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Research Article

EVALUATION OF THE PERFORMANCE OF AEROBIC RICE USING DRIP IRRIGATION TECHNOLOGY UNDER TROPICAL CONDITIONS

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Abstract: Conventional method of rice cultivation consumes large volumes of irrigation water. The introduction of direct dry seeding of rice, in upland environment is found to reduce water consumption to some extent. In this paper, a novel method of irrigation for rice through drip method and fertilizer application through drip system, fertigation, are tried on rice crop and found that the results are quite positive. The experiments are conducted in the Research farm of Jain Irrigation, in Tamilnadu in 2010 and 2011. Six rice varieties, known for adaptation to aerobic growing conditions were tested. Rice grew well under drip and fertigation. Rice yields under drip irrigation ranged from 4.5 to 8.2 t/ha among the varieties; indicating an increase in yield of 17-22% over those from conventional flood irrigation treatment. The water saved in drip method was around 50-61%. Highlighting that drip method of irrigation results in high water use efficiency, we could record water productivity of rice from 0.365 kg/m^3 to 0.714 kg/m3 among the varieties tested. These water productivity figures are way above those obtained in flood method of irrigation, 0.097 to 0.224 kg/m^3.
Keywords: Drip irrigation, Fertigation, Water productivity, Aerobic rice

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Introduction

Rice is the second important crop globally, producing 715 million mt paddy (482 million mt milled rice). China is the largest producer with 210.1 million mt from an area of 29.5 million ha followed by India producing 165.3 million mt from an area of 44.1 million ha. It is an important staple food for more than 50 % of world population [1]. More than 90 % of global rice is produced from conventional lowland irrigated system, 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 is used under aerobic 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 [2-4]. Exploitation of surface and ground water has reached its maxima in many States, that unless water saving technologies are used, it will be impossible to practice, sustainable agriculture in coming years. 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 including water guzzlers such as banana, sugarcane and rice and found that the water requirement of these crops has been reduced to 40-50 %;using micro irrigation system; 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.

Peng, *et al*., [5] working in International Rice research Institute (IRRI),Los Banos observed that the tropical aerobic rice variety APO yielded 4-5.7 t/ha under aerobic conditions. Tuong and Bouman, [6] reported that in Brazil aerobic rice cultivar.yield 5-7.6 t/ha,under sprinkler irrigation in farmers' fields. They added that these cvs are grown commercially in2,50,000 ha in the state of MatoGrosso. According to Yang, *et al.,* [7] in North China aerobic rice cv.HanDao yield up to 6-7.5 t/ha under flash irrigation in bunded field. It is estimated that cv. Han Dao being pioneered on 1,20,000 ha in Northern china plains. Xue, *et al.,* [8], indicated that as little as 600-700 mm water was needed in soils having 75 % sand and 5 % clay for aerobic rice .Their studies using HD-297 with four irrigation levels and N in five splits showed the highest yield 4460 kg/ha,with 688 mm (including rain fall) in 2003 and 6026 kg/ha with 705 mm water in 2004.Yield increase was maximum with total amount of water and nitrogen in five splits. Medonalt, *et al.*, [9] observed in drought resistant rice, Huhan-3, in shanghai that drip irrigation maintained competitive grain yield and water productivity ,reduced pollution to environment. Haibing He, *et al.*, [10] demonstrated that Rice performance under plastic mulch and drip irrigation has greater water saving capacity,with lower yield and highest water use efficiency. Parthasarathi, *et al*., [11] observed sub surface drip irrigation increased yield and water productivity in aerobic rice.

Templeton and Bayot, [12] observed that locally adapted high yielding temperate and tropical aerobic rice varieties suited to conditions in China, Philippines and India. They observed that in Philippines, India and elsewhere, adoption of aerobic rice technology is still very low, where as in China it was conservatively estimated that by 2015, the aerobic rice growing area will increase to one million ha as the cultivation of aerobic rice is economically viable.

