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A study on saving water using drip irrigation technologies in paddy and enhancing yield

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Abstract
We know that water is essential for growing rice and it requires standing–water for proper growth and successful cultivation. The practice probably started when under prevailing conditions the farmers has tweaked rice seedlings to grow in accumulated water. The first records of rice cultivation project it as a dry seeded crop grown in ends of high land and forests cleared for shifting cultivation. It's in China that the process of puddling soil and transplanting seedlings began in low-lying areas and river valleys. As transplanting gives a head–start for rice seedlings in their fight with weeds, this method took an easy route of acceptance in other parts of the world, especially in South Asia where originally rice is grown under dry land conditions. But the current scenario is entirely looking for water saving technologies and the aim has been shifted from 'crop productivity' to 'irrigation/water efficiency'. This can be by micro-irrigation that can improve the water use efficiency", stated the survey. The issue of the growth of water-saving /intensive crops in the agriculture of the country. "Around > 89% of groundwater pumped is used for irrigation. The paddy and sugarcane consume > 60% of irrigation water," said the survey. According to a report, as compared to the ratio of the total used volume of water to the production quantity of the world average: India's rice production is 2020:1325 m3 per tonne (UNESCO 2010).
Paddy is a great guzzler, and as compared to flood prone plains of Indo-Gangetic plains of west Bengal and Bihar, paddy takes three times more water in Punjab due to the availability of groundwater and canal systems. Out of 5.0 million hectares area under cultivation in Punjab, the major share is of rice (paddy and basmati 3.0 million hectares, whereas in contrast to 1.23 lakh ha of maize and 2.83 lakh ha of cotton, Like other crops paddy has been reported to be a successful drip fed crop. Thus, rice cultivation is water intensive; it uses 1600 mm per season as per literature, (65 lakh l /ac). But in actuality, much more volumes are applied in many delta areas in India (up to 2200 mm, 90 lakh l /ac).
The use of micro irrigation accompanied by fertigation has a benefit for rice production. On one side water consumption is reduced to a great extent when we use drip and at the same time under non-stress situation, paddy responds with higher yields. Irrespective of the planting technique, varieties, method, climate and location. While rice yields enhancement due to drip-fertigation ranged from 14.7% to 29.9%. (Over that in flood method) averaged up to 11.61 t/ha (2) ability in the soil is kept close to field capacity and the crop is grown to result in enhanced yields. It's possible by micro irrigation technologies.
The topic is reviewed in view to see the reports and works carried out by drip companies. We believe that results from such effort would lead to an actual extension possibility of that technology in the coming years. Of the 43.8 million ha of paddy cultivated in India, even 10% of it gets into drip irrigation which is 4.4 million ha. The impact would be multifold: Substantial saving of irrigation water; meaning irrigating more area under paddy with the available water. Substantial saving of energy; a boon power starved. Increased production of rice; a much-needed requirement for the country.
The paper will help to make awareness that paddy is not a waterlogged crop and can be successfully grown with Drip irrigation.

Keywords: Paddy, drip irrigation, micro irrigation, transplanted rice, yield

Introduction
Currently, in India, total food grain production has been estimated at a record 291.95 mt which is 6.74 million tonnes higher production of food grain of total 285.21 mt achieved during 2018-19. (Abdelraouf, 2013) [2]. The rice production is at a record estimated 102.36 mt in the kharif season (2020-21) crop year on the back of good monsoon rains and acreage, according to government data (FAO, 2010) [18]. The demand augmenting in parallel to the growing population. India should be producing 1.7 mt of additional rice every year to ensure national food security (Das and Chaandra, 2013) [7].

By 2050, Demand for rice is expected to rise by 25% it will have to produce 494 mt of food grains. That is unlikely to happen unless farmers adopt GAP-good agriculture practices, better farming techniques and utilize the inputs like fertilizers and water judiciously. Rice is an obvious focus for water saving as, it is grown on more than 50% of irrigation water and 30% of irrigated land (Barker *et al*., 1999) [4].

