International Journal of Plant & Soil Science

34(22): 133-143, 2022; Article no.IJPSS.90232
ISSN: 2320-7035

Impact of Field Water Tube based Irrigation and Split Application of Nutrients on Yield and Water Productivity (*Oryza sativa* L.)

P. Satheeshkumar [a#], S. K. Natarajan [b*†], N. Thavaprakaash [c‡] and K. Vanitha [d¥]

[a] Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.
[b] Controllerate of Examination, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.
[c] Centre for Students Welfare, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.
[d] Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i2231366

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/90232

Original Research Article

Received 01 June 2022
Accepted 01 August 2022
Published 02 August 2022

ABSTRACT

A field experiment was conducted at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Navarai* season (December-April) of 2021-22 to study the influence of field water tube and split nutrient application on yield and water productivity in transplanted rice (*Oryza sativa* L.). The field experiment was laid out in randomized complete block design having seven treatments and replicated thrice. The treatment details *viz*., T_1 – Control (conventional planting 100% Recommended Dose of Fertilizer (RDF), T_2 – Alternate wetting and drying + Leaf Colour Chart (LCC) based nitrogen management, T_3 – Alternate wetting and drying with automated field water tube + 100% RDF, T_4 – Irrigation through field water tube + 100% N & K application in 7 days intervals, T_5 – Irrigation through field water tube + 100% N & K application in 10 days intervals, T_6 – Irrigation through field water tube + 75 % N & K application in 7 days intervals, T_7 – Irrigation through field water tube + 75% N & K application in 10 days intervals. Experimental results shows that significantly more yield was recorded in T_5 which was on par with all other treatments expect

---

[#] *PG Student;*
[†] *Assistant Professor (Agronomy);*
[‡] *Associate Professor (Agronomy);*
[¥] *Assistant Professor (Crop Physiology);*
**Corresponding author: E-mail: kandunats@gmail.com;*

conventional method. Among the irrigation treatments T_5 recorded a higher grain yield of 6587 kg ha^{-1} and which was on par with T_6 (6307 kg ha^{-1}). Hence, this study revealed that the Irrigation through field water tube with 75% N& K application in 7 days intervals confer 34.7 % water saving and better results in yield attributes in transplanted low land rice.

Keywords: Rice; alternate wetting and drying; field water tube; water productivity.

1. INTRODUCTION

Water is the single most vital component of sustainable rice production, especially in the traditional rice growing area. In recent years, changes in environmental conditions imposed multiple abiotic stresses that severely affected rice production in all ecosystems by strongly inhibiting plant growth and development [1]. According to Joshi et al*.* [2], Caine et al*.* [3] to produce 1 kg of rice, 2000–5000 L of water are required. Therefore, the need for "more rice with less water" is the need of the hour for global food security [4,5]. Thus, water availability is the key requirement for rice cultivation in each of the rice ecosystems. This forces us to develop new techniques of water management for rice cultivation that specifically improve production in different ecosystems [6].

Already there are different techniques such as aerobic rice and SRI in rice to reduce the water requirement including other production factors. However, the monitoring and regulation are very difficult to control timing and the quantity of water and it is also not really match with the actual time of water requirement [7].

Alternate wetting and drying is a water-conserving technology for irrigated rice cultivation that has the prospective to contribute to more efficient and sustainable water and energy use. This AWD gadget is a single instrument that measures water levels in rice fields to determine irrigation scheduling. It entails putting a perforated pipe (ideally PVC) in a rice field to monitor the water level. In one segment, a 15 cm diameter, 40 cm long pipe is installed at 10 cm above and 30 cm just below ground surface. Using AWD, farmers can save 15 to 30% of their water source [8].

In the case of AWD system, irrigation under various establishment methods and even under (System of Rice Intensification) SRI system the irrigation adopted only provisionally and not suits with actual time of crop requirement or not a demand-based approach. Its efficiency and suitability have to be assessed for effective irrigation and an easy tool to the farmers to regulate the irrigation as per demand driven approach. Split applications of nutrients are playing the major role in different growth stages of rice and avoid the nutrient losses, so the treatments contain 7 days and 10 days intervals with 75% and 100% RDF. Hence, the current study planned to evaluate the alternate wetting and drying on effect of yield attributes, yield and water use efficiency of transplanted rice in lowland ecosystem.