Yoichiro Kato and kaisuke Katsura, [13] stated that aerobic culture is a water saving technique for direct seeded rice cultivation, maximize water-use-efficiency and minimize labor requirement and green-house gas emission. Under temperate climate, aerobic rice yields greater than 9 t/ha especially in Central Japan (11.4 t/ha); however, yields remain at less than 8 t/ha in the tropics. The high yields of Japanese aerobic rice are mainly attributed to vigorous nitrogen uptake during the reproductive stage which enables rice plants to produce more spikelets and biomass. Aerobic rice RT CLXL 729 under large scale Centre pivot system in silt and sandy loam soils with 75 cm water recorded yield 10.3 t/ha in Missouri, USA [14]. Anandan, *et al.,* [15] stated that aerobic rice is an alternative option to reduce labour drudgery, quantity of water usage and increase water productivity. Pradhan, *et al.,* [16] have stated that increasing scarcity of water has threatened the sustainability of the irrigated rice production system and hence food security and livelihood of rice farmers. Adoption of aerobic rice is facilitated by the availability of efficient herbicides for weed control and suitable rice varieties for aerobic conditions. Yield varied from 3.5-6 t/ha which is almost double that obtained from upland rainfed varieties; 25-30 % less than that obtained from lowland irrigated varieties. They suggested breeding drought tolerant varieties, increased availability of N,P,Fe and Zn efficient weed control, tolerance to root knot nematodes. Sashidhar, [17] recommended aerobic rice hybrid ARB-6, parentage (Budda (local) X IR-64 of IRRI), duration 120 days ,medium height, yield 6.5-7 t/ha, medium slender grain, high milling 83.25 % and suggested that this is certain solution, at least in part to the century old Cauvery water problem facing Tamil Nadu and Karnataka. This technology saves water, labour, fertilizers. Soil bacteria decompose organic matter under aerobic conditions unlike under flooded system decomposition is anaerobic, causing methane emission. yield 5.5 t/ha,;80 % saving in seeds. In another studies, Ningaraju, *et al*., [18] showed that KRH-4 rice hybrid recorded maximum yield 6209 kg/ha and on par with KRH-2 and found significantly superior to other varieties and hybrids.MAS-946-1 recorded 5032 kg/ha. The water productivity of KRH-4 (54.47 kg/ha cm), KRH-2 (53.25 kg grain/ha cm) compared to MAS-26 (43.95 kg grain/ha cm), MAS-946-1(43.71 kg/ha cm). Four aerobic rice cvs. released by Central Rice research Institute, Cuttack, India viz.CR Dhan-200, CR Dhan-201,CR Dhan202,and CR Dhan-204,120-125 days duration, short-bold grains, moderately tolerant to stem borer, thick culms, non-lodging, responding to high fertilizer dose and observed that these cvs. can be grown by using water sparingly without crossing the requirements beyond the levels of field capacity like other dry land crops.

Belder, *et al*., [19] reported relatively low uptake of nitrogen under aerobic cultivation. Of the 150 kg N/ha applied, only an average of 22 % was taken up by the crop, while 31 % was left in soil and roots after harvest. Most of the 47 % N unaccounted for, must have been lost as gaseous N promoted by rapid nitrification-denitrification process. They suggested combining water treatments with N treatments to optimize yield and resource –use-efficiency. High N recoveries in rice might be possible when N dose and time of application better match the N requirement of the crop. Zinc deficiency is a fairly widespread agronomic constraint in many of the rice producing regions. Hafiz-ur Rehman, *et al.,* [20] suggested that organic and chelated source of zinc in soil application, seed treatment, foliar application in association with mycorrhizal fungi may improve Zn-use-efficiency in rice. In aerobic rice systems, iron oxidation by root-released oxygen causes reduction in rhysosphere pH. The reduced pH limits the release of zinc from highly insoluble fractions. Redox potential often increases in aerobic cultivation leading to iron oxidation and concomitant acidification and precipitation of Fe(OH)3 on to which Zn may adsorb [21]. The present report 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, TamilNadu, India and discuss 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. The major objective is to test the efficacy of drip and fertigation technology, poly and paddy husk mulch in suppressing weed growth vis-à-vis conventional puddled, flooded system , cost economics and selecting suitable aerobic rice varieties with high water productivity and yield potential under tropical conditions.

