gulati and Gayathri Mohan [2]. Their study brought out the non- uniformity in rice water consumption across Indian States. Farmers in Punjab consumed twice the quantum of water to produce a unit of rice compared to farmers in West Bengal and Bihar.

MATERIALS AND METHODS

At Jain Irrigation systems whose motto is *"more crop per drop',* we have carried out extensive field trials using drip irrigation and fertigation technology on important economic crops including water "guzzlers" such as banana, sugarcane and rice and found that the water consumption of these crops has been reduced to 40-50 % by using micro irrigation systems; under this system moisture availability in soil is kept close to crop water requirement and the performances of crops are optimal and 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 since 2007, several rice varieties and genotypes under upland aerobic and low land transplanted conditions in farmers' field using drip irrigation system to maximize yield and water productivity.

The drip technology is tested and found suitable in both the traditional wet rice and the dry seeded rice (DSR). Dry seeding is practiced in aerobic rice cultivation; and it is similar to what is generally referred to as upland rice (topographically high altitude).

This article mainly discusses both the experimental trials and farmer demonstrations in an effort to commercialize a package of technology for growing rice with optimum water economy.

Experimental Stage: Basic experiments were carried out during the rice season of 2010 and 2011 in a sandy clay soil with good drainage, pH-7.66, E.C 0.21 dsm^{-1}, in Jains experimental farm, Udumalpet, Tamil Nadu (geographical coordinates 10-36'N and 77-14' EL). The experimental fields were dry ploughed and harrowed, raised beds of 15 cm height, 120 cm width have been formed. A basal dose of fertilizers at 345 kg SSP, zinc sulphate 50 kg,

Table 1: Irrigation schedule for Drip Method $

S.No.	Period	Mean Daily Evaporation (mm/day)	Crop Water Requirement (l/ha/day)
1	June 1 fortnight	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,) is an example for the different schedules followed in different locations mentioned in the paper.

Table 2: Fertilizer recommendations for each state (basis for fertigation schedules)

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

Table 3: 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

Ferrous sulphate 50 kg/ha incorporated. The plot size in 2010 was 28 mX23 m and replicated three times. 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 used. Two 16 mm drip laterals with 4 lph emitters spaced at 50 cm were laid at an interval of 40cm on each bed. The row-row X plant-plant spacings were 20 x 15 cm respectively. The beds wetted before pre- germinated seeds were dibbled at 2 cm depth in each hole. Five holes in each row and covered with soil. Before sowing the wet seeds were treated with monochrotophos at 3 ml/l water for 20 minutes. A pre-emergence herbicide of pendimethalin at 1.25 kg a.i. per ha was applied 3 days after first irrigation. Irrigation was given daily, based on estimated crop ET (Table 1). Fertilizers applied through drip system (fertigation) following a schedule given in Tables 2 & 3.

Multi Location Field Trials: Using the basic methodology described above trials were conducted by establishing drip irrigation systems in several rice ecosystems spread in many States in India- Andhra Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Tamil Nadu. Trials were also conducted in the two major crop seasons, Rainy (June-August) and Post rainy (September-December) and in Summer (February-May). Trials with drip irrigation and fertigation were conducted in both dry seeded rice (DSR) and in transplanted rice (TPR) methods of cultivation.

Varieties Used: Hybrids used are Arize 6129(Bayer), RH 257(Monsanto), MK 2325(Syngenta), duration of crop after sowing is 115 to 140 days. Other varieties released by PAU like PR 111, PR 113, PR 114, PR 115 and PR 120 are used, duration of crop after sowing is 130 to 145 days. In Basmati, varieties used are Basmati 370, Basmati 386, Super Basmati, Pusa Basmati 1121; duration of crop 130 to 150 days. Additionally, other local prominent varieties were also included in each location.

Agronomy practices followed during the on farmtrials.