2. MATERIALS AND METHODS

A field experiment was laid out during *Navarai* season (December-April) of 2021-22 at Wetland farmfield No.M_3 of Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore which is located at the latitude of $11^0$0' N with longitude of $77^0$92' E and an altitude of 426.7 m above mean sea level. The soil details of the experimental field given below:

Soil texture	Clay loam
Soil classification	Typic *Haplustalf*
pH	8.70
EC	0.31 dSm^{-1}
Available Nitrogen (N)	252 kg ha^{-1} (Low)
Available Phosphorus (P)	11.5 kg ha^{-1} (Medium)
Available Potassium (K)	751 kg ha^{-1} (High)
Organic carbon	0.80 %

The research plot was laid out in randomized block design having seven treatments with three replications. The treatment details *viz.*

T_1	Control - conventional planting + Fertilizer (100% RDF)
T_2	SRI- Alternate wetting and drying + LCC Nitrogen management
T_3	Alternate wetting and drying with automated field water tube + Fertilizer (100% RDF)
T_4	Irrigation through field water tube + Fertilizer (100% N&K) application in 7 days intervals
T_5	Irrigation through field water tube + Fertilizer (100% N&K) application in 10 days intervals
T_6	Irrigation through field water tube + Fertilizer (75% N&K) application in 7 days intervals
T_7	Irrigation through field water tube + Fertilizer (75% N&K) application in 10 days intervals

Rice variety 'CO51' was used for the experiment. Transplanting was done in both conventional (20 cm x 15 cm) and SRI (25 cm x 25 cm) methods as per treatments. The recommended dose of fertilizer (150 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}) was applied as basal and top dress as per treatment schedule (Crop Production Guide, TNAU 2020). Observations were taken from five plants randomly selected from each net plot at different growth stages like active tillering, panicle initiation, flowering and maturity. Harvesting was done at the maturity stage and yield parameters were calculated. The yield and yield attributes such as productive tillers m^{-2},1000 grain weight (g), filled grains (%), panicle length (cm), panicle weight (g), number of filled grains $panicle^{-1}$, grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index were calculated at the time of harvest stage of rice. Water productivity such as number of irrigation, total irrigation water (mm), Water savings (%), and Field water use efficiency (WUE) was computed using the equation of Viets [9].

$$WUE = Y/W \text{ (kg ha}^{-1}\text{ mm}^{-1}\text{)}$$

Where,

Y = Grain yield (kg ha^{-1})
W = Total water used (I + Re) to produce the yield (mm)
I = Irrigation water applied (mm)
Re=Effective rainfall (mm)