"Irrigation capable to improves yields by 60-100% and is a real option to enhance food grain figures", says (Soman *et al.* 2018) [17]. The water saved by drip irrigating paddy - as much as 40 percent of current usage - can be used to irrigate a larger area. This method of cultivation of rice utilizes more than 30 to 45% of the world's freshwater resources (Humphreys *et al*., 2010) [12]. Normally in one hectare area under traditional practice, 2000 mm of water is used on the higher side as reported 1300-1600 mm [7].

"We want to increase the production without increasing water use or lowering quality", said Michele Conte, whose family has managed La Fagiana for decades and who has adopted the Netafim system on some of his land. In Asia, 17 mha of irrigated rice will have physical water scarcity and economic water scarcity respectively by 2025 (Tuong and Bouman, 2001) [6].

Rice is cultivated usually in a puddled condition with large volumes of water and grown in standing water. The water productivity is hardly 0.15 kg/m³ water, which is very low. Even in SRI (Sustainable Rice Initiative) method, the total water use is 745-800 mm per ha with standing water during the major crop phase. Aerobic rice is crop grown in non-puddled, well-drained, & non saturated soils without accumulating water.

A comprehensive package was tested that could reduce resource use and increase productivity in direct seeded rice which forms 28% of Indian rice cultivation. Jain Irrigation, the most highly water conscious Corporate in the country is contributing in its own way to food security by doing research and innovations in water saving and conservation technologies. The company has now tested and released an innovative method for cultivating rice on drip irrigated.

Distribution of Paddy/Rice

The paddy second most important, food grain crop of the world, cultivated in as many as > 118 countries > 153.80 mha with a production of about 618.50 mt. The Asian region consumes > 90% rice produced. The highest average yield productivity is reported from Egypt to the tune of 94 q/ha as against the world's average of 40.4 q/ha. Table 1 depicts the area, production and yield of major rice growing countries.

Table 1: Rice, acreage, production and productivity in major countries

Continent/Country	Area (m ha)	Production (m t)	Yield (t/ha)
Egypt*	0.65	6.35	9.84
USA*	1.35	10.47	7.78
Japan*	1.7	10.91	6.42
China	29.3	185.5	6.33
Vietnam	7.34	36.3	4.95
Indonesia	11.8	54	4.58
Myanmar	6.27	24.5	3.91
Asia	136.56	532.98	3.9
Bangladesh	11	40.1	3.64
Brazil*	3.73	13.28	3.62
Philippines	4.12	14.8	3.6
India	43	129	3
Pakistan	2.4	6.9	2.88
Thailand	10.2	27	2.65

Production values are for brown (unhusked) rice

Source: FAO Quarterly Bulletin of Statistics, 2005;12(3/3):18-19 and * FAO Production Year Book, 2004.

Approx. 41% of the annual food grain production area in India, about 12 million hectares are utilized for the paddy-wheat (Crop rotation) production system, It is grown in almost all the states, with Uttar Pradesh, West Bengal and Punjab leading in area, production and productivity, respectively. Table 2 depicts major states production data with respect to Paddy.

Table 2: Area, production and productivity of rice in various states of India (2020-21)

State	Area - Million Hectares	Production - Million Tonnes	Yield - Kg./ Hectare
Andhra Pradesh	2.11	7.45	3540
Assam	2.47	4.73	1916
Bihar	3.34	8.24	2467
Chattisgarh	3.83	8.05	2101
Odisha	3.85	8.33	2160
Punjab	2.9	11.59	3998
Tamil Nadu	1.44	2.37	1642
Telangana	1.68	5.17	3075
Uttar Pradesh	5.99	13.75	2295
West Bengal	5.5	15.3	2784

Source: Maps of India.com-2021

Origin and History

Rice unlike other crops that man grows is intimately involved in the culture of numerous world societies the rice grain forms an integral part of rituals in Hindu and Buddhist religions. Hence the interlinking of rice with humans is not just as a commodity but as a substance that goes deep into the cultural milieu of the human race.