- Prepare well leveled and pulverized soil with adequate moisture. (Do a pre- planting plough, irrigate and germinate weeds and plough gain before land is ready for rice planting).
- Prepare Bed and furrow if possible.
- Hand sow / drill the seeds.

- Row to distance (20 x 15 cm)(ROW –ROW x PLANT –PLANT)
- Depth of seed 2 cm in dry seeded cultivation.
- Fully drip Irrigate the field after sowing to provide the required moisture.
- Drill the basal dose using a drill or apply on the bed before planting and incorporate.
- Weed control : In the absence of standing water heavy weed infestation was envisaged. However weeds could be easily controlled by a combination of hand weeding and rice husk mulching or by weedicide application. Application of Pendimethalin at 500ml/acre at 72 hours after sowing provided effective control.
- Routine observation for insects (Stem borer , Leaf roller) and disease incidence were made during the crop.
- Irrigation in drip plot was done by placing two drip lines on each bed (Jain inline drip laterals 16 mm diameter with drippers of 4 lph placed at 50 cm spacing along the drip line).
- Fertilizers were injected (fertigation) thru a ventury system following a schedule that was prepared for each location.

The quantum of irrigation varied from location to location based on the evaporation of the location (Table 1). The fertilizer doses are varied based on the fertilizer recommendations prevailing in each location (Tables 2 & 3).

RESULTS AND DISCUSSION

Rice Yield and Water and Power Use under Drip Irrigation: Drip irrigation enhanced rice yield by 22.5% and reduced water and power consumption respectively by 66 and 52% each (Table 4). The yield improvement occurred in all rice varieties tested (Table 5).

The field trials proved that: (1). Keeping the soil wet alone and not providing standing water results in yields comparable or more than in flooded (with standing water) condition.; (2.) Weeds, thought to be a major issue in non-flood situation can be managed by a) mulching the seedbed with rice husk at planting and one manual weeding or by minimum weedicide application 3. The performance of several varieties indicated that provision of soil moisture is the key requirement and not standing water for rice production.

Demonstrations in Farmers' Field: As a second step the drip irrigation technology for rice production was demonstrated in farmers' fields in many states during 2009- 2011 (Table 6). Irrigation systems were installed by the company and operated by farmers. Necessary training on operation and maintenance were given to the farmers. Irrigation and fertigation schedules were prepared by Jain expert who advised the farmers. Rice yields were higher in drip than in the conventional irrigated plots in all locations and all varieties.

Benefits from Drip Irrigation in Rice Cultivation: Observations from the research plots and farmers' fields can be summarized as follows:

- Early and Uniform maturity of the crop
- Lesser labour use for cultivation
- Lesser Cost of cultivation
- Higher input use efficiency- Water and Fertilizer
- Higher yield
- Less water consumption
- Less pumping energy use
- Lower ground and canopy humidity resulting in low incidence of pests
- Lower rates of leaching and absence of run off resulting in lesser pollution by fertilizer and agrochemicals.
- Drip- Fertigated rice has been found to have acceptable grain qualities.

The grain quality tests indicated the following attributes for rice produced by drip and fertigation instead of flood irrigation.

- Lower percent of chaff
- Lower percent of broken grain
- High millabililty
- No perceptible shift in cooking time
- No perceptible change in taste of cooked rice
- Lower levels of pesticide residue in the produce
- Reduced methane emission from the fields
- Reduced mosquito population due to lack of standing water.
- Contributes to human health maintenance

Economic benefits of drip are analyzed using field data collected from different locations (Table 7).

Table 4: Water and power use under two different Irrigation methods (2009-2010) trial, Elayamuthur farm, (10o 34' 48'' N /77o 14' 24'' E), Coimbatore, Tamil Nadu (Rice variety, ADT 45)

Method	Yield (t/ac)	Water use (million liter/ac)	Power Use (units/ac)
Flood	3.1	9.5	467
Drip	3.8	3.2	226
Difference%	22.5	66.3	52

(Source: P. Soman *et al*. [6])

Table 5: Yield of different varieties under drip and conventional flood plots (harvested from Jalgaon, (21o 2' 54'' N/ 76o 32' 3'') Maharashtra.