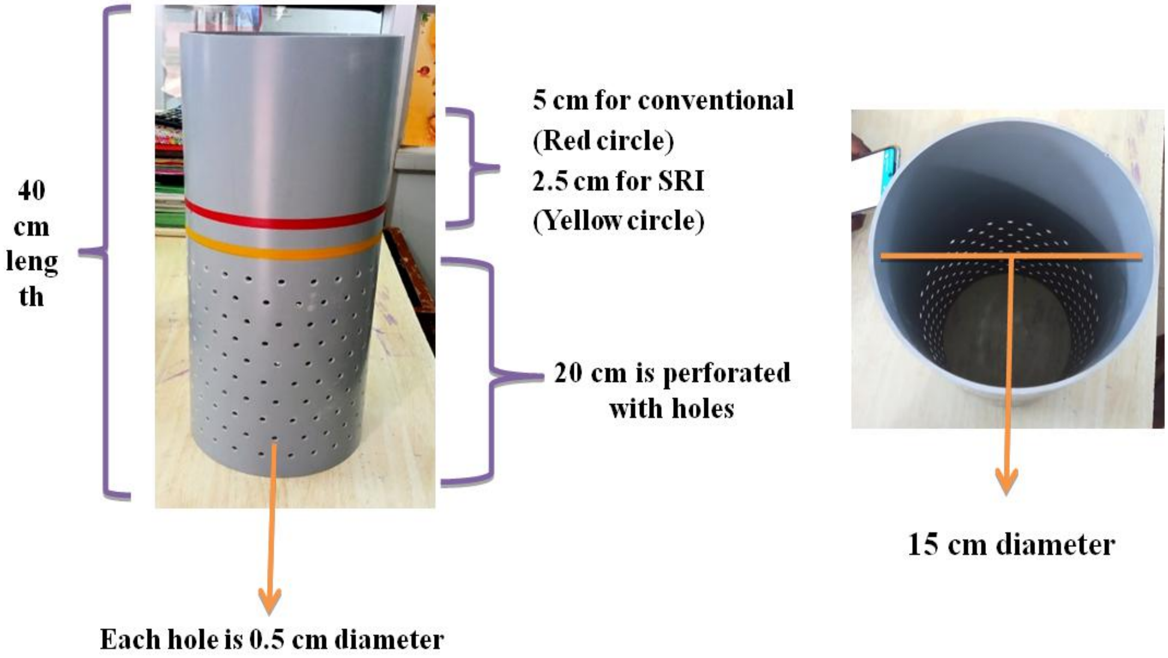

Plate 1. Field water Tube specification

Before Irrigation

During Irrigation

Maintaining of 5 cm water level

After irrigation

Plate 2. After Field water Tube Installation

Vertically insertion by hand

Water level measurement

Plate 3. Field water Tube Installation

2.1 Field Water Tube

The tube is made of 40-cm or more length plastic pipe or bamboo, andhave a diameter of 15 cm or more so that the water table is easily visible (Plate 1, 2, 3). The tube is to be perforated with holes on all sides. The tube is to be placed inside in the soil so that 15cm protrudes above the soil surface. Care is to be taken in such a way that the tube should penetrate through the bottom of the plough pan. The soil is to be removed the inside the tube so that the bottom of the tube is visible. The water table inside the tube is to be checked for the same level as that of outside the tube. The tube can be placed in a flat part of the field close to a bund at least 1m away, so it is easy to monitor the ponded water depth. After irrigation, the level of the water in the tube can be seen going down every day. The water depth from the top of the tube to the level of water inside the field water tube measured using a ruler. 15 cm is to be subtracted from the reading to obtain the depth of water level. A negative value means the water is standing on the field; positive value means water level is below the surface. After transplanting initially irrigation were given up to active tillering stage as usual continues flooding (1-35 DAS) and irrigation through field water tube was followed active tillering to flowering stage (36 – 80 DAS) based on the treatment intervals. The irrigation water was measured by water meter.

3. RESULTS AND DISCUSSION

3.1 Water Productivity of Rice

The water use and water use efficiency were presented in Table 1 and Fig. 1. Results shows that the number of irrigation was recorded to be the highest (27) under the treatment T_1 conventional planting with 100 % recommended dose of fertilizers followed by treatment T_2 (Alternate wetting and drying with LCC based nitrogen management), T_3 (Alternate wetting and drying with automated field water tube with 100 % recommended dose of fertilizers), T_4 (Irrigation through field water tube with 100% N & K application in 7 days intervals) and T_6 (Irrigation through field water tube with 75% N & K application in 7 days intervals) which were provided with 19 irrigations. The lowest number of irrigations (18) was recorded under irrigation through field water tube with 100% N& K application in 10 days intervals (T_5) and Irrigation through field water tube with 75% N & K application in 10 days intervals (T_7). The results are in conformity with the findings of Faruki et al. [10] and Rahman and Bulbul [11]. Reduction in the number of irrigations under alternate wetting and drying was due to the irrigation intervals. The number of days taken for depleting 7, 10for 20 cm below the ground level is more when compared to treatment T_1 (conventional planting with 100 % recommended dose of fertilizers) and

T_2 (SRI with alternate wetting and drying with LCC based nitrogen management). Among the different treatments alternate wetting and drying depletion levels irrigation after 20 cm depletion, increased the intervals between one irrigation to another.

The total irrigation water consumed was the highest1203 mm under treatment T_1 (conventional planting with 100 % recommended dose of fertilizers) followed byT_2– Alternate wetting and drying with LCC based nitrogen management. A considerable decline in total irrigation water was observed with the minimum of (785 mm) underirrigation through field water tube with 75% N & K application in 7 days intervals (T_6). The reduction in total irrigation water was due to widening interval between irrigations. The results are in concord with the findings of Oliver et al*.* [12], Latif, M. A., & Yamaji, E. I. J. I. [13] and Rahman and Bulbul [14].