India and Burma/Myanmar are reported to be the centre of origin of cultivated rice Vavilov (1926). Rice has been the first domesticated crop in Asia, as proved by the Sanskrit literature. Carbonized grains of rice were found in the excavations at Hastinapur (Uttar Pradesh) which belongs to 1000-750 BC. Suggested. Chang (1985) reported the foothills of the Himalayas and the Gangetic belt touching China. 24 various species are considered in the *Oryza genus.*

Precision farming of paddy

Precision farming is considered a modern technology of farming where 1) Timeliness of operations and 2) Precision in quantities of inputs and control measures are practised. The different steps followed in precision farming varies from crop to crop and differences of these practices from conventional practices also vary from crop to crop.

In Precision farming of rice we recommend the following steps: Planting on raised beds, adopting a plant spacing of 0.2 x 0.15 m, irrigating with drip following an irrigation schedule and fertilizer through fertigation scheduling and weed control by weedicide and chemigation for pest control.

Cultivation Method

Based on experiments and field trials over a number of years, the cultivation method and drip system for rice should have the following components:

Adopt dry seeded aerobic method of rice cultivation Disc plough the field twice; first East-West and second-time North-South directions for rainy season crop, it is advisable to prepare broad bed and furrow (BBF) system that will take care of drainage during heavy rain. For Rabi and summer crops even flat seed bed is appropriate For BBF system for seeding; Bed width of 1 m, and height of 0.15 m and furrow width of 0.2-0.3 m Sow rice in rows on a broad bed or on flat seed bed. Rotavate to break

clods on the bed surface to achieve fine Mulch the seeded surface with rice husk.

Rice varieties
Identification of varieties suitable for drip irrigation would take a large number of time-consuming experimental trials. However, it is an intelligent assumption that all the varieties so far found suitable for dry-seeded cultivation would also be suitable for drip. Varieties tested under drip irrigation and fertigation by Jain irrigation.

Varieties tested under drip fertigation
US 311, Arise 6129, SBH 999 (basmati), 25P25, 25P31, Try-R (2), BPT, Pusa Sugandha (basmati), ADT-45, Pusa-2, WGL 32100.

Types of rice cultivation
Paddy is mainly cultivated as uplands and lowlands, upland rice cultivations done with drill or broadcasting or can be cultivated by drip irrigated plots in line sowing. A good area under paddy in, Uttar Pradesh, Bihar, Orissa, Andhra Pradesh, and Tamil Nadu is under rainfed /upland cultivation method. (Abhishek, 2020) [1].
The seed beds are maintained at adequate moisture with periodic drip irrigation in place of flooding. Another practice of Lowland rice cultivation with puddled soils, transplanting, or dapog/matt nursery method is done.

Drip Irrigation - The concept
Drip irrigation is the slow, even application of water at low pressure to the root –zone using a network of plastic tubing placed above the rooting zone (surface drip) or buried among the root branches inside the rhizospheres soil at a certain depth from surface. (Subsurface drip).
In drip irrigation method, crops are irrigated daily to the precise volume of water equivalent to the evapo-transpiration (ET) of the crop. It is estimated from daily Evaporation data using crop and canopy coefficients, the latter two factors vary with the age of the crop and the size of its canopy. These are the two factors that affect the volume of transpiration of the plant/ crop that changes with growth of the crop. Factoring in of these two coefficients is what makes the water requirement estimate unique to that particular crop at that particular stage of its growth.

Sowing and germination Irrigation
It is essential to pre-irrigate and fully wet the broad bed before sowing the seeds. Keep the bed uniformly wet till germination and crop establishment.

Mulching
One of the main issues in dry-seeded and drip-irrigated rice is the germination and growth of weeds. The standing water in the conventional flooded rice will suppress weed germination. We recommend the use of rice husk mulch on the beds after seeding. Mulch is applied 2-3 cm thick on the bed surface. Besides reducing weed growth it also helps reduce evaporation from the soil surface. However, this is an optional recommendation.

Weedicide application
The use of weedicide to prevent weed growth is also plausible. Studies have shown that a pre-emergence weedicide, Pretilachlor sprayed to the seed bed at 1250 ml/ha rate within 72 hours of sowing controls weed infestation effectively.