Materials and Methods

Investigations 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 Jains experimental farm, 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 have been formed. A basal dose of fertilizers at 345 kg SSP, zinc sulphate 50 kg, ferrous sulphate50 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 laterals with 4 lph turbo aqura spaced at 50 cm were laid at an interval of 40cm in each bed. The beds for treatment of plastic mulch were covered with plastic sheets of 100 microns thick with 5 cm diameter holes punched at 20 X 15cm(Row-row X plant-plant) and the beds wetted before two 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 mono-chrotophos at 3 ml/L water for 20 minutes. A pre-emergence herbicide of pendimithalin at 1.25 kg a.i. per ha was applied 3 days after first irrigation. Paddy husk of 5 cm layer spread on the beds as mulch in the second treatment. the treatments were replicated thrice. Irrigation was given daily, based on previous day's crop ET (Table-1)

Table-1 *Drip irrigation schedule followed in the experiment*.

Month	Evaporation(mm)	water requirement L/day/ha	Water requirement for drip plot 2160 m^2
Feb.16-28	6.68	18704	4040
March 1-15	6.73	40044	8650
Mar.16-31	6.82	47740	10312
April 1-15	6.09	56840	12277
April 16-30	6.53	60947	13165
May,1-15	7.44	70019	15124
May,16-31	7.57	58878	12718

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 P_2O_5 and 175 kg K_2O/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.

Table 2- *Fertigation schedule*

Frequency	urea/dose/ha	MOP/dose/ha
2 times a week 10 days after sowing		
4 occasions	13.75	0
4 occasions	41.25	12.5
3 occasions	18.33	12.5
3 occasions	16.7	50.0
4 occasions	0	16.7

All P_2O_5 as SSP 345 kg/ha applied to soil at planting.

Control plot with inundated water was prepared in conventional puddle and sowing done in the same way, weeds growth was controlled using weedicide and manual weeding during the critical period of weed growth. Four sprays of quinolphos at 2ml/L were given against targeted pests –stem borer and leaf roller at critical period. During 2010, data on water used for irrigation including control (flood irrigated, puddled) plus monsoon rains received during the crop duration per ha; yield in kg/ha, water productivity in kg grain per m^3, water used for irrigation calculated for each variety, and the sub-treatments, poly and paddy-husk mulch treated plots. the data presented in table. The total expenditure incurred on inputs such as seeds, manures and fertilizers, chemicals, polythene sheet mulch, paddy husk, pest's management, weeds control, energy, labour used for various operations from land preparation to final harvest, cleaning etc. are recorded and the savings in water and expenditure over control calculated. In the second year, 2011, five aerobic varieties used in the trial *viz*., 27P-31(duration 128-132 days, medium bold grain);27P-63 (132-137 days, medium slender grain) PHB-71

(128-132 days; long, slender grain),Arize-6129(115-120 days,);Arize6444 (135-140 days) were used. Data on average number of tillers/hill, plant height in cm, average panicle length (cm), number of filled grains/panicle, test weight in gm calculated by selecting five hills at random in each replication and the average is calculated by taking the mean of 5 hills. Grain yield in kg per ha, yield increase in drip over flood, water productivity Kg/m3 based on applied water plus effective rainfall during crop duration recorded.