Significantly higher water use efficiency 8.0 kgha^{-1}mm^{-1}was registered under irrigation through field water tube with 75% N&K application in 7 days intervals (T_6) which was on par with treatments T_5 (Irrigation through field water tube with 100% N & K application in 10 days intervals), T_3 (Alternate wetting and drying with automated field water tube with 100 % recommended dose of fertilizers) and T_4 (Irrigation through field water tube with 100% N & K application in 7 days intervals). The lowest water use efficiency (5.0 kgha^{-1}mm^{-1}) was recorded under conventional planting with 100 % recommended dose of fertilizers (T_1). Monitoring depletion water level below the soil surface with the use of field water tube in AWD is safe to limit water use by 18 % without reduction in rice yield [15]. The Higher water use efficiency in the rest of the AWD treatments as against the conventional irrigation practice could be attributed to optimum need based irrigation using monitoring device *i.e.* field water tube. Higher consumptive use with more frequent irrigations without increase in yields could have led to decreased water use efficiency under conventional practice of irrigation. This is in agreement with the findings of Bouman et al. [8]. The above results are in accordance with the findings of Oliver et al*.* [16] and Rahman and Bulbul [11].

The maximum water saving (34.7 %) was noted when transplanted rice was irrigated through field water tube with 75% N & K application in 7 days intervals (T_6) followed by irrigation through field water tube with 100% N & K application in 10 days intervals (T_5). The minimum water saving (14%) recorded under Alternate wetting and drying with LCC based nitrogen management (T_2). Bhuiyan and Tuong [17] concluded that a standing depth of water throughout the season is not needed for high rice yields. About 40–45 percent of the water normally used in irrigating the rice crop in the dry season was saved by applying water in small quantities only to keep the soil saturated throughout the growing season, without sacrificing rice yields. A similar result was obtained by Sato and Uphoff [18] with the use of intermittent irrigation in SRI management. These results are in line with the findings of Bouman et al*.* [8] and Chapagain et al*.* [19].

3.2 Yield Attributes and Yield of Rice

The yield and yield attributes are presented in Table 2 and Fig. 1. Results shows that imposing of Alternate wetting and drying along with LCC based nitrogen management (T_2) recorded significantly higher number of productive tillers (364m^{-2}) at harvest stage and it was on par with all other treatments except T_1(conventional planting with 100% RDF) and T_7 (Irrigation through field water tube with75% N & K application in 10 days intervals). The lowest number of productive tillers (311m^{-2}) was recorded under T_1 (conventional planting with 100 % recommended dose of fertilizers). Higher tiller production under the above irrigation practices would have favoured greater conversion to productive tillers, due to enhanced nutrient uptake and development of more floral and fruiting bodies *i.e.,* panicle with high productive components. This may further be attributed to the capacity of sink to receive the photosynthesis from assimilating surface and store effectively under favorable soil plant water status as evidenced by Sathyanarayana et al*.* [20].

Thousand grain weight (g), filled grains (%), panicle length (cm) and panicle weight (g) were not influenced significantly due to various treatments.

More number of filled grains (170 panicle^{-1}) was observed in Alternate wetting and drying with LCC based nitrogen management (T_2)which was on par with all other irrigation and fertilizer treatments under study except T_1 (conventional planting with 100 % recommended dose of fertilizers) and T_7 (Irrigation through field water

Table 1. Effect of different levels of AWD on water use (mm) and water use efficiency (kgha^{-1}mm^{-1})