Fertilizer application through Fertigation
Use of drip technology provides a golden opportunity to apply nutrients as per the need of the crop at each growth stages. In rice also this technology enhances nutrient use efficiency.
Water is not the only need of the plant. To uptake this water efficiently, it requires proper air-water balance within the root zone. Drip irrigation, with its low application rate, prevents the saturation of water within the root zone and continuously maintains field capacity. This provides a favorable condition for the growth of the plant. Drip irrigation also helps to use fertilizer efficiently. With drip irrigation water can be provided at frequent intervals which helps maintain required soil moisture level within the vicinity of the plant roots.

Crop Rotation
Drip irrigated rice can be followed by drip irrigated wheat. The rotation crops can be, a second rice, mustard, vegetables, or seed spices. Both the rotation crops are adjusted in their spacing to suit the drip system on the ground.

Fertigation schedule

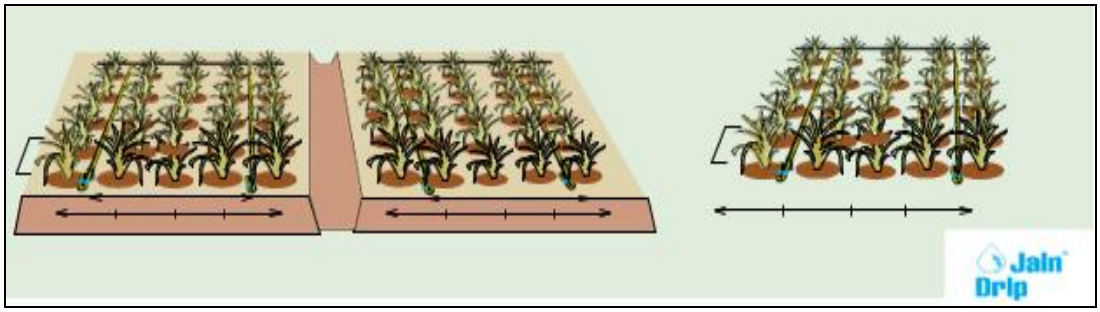
Table 3: Fertigation schedule adopted in drip irrigated rice in AP* (Fertilizer dose 180:80:80 kg NPK per acre) $DAP-days after Germination * Schedule will vary with location.

	Urea	SSP	MOP	$ZnSO_4$	Schedule (urea) kg/day/ac	Schedule (MOP) kg/day/ac
Basal (soil)		500	0	10	-	-
till 10 DAP$	65	0	0	-	6.5	-
11-35 DAP	196	0	16	-	7.8	0.64
36-55 DAP	65	0	17	-	3.3	0.85
55-65 DAP	65	0	50	-	6.5	5
65- 70 DAP	0	0	17	-	-	3.4

Integrated Nutrient management
- Incorporate green manures/bio fertilizers
- Nitrogen management by leaf color chart (LCC)
- Practice fertigation daily.

The different fertilizers are applied in foliar form with water solubilizing fertilizers in periodic intervals under fertigation, but basal is applied in the seed beds while making the beds.

Water Management
By reducing infiltration, seepage, percolation, and evaporation, efficient water use during field preparation in upland aerobic rice is lowered to the tune of about 51% and 32-88% higher water use efficiency, than flooded rice (Bouman *et al*., 2005) [5]. The labour used is also saved in aerobic rice as more labor is required for puddling, land preparation, transplanting, and irrigation activities in flooded rice (Wang *et al*., 2002) [19].



Drip Irrigation - The concept

The concept of using each drop of water in a useful way that leads to production is the aim behind Drip irrigation. earlier it was considered that only a few crops can be grown with drip and with time many new crops brought under drip but crops like paddy are still be considered non-drip crop, the crop is responsible for heavy water use and also responsible for 10% methane leading to Greenhouse effect. The earlier experiments by drip companies like Jain Irrigation and Netafem resulted in at par production of rice. (GOG, 1994) [10].