Rice yield in a trial, Jalgaon, Maharashtra (t/ac)		
Variety	Flood	Drip
SBH-999	2.4	3.2
25P25	1.8	2.7
25P31	2.8	3.2
MAS- 946-1	2.5	2.5
Try (R)-2	2.8	2.9
BPT	1.9	2.2
Pusa Sugandha	2.3	3.4

Table 6: Farmer name, location, rice planting type, Drip line type, Rice variety and yield performance

S.N	Farmer Name	Location	Planting Type	Season	Drip Type	Rice Variety	YIELD t/ha Drip	Flood	% Yield Increase Over Flood	Remarks
1	V.RangaRao	Medak, Telengana (TGA)	DSR (direct seeded)	July,2009	J-Turbo line	US311	9.386	7.41	26.7	
2	G.Srinivas	Medak,TGA	Transplanted (TRP)	Jan,2011	J- Turbo line	MTU1010	8.15	6.42	26.9	
3	G.Srinivas	Medak,TGA	TRP	July 2011	J- Turbo line	MTU1010	8.4	7.5	14.7	
4	D.ChandraAppa Rao	Vizag,Andhra Pradesh (AP)	TRP	Jan-11	J- Turbo line	MTU-3626	7.41	5.928	25.07	
5	Siva Reddy	Kadapa,AP	TRP	Jul-11	J- Turbo line	MTU 4870	9.386	7.41	26.7	B:C = 1.5
6	MahipalYadav	Kareemnagar, TGA	TRP	Jun-13	J-Turbo Aqura	MTU1010	8.892	7.163	24.1	
7	Repeated	Kareemnagar,TGA	TRP	Oct,2013	J-Turbo Aqura	MTU1010	6.42	4.94	29.9	Partially damaged by hailstorm
8	Shankar Reddy	Kurnool,AP	DSR	Jun-13	J-Turbo Aqura	MTU 1010	7.9	6.175	27.9	
9	VeerarajuChaudary	East Godavari, AP	TRP	Jun-2013	J-Turbo Aqura	BPT5204	8.586	6.669	28.7	
10	MVV Satyanarayana	East Godavari, AP	TRP	Jun-2013	J-Turbo Aqura	MTU-7029 Swarna	8.892	6.916	28.6	
11	Mrs.Kranti	Vijayanagaram AP	TRP	Jun-2013	J-Turbo Aqura	Arize-6449	7.163	5.681	26	
12	Nanda kumarvarma	Durg, Chhattisgarh	TRP	Mar,2010	J-Chapin tape	MTU-1010	7.41	6.175	20	B:C = 1.5
13	R.Vijay	Kota,Rajastan	TRP	July,2009	J-Turboline	Pusa-1121	8.398	7.163	17.2	B : C = 1.9
14	S.Taparia	Kota,Rajastan	TRP	July,2010	J-Turboline	pusa1121	8.4	6.916	21.4	
15	Govt.seed farm	Patiala,Punjab	DSR	Jul-11	J- turbo aqura	PR115	6.363	5.43	17.2	Grain test wt. 39.9gm
16			DSR	Jul-11	Microsprinkler		5.829	6.363	7.34	Test Wt,37.6 gm
17	Diddarsingh	SBS nagar,Punjab	DSR	Jun-10	J-Turbo Aqura	Arize 6129	8.01	6.916	15.8	B: C = 1.8
18	V.Annamalai	Tiruvannamala Tamil Nad (TN)	DSR	Feb-12	J-Turbo line	ADT-45	9.633	7.657	25.8	
19	Solamalai	Madurai,TN	DSR	Aug-13	J- Turbo line	JGL-1798	11.61	9.139	27	
20	SekharBadsavale	Raigarh, Maharashtra	DSR	Dec-09	J-Turbo line	Pusasugandh	5.928	4.693	26.31	

Source : P.Soman *et al*. [7].