Treatments	Number of Irrigations	Water consumed (mm)	Effective rainfall (mm)	Total irrigation water (mm)	WUE (kgha^{-1}mm^{-1})	Water saving (%)
T_1 : Control - conventional planting + Fertilizer (100% RDF)	27	1188	15	1203	5.0	0
T_2 : SRI- Alternate wetting and drying + LCC Nitrogen management	19	1020	15	1035	6.2	14.0
T_3: Alternate wetting and drying with automated field water tube + Fertilizer (100% RDF)	19	840	15	855	7.7	28.9
T_4 : Irrigation through field water tube + Fertilizer (100% N&K) application in 7 days intervals	19	832	15	847	7.5	29.6
T_5 : Irrigation through field water tube + Fertilizer (100% N&K) application in 10 days intervals	18	825	15	840	7.8	30.2
T_6: Irrigation through field water tube + Fertilizer (75% N&K) application in 7 days intervals	19	770	15	785	8.0	34.7
T_7 : Irrigation through field water tube + Fertilizer (75% N&K) application in 10 days intervals	18	912	15	927	6.6	22.9
SEd.					0.2	
CD (p=0.05%)					0.5	

Table 2. Effect of different levels of AWD on Yield and Yield attributes

Treatment	Number of productive tillers m^{-2}	1000 grain weight (g)	Filled grains (%)	Panicle length (cm)	Panicle weight (g)	Number of filled grains $panicle^{-1}$	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 : Control - conventional planting + Fertilizer (100% RDF)	311	16.1	90.6	22.3	2.7	145	5992	11464	0.33
T_2 : SRI- Alternate wetting and drying + LCC Nitrogen management	364	16.1	91.7	22.1	2.8	170	6407	11537	0.36
T_3 : Alternate wetting and drying with automated field water tube + Fertilizer (100% RDF)	335	16.0	92.2	21.3	2.7	158	6573	10533	0.38
T_4 : Irrigation through field water tube + Fertilizer (100% N&K) application in 7 days intervals	340	16.1	91.4	21.1	2.9	164	6373	9667	0.40
T_5 : Irrigation through field water tube + Fertilizer (100% N&K) application in 10 days intervals	346	16.0	90.0	20.9	2.8	152	6587	9747	0.40
T_6 : Irrigation through field water tube + Fertilizer (75% N&K) application in 7 days intervals	355	16.1	92.7	20.7	2.5	154	6307	10240	0.38
T_7 : Irrigation through field water tube + Fertilizer (75% N&K) application in 10 days intervals	325	16.0	91.8	20.8	2.5	139	6100	9820	0.39
SEd	13	0.87	5.32	1.20	0.2	10	219	488	0.02
CD (p=0.05%)	29	NS	NS	NS	NS	21	477	1064	0.05