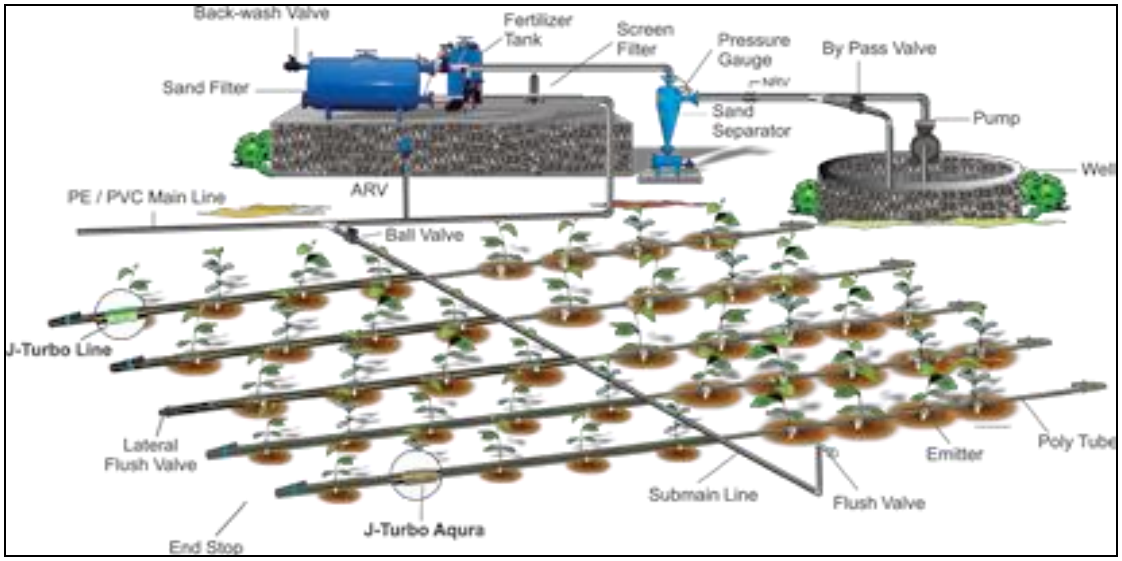


Fig 1: Drip irrigated paddy layout

Drip irrigation means the slow, even application of irrigation water at low pressure to the root –zone using a network of plastic tubing placed above the rooting zone (surface drip) or buried among the root branches inside the rhizospheres soil at a certain depth from surface (Subsurface drip).

In drip irrigation method, crops are irrigated daily to the precise volume of water equivalent to the evapo-transpiration (ET) of the crop. It is estimated from daily Evaporation data using crop coefficients and canopy coefficients, the latter two factors vary with the age of the crop and the size of its canopy these are the two factors that affect the volume of transpiration of the plant/ crop that changes with the growth of the crop. Factoring in of these two coefficients is what makes the water requirement estimate unique to that particular crop at that particular stage of its growth (Soman *et al.* 2018) [17].

Table 4: Water requirement in Rabi paddy

Month	Pan E (mm/day)	Total water Reqt. (lit/Day/ha)
Feb 16-28	6.68	18704
Mar 1-15	6.73	40044
16-31	6.82	47740
April 1-15	6.09	56840
16-30	6.53	60947
May 1-15	7.44	70019
16-31	7.57	58878

A farmer from the Tirupur district of Tamilnadu of village Govindouram named Parthasarathy and 23 other farmers has used Drip on Paddy, onion and Maize. He observed a 15-20 percent increase in yield and also water saving 30-40 percent. He got Innovative Farmer Award for this in 2015. **(**Rao, 2003).

20% of global white rice area is in India making it to cover largest area and output 42% of total grains produced, the flood irrigation is practiced in 85% area, so if this 50% area out of this be brought into the Drip will be a great contribution in water saving. (Ahmad *et al.* 2004) [3]

Sowing and germination Irrigation

Fig 2: Paddy grown with drip irrigation

It is essential to pre irrigate and fully wet the broad bed before sowing the seeds. Keep the bed uniformly wet till germination and crop establishment. And after that a periodic irrigation is

prescribed as water IR scheduling.