Table 7: Summary of cost and benefits accrued to the farmers who adopted drip irrigation for rice cultivation.

State	Punjab	Rajasthan	Chhattisgarh	Andhra Pradesh
Farmer details	Didda Singh, Mahalo, SBS Nagar Dist.,	Rajesh Vijay, Bhadana village, Kota dist.	Nanda Kumar Varma, Pirda, Durg dist.	Siva Reddy, Buddaipally, Kadapa dist.,
Rice variety	Arize, 6129	Pusa-4 (1124)	1010	MTU 4870
Crop area	0.5 acre	15 acre	1 acre	0.5 acre
Yield	3.24 t/acre	1.2 t/acre	3t/acre	3.8 t/acre
Incremental yield (due to drip)	0.8 t/acre	0.6 t/acre	1.0 t/acre	1.5 t/acre
Cost of Cultivation INR	9,260 /acre	11,000/acre	9,000/acre	13,300/acre
Cost of drip equipment INR	30,000 /acre	60,000/acre	28,000/acre	45,000/acre
Subsidy for equipment## INR	18,000/acre	42,000 /acre	nil	40,500/acre
Life of the equipment$$	7 years (14 seasons)	7 years (14 seasons)	3 years (6 seasons)	7 years (14 seasons)
seasonal cost of equipment INR	2142.9 /acre	4285.7 /acre	4667.00/acre	3214.3/acre
COP + equipment cost (seasonal) INR	11,402.9/acre	15285.7/acre	13667.00/acre	16514.3/acre
Gross income INR	35640 /acre	44,000.00/acre	34,500.00	38,000 .00 /acre
Net income INR	24,380/acre	28714.3/acre	20833	23867/acre
B C ratio	2.1	1.9	1.5	1.4
Pay Back period&&	1.23 seasons (= 1 year)	2.09 seasons (= 1 year)	1.3 seasons (= 1 year)	1.9 seasons (= 1 year)
water saving % **	40	40	35	45

** As % of water applied in conventional flooded plots.
$$ Drip equipment is generally used for 7 years ; total of 14 crops on rotation.
Subsidy component is not considered for B C and Payback period estimates.
&& Income from rotation crop (Rotation crop after rice) is taken as equivalent to rice net income.
Source: P.Soman, [3]

Table 8: Performance of a rotation crop after the main rice crop under drip irrigation and the enhancement of annual return from the farm

FARMER Details	Kharif Crop	Yield t/ac	Gross Income/ac	Cost of Cultivation Rs/ac	Net Rs/ac	Rabi - rotation	Yield t/ac	Gross Income Rs/ac	Cost of Cultiva-tionRs/ac	Net Rs/ac	Annual Net income Rs /ac
Sri.T. MahipalYadav, Chintelpet, Karimnagar	Rice -MTU 1010	3.6	48600	22800	25800	Rice	2.6	35100	21250	13850	39650
M.Veerarajuchowdary, Kotapadu, E.Godavari	Rice-BPT 5204	3.4	50625	21600	29025	Maize	5.2	65000	14250	50750	79775
MVV, Satyanarayana,Nallamilli, E.Godavari	Rice-Swarna 7029	3.6	52560	22500	30060	Brinjal	40	120000	20500	99500	129560
Srimati. Kranthi, Itlamamidipalli, Vijayanagarm	Rice- Arize 6449	2.9	43875	19750	24125	Gherkins	16.5	148000	47500	100500	124625

In all these demonstration farms drip field recorded higher yields than what the respective farmers used to get in conventional cultivation. On average, the investment cost of the equipment could be recovered within a year, in two seasonal crops. Although subsidy was obtained for the equipment in 3 out of 4 cases, the subsidy component is not adjusted for estimating payback period and BC. Introduction of subsidy for equipment for rice is a major policy intervention expected. Most of the framers we were working with already had drip equipment that could be easily modified for rice crop planting pattern.