Results and Discussion

The performance of ADT-45, aerobic paddy hybrid, under drip system, using poly and paddy-husk mulch and conventional puddle system in Udumalpet are presented in table. Water used to include rainfall during the crop duration, water productivity is also given in the table. Observations recorded during 2011, on average plant height (cm), number of productive tillers per hill, panicle length (cm), number of filled grains per panicle, test weight in gm, grain yield per ha, yield increase over flood, water productivity etc of the five varieties are given in table. ADT-45 recorded 8440 kg/ha yield under drip plus paddy husk mulch (total expenditure Rs 40155),7833 kg/ha under drip plus poly mulch (Expenses rs.53915) with water productivity 0.570 kg/m3,0.529 kg/m3 respectively. Under conventional puddle system, the yield was 6980 kg/ha (expenses Rs.44535) and 0.229 water productivity. The saving in water under drip was 49.67%. The expenses under drip plus paddy husk mulch was the lowest, while it was maximum in Drip plus polythene, due to the costly polythene. However, the higher cost for conventional flooded rice was due to the extra expenditure incurred on puddling and soil preparation. The water used in this system was more than double, that of used under drip. During 2011 season amongst the five varieties tested,27p31, recorded maximum yield of 8912 kg/ha under drip (25 .2 % increased yield over flood irrigated control) using 5056 m3 water; while under flood system, the yield was 7119 kg/ha having used 12884 m3 water and the water productivity being 0.713 kg under drip and 0.224 kg/m3 under flood. Under drip, the average height of the plant was 98.5 cm with 30 tillers/hill, maximum195.5 filled grains per panicle,24.4 gm test weight. The corresponding values were lower in flood treated plants. 27p31 is followed by PHB-71 in yield 7924 kg/ha under drip and6533 kg/ha under flood,28.4 tillers/hill (drip) as against 7.8 tillers/hill under flood. The water productivity 0.635 kg under drip and 0.205 kg/m3 under flood. 27p63 ranked third in its yield securing 7657 kg (drip) 6506 kg/ha under flood system; water productivity 0.635 kg/m3 under drip and a measly 0.205 kg/m3 under flood. Arize 6444 ranked four amogst the five varieties, recording 7205 kg/ha yield under drip, water productivity being 0.577kg/m3 and 5866 kg yield per ha under flood (W.P.0.184 kg/m3). Arize 6129's performance was the least among the five tested.

A critical evaluation of the results of two-year trial 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. 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/m^3 maximum recorded by 27p31.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 as27p31 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.,* [9], Haibing He, *et a*l., [10] Ramadass and Ramanathan, [22], Soman, [23], Soman, *et al.,* [24] Rachel Predeepa's, [25] observation that aerobic rice is the next generation innovation in rice cultivation Technology. Aerobic rice can be grown in marginal soils with moderate alkalinity by applying fertigation twice a week to circumvent adverse soil conditions, enabling the crop to absorb nutrients before they are made unavailable by adverse soil reactions. The weeds can be managed by using paddy husk or polythene mulch, judicious application of herbicides and manual weeding at critical stage of growth. Aerobic rice reduces methane emission (not estimated in the present studies), environmental friendly, economically viable. The Challenges remain, scope for improving the crop stand, increasing seed set etc. indicating the need for evolving dwarf, high yielding hybrids/varieties, suitable to local conditions, resilient to drought and marginal soil conditions. It may be concluded that varieties such as ADT-45, 27p31, PHB-71, 27p63, arize 6444 can be cultivated profitably, using drip and paddy husk/polythene mulch with water saving about 50-60 %. The technology has been demonstrated in farmers' field of Punjab, Rajasthan, Chattisgarh, Andra Pradesh and in different university farms and its profitability over conventional flood system has been well established, Soman, [23]. 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 [17], 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 lye 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 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.

Application of research: The value of this research and its findings are very timely as the global rice production is facing the biggest challenge of declining water availabilities. Technologies like drip and fertigation are going to be answers for the challenges on water and overall need for high efficiency input management and higher production efficiencies.

Research Category: Irrigation management, Rice cultivation.

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