Some advance work under funded projects from Israel are also going in TNAU titled, 'Feasibility of growing rice under drip irrigation', the experiment has been taken close to the 'kuruvai' season and scientists have planted four varieties 'TRY II', 'ADT 45', 'ADT 36' and 'Anna (R) 4' for ascertaining the growth of paddy in saline fields on the campus of the institute (Puranik *et al*., 1992) [14].

The institute, located in the Manikandam block, has taken up various research programmes on evolving paddy varieties suitable for sodic soil. Netafim', an Israeli company specialising in drip irrigation technique, had sanctioned Rs. 4 lakhs to the institute to take up the research, said P. Pandiyarajan, Dean of the Institute.

Speaking to The Hindu after inaugurating the programme, Mr. Pandiyarajan said that this was the first time the institute had taken up the research using the drip irrigation technique, although similar experiments had been conducted at Aduthurai and other places. About 2 kg of seeds were used for each variety. He said that the experiment would include a study on nutrient management, irrigation management and good cultivation practices. The entire 60 cents of the field has been covered with over 77 laterals, each 50 metres in length. "Each lateral contains 130 holes or drip spacing through which water and water-soluble fertiliser will be supplied," he said (Rangachari *et al*, 2000) [15].

Sustainable Rice Production

With drip- fertigation one achieves a sustainable method for rice production. Conservation of water, energy and fertilizer while enhancing yield by 1 to 1.5 ton per ha or more results in a Win-Win situation. We produced 22% more rice using 66% less water; (water use in drip is 8 million liter per ha compared to flood irrigation where it is 23.75 million liter per ha) and using 52% less power for pumping water. More rice is produced per unit input; Water productivity also improved to 500 to 1000 g/1000 liter from a figure of 120 to 290 g/1000 liter.

Table 5: Sustainable use of water resources

Irrigation	Flood	Drip
Area, ha	1	1
Water Use, m^3/ha	23,750	8,000
Yield, kg/ha	7,000	8,500
WUE (Water Use Efficiency) kg/m^3	0.29	1.06
Selling Price of Rice/Kg	20	20
Income/acre	1,40,000	1,70,000
Value Creation Efficiency/m^3	5.89	21.25

S Improving yields of rice is imperative to addressing growing food security challenges S Improves water use efficiency of rice crop and the value of water. The value creation efficiency in flood method is only 5.89 per 1000 liter water compared to` 21.25 per 1000 liter in drip.

S Smallholder farmers have an impact on biodiversity and ecosystems and are dependent on them S At the same time, improving their practices and water productivity can help better preserve and protect natural resources S Improves yield, income and reduces water, energy and fertilizer use of the follower crop after rice also. Thus drip-fertigation ensures water, energy and food security in a sustainable manner.

Harvesting paddy

Various Paddy varieties normally mature in 95-160 days. The visual symptoms that the crop is ready for harvesting proper stage for harvesting is yellow coloring and ripening of about > 80% panicles of the area. The harvest is of good quality specially when harvested at proper stage and time in a dry weather. These days harvesting with combine harvesters is quite common and fast and time saving.

Threshing operation

The trashing practice with manual operation is still common in countries where the rice threshing is done on the farm itself. But nowadays combine threshers are available which do all three operations simultaneously and that too time saving.

The produce moisture content for storage and for selling in mandis of rice grains is 12%.

Conclusion

Drip Irrigation or micro irrigation has been proven as one of the best water conservation technology for heavy consumption of water in rice growing, that too without scarifying the yield. The aerobic rice can be successfully grown just like all other crops with drip by maintaining moisture at an adequate level in root zones

The investment cost of drip irrigation is a concern that costs between Rs. 30,000-70,000 per acre. The initial cost of installation is beyond afford capacity of marginal farmers (86%) and cannot afford this. In many states under centre or state Govt schemes subsidies to the tune of 60-90% against the beneficiary share of 10-40%. In many cases, this beneficiary share is also adjusted in digging trenches or civil works by the service provider companies.

There is a need to provide subsidies to farmers so that the MIS systems can be promoted in the rice system also.

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