Irrigation water could not be metered in the farmers' fields. However, from the pumping data, the water use for drip could be estimated.

Commercialization of the Technology: While the experimental and farmer field data are promising for the introduction of the technology, we realize that it will not be an easy ride all the way through. The attitudinal change required to accept the new method of irrigation especially for rice is huge. The following steps are taken to accelerate the process: Working in collaboration with public scientific and extension institutions: national agriculture research bodies, regional research stations, Krishivigyan Kendras, International Agriculture Research institutions and progressive farmers, participation in National and International seminars and conferences [3, 4].

Regional rice research stations are keeping drip irrigated rice plots for visiting farmers.Technology is also tested in collaboration with International Rice Research Institute (IRRI), Manila, at Los Banos, Philippines and Varanasi and Modipuram, India for the last four years and with International Water Management Institute (IWMI) in Medak, Telengana. We partner with research organizations both in the area of rice research and water management. Currently, a demonstration plot is maintained at the Rice research Institute, Hyderabad where Jain is collaborating with IIRR.During 2019-2021, drip –rice technology is routinely introduced in AP and Haryana on a commercial scale with 50 ha in each state.

Among the multiple reasons for the poor adoption of the drip technology is the huge *mental block*; farmers cannot conceive the idea of rice crop growing without standing water. The tradition is very strong and been followed by generations. One of their concern is the issue of weeds which they think that in the absence of standing water would be difficult to control. Introduction of husk mulching or limited use of herbicides are solutions; but farmers fear about the cost and the additional work involved.

A second factor is the cost of drip system; which varies from 65,000 to 100, 000 INR per ha based on the soil textural type. This issue is in the know of the government and though subsidy assistance was not there for cereal crops in the past, the situation is slowly changing. Few State governments in India andhra Pradesh and Haryana for example, began the process of providing financial assistance to small farmers for rice as well.

More focused extension and farmer awareness programs both by private supplier companies and government departments have to come into the fore. There are successful farmers who use the drip technology for rice and then the rotation crop (wheat or Mustard in Haryana, Punjab, a second rice or pulses or vegetables in Andhra Pradesh and Tamilnad). Their experiences have to be highlighted and spread across all rice growing regions.

Table 8 demonstrates the overall economics of the drip system with first rice crop followed by a rotation crop. The overall incomes from unit land has gone up annually. This is another factor encouraging the farmers to adopt drip irrigation for rice.There should also be interventions at the policy level even incentivizing the farmers to adopt the drip technology.

Environmental Issues: Apart from the water conservation issue by the large scale adoption of the drip technology; conversion of one acre into drip from flooding would generate (based on our field data) sufficient water for another 2.9 acre rice or 3.2 acre vegetable crop, drip adoption would result in other benefits in areas crucial to the sustainabilityof the environment.

Emission of methane gas in rice ecologies is a major environmental issue; one of the factors, resulting in methane emission from rice fields is the standing water and the anaerobic decomposition of organic matter. In the non-flooded situation like drip irrigated rice the conditions for methane formation would be minimal. However, quantification of the methane gas emission from drip fields is yet to be confirmed. Our collaborative research with IRRI on these aspects is currently in progress at IRRI main campus in Philippines and the Indian IRRI station at Varanasi.

Similarly fertigation- application of fertilizer as a dilute solution in multiple doses for rice crop - would also bring down nitrate pollution into community water bodies. It is also noted that in rice dominated villages the standing water provides a suitable environment for mosquito breeding and diseases transmitted thru them.

Water Productivity of Rice: Generally speaking,water use by rice crop includes transpiration by rice plants and evaporation from the rice growing field; these two are essential components of the water *fate* of the crop; seepage and percolation into the soil profile of the field, the two non-essential components of the water consumption in a rice field.

Studies at IRRI has estimated the transpiration from rice plants range from 500 to 1000 liter per kg unmilled rice. The average evapotranspiration from a rice crop is 1432 liter /kg unmilled rice growing in controlled conditions. This is same as world average water use for wheat. Rice field water use (ET plus Percolation and Seepage) is estimated to be 2500 liter /kg unmilled rice [5]. For every kg rice 1000 liter water is wasted into the soil profile! As we are staring into a future with a reality of water stress (Physical shortage) rice irrigation needs to change: change should avert that 1000 liter going into the deep soil and a change to reduce the water from the 2500liter that currently produces a kilogram of unmilled rice.

It is imperative to modernize irrigation methods and achieve precision in irrigation to restrict the water application only to the extend equivalent to the Evapo-Transpiration (ET) of the crop. Apply only what is required at each time / stage of the crop. Our field studies with metered water supply through drip method repeatedly showed that 1 kg of unmilled rice used only 1724 liter of irrigation water (Table 8).

Table 9: Water productivity in flooded and drip irrigated rice (kg/m^3)*

Variety	Flood rice	Drip
SBH-999	0.13	0.67
25P25	0.1	0.57
25P31	0.14	0.62
MAS- 946-1	0.14	0.52
Try (R)-2	0.13	0.53
BPT	0.1	0.46
PusaSugandha	0.12	0.7
Mean	0.12	0.58
Water required to produce 1 kg unmilled rice	8333 l/kg	1724 l/kg

*P.Soman *et al.* [6]

Extensive data collected from farmers field Haryana, also showed the higher water use efficiency of rice under drip irrigation [4]. Drip irrigation and fertigation together can deliver the two major inputs for crop production; water and minerals and result in enhanced productivity from unit land area with highest possible efficiencies of water and fertilizer use.

CONCLUSIONS

Drip and fertigation method improved rice yield, reduced power and water consumption and enhanced water productivity of rice. The technology is found to work consistently in many but different rice growing environments, across seasons and in different rice growing methods- direct seeding to transplanting. The agronomy package developed over the years offers a solution for water stressed regions to continue with ricefarming.

ACKNOWLEDGEMENTS

The Author expresses his gratitude to Jain Irrigation Systems Ltd. for their active support and encouragement for pursuing this area of research.

REFERENCES

1. Bas Bouman, 2009. How much water does rice use? Rice Today (Jan-March issue 2009) https://www.researchgate.net/publication/281474989
2. Asok Gulati and Gayathri Mohan, 2018. Towards sustainable, productive and profitable agriculture : case of rice and sugarcane. Indian Council for Research on International Economic Relations, April 2018.
3. Soman, P., 2012. Drip Irrigation and Fertigation Technology for Rice cultivation: Asian Irrigation Forum, Asian development Bank, Manila, April 11-13, 2012. ADB. Manila.Philippines.
4. Soman, P., A.K. Sarvan Singh, T. Bhardwaj, Pandiaraj and R.K. Bhardwaj, 2018c. On-Farm Drip Irrigation in Rice for Higher Productivity and Profitability in Haryana, India. Int. J. Curr. Microbiol. App. Sci., 7(02): xx-xx. doi: https://doi.org/10.20546/ijcmas.2018.702.xx
5. Bouman, B.A.M., R.M. Lampayan and T.P. Tuong, 2007. Water management in irrigated rice: coping with water scarcity. Los Baños (Philippines): International Rice Research Institute, pp: 54.

6. Soman, P., Sundarsingh, Balasubrahmanyam, V.R. and Chaudhary Amol, 2018a. Evaluation of the performance of aerobic rice using drip irrigation technology under tropical conditions. International J. Agri. Sci., 10(10): 6040-43.

7. Soman, P., M.S. Prasad, V.R. Balasubramaniam, Sarwan Singh, C. Dhavarajan, V.B. Patil and Sanjeev Jha, 2018b. Effect of drip irrigation and fertigation on the performance of several rice cultivars in different rice ecosystems in India. International Journal of Agriculture Sciences, 10(14): 6672-6675.