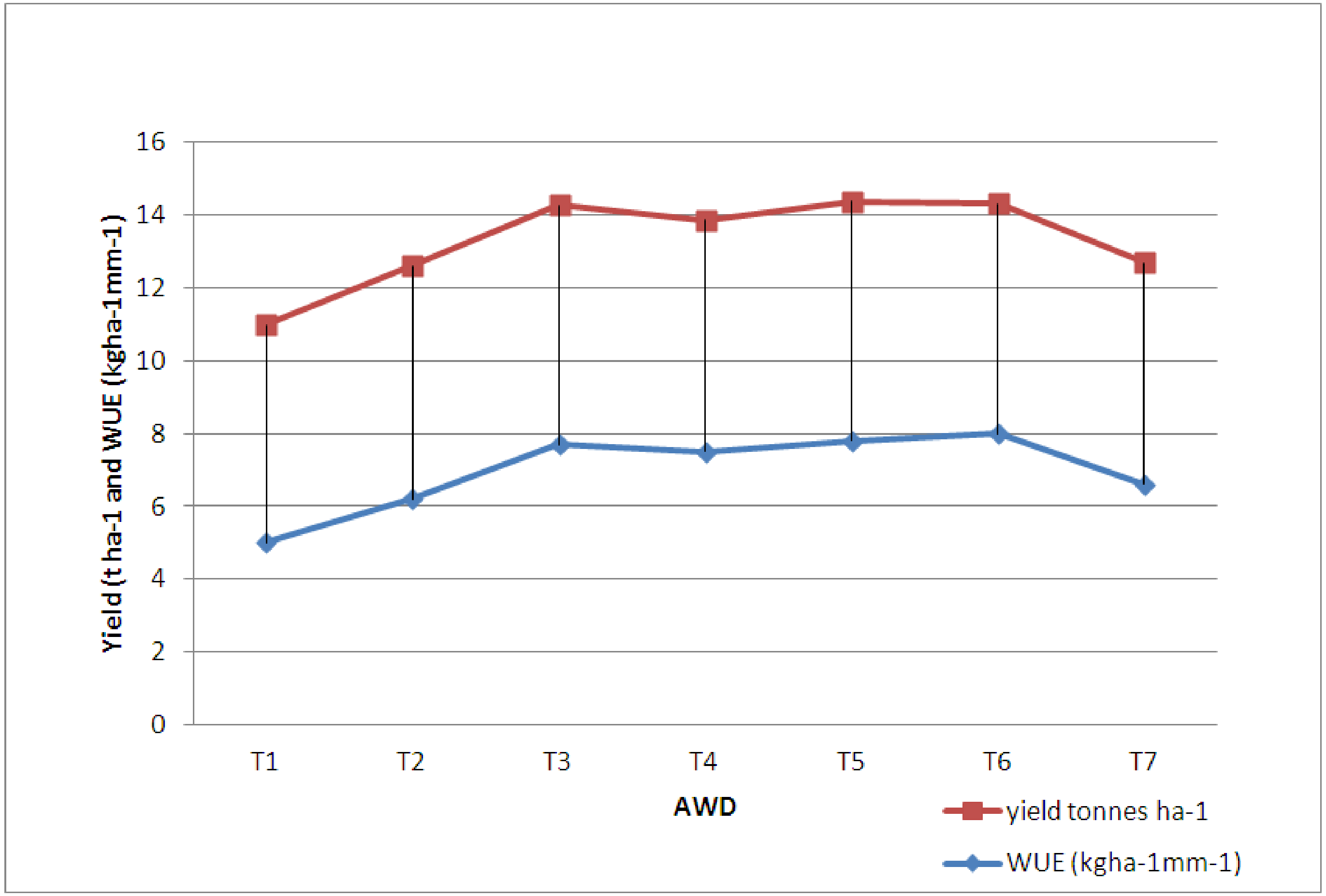

Fig. 1. Effect of AWD on WUE (kgha^{-1} mm^{-1}) and yield (kg ha^{-1}) of transplanted rice

tube with 75% N & K application in 10 days intervals). The lowest number of filled grains (139 panicle^{-1}) was recorded underirrigation through field water tube with 75% N & K application in 10 days intervals. These results are consistent with findings of Hameedet al. [21]. This result maybe attributed due to water deficits during floral development can severely damage seed set, through pollen sterility or abortion of embryos, or can prematurely end grain filling [22].

Similar to productive tillers and filled grains the grain yield was also significantly higher (6587 kg ha^{-1}) in irrigation through field water tube with 100% N&K application in 10 days intervals (T_5) compared to all other treatments except T_3, T_2, T_4, and T_6. The lowest grain yield (5992kg ha^{-1}) was recorded in conventional planting with 100 % recommended dose of fertilizers (T_1). The results shown that grain yield did not decline when plants grieved little water stress. If water deficit is properly controlled especially during grain filling stage of rice, it enhanced whole-plant senescence. The increase in yield components might be due to adequate moisture availability throughout the crop growth period. The improved yield might also be due to increased nutrient uptake. This result in agreement with the findings of Oliver et al. [17] and Rahman and Bulbul [11]. Rice is more sensitive to water stress especially at critical growth stages such as panicle initiation, anthesis and grain filling [23]. Water stress executed during the reproductive period can lead to reduce in grain yield [24]. Decrease in yield can be attributed to decrease in number of filled grains panicle^{-1} and average length and low percentage of grain filling.

Higher straw yield (11537 kg ha$^{-1)}$ was produced in Alternate wetting and drying with LCC based nitrogen management (T_2) over all treatments barring T_1 and T_3. The lowest straw yield (9667 kg ha^{-1}) was recorded under irrigation through field water tube with 100% N & K application in 7 days intervals (T_4). The increase in straw yield was also due to the enhanced nutrient uptake throughout the crop growth period under sufficient water supply and increased nitrogen application. The lowest straw yields which can be attributed to water stress suffered by the crop because of the prolonged dry period. These results are consistent with findings of Hameed et al. [21].

The harvest index was significantly higher (0.40) in Irrigation through field water tube with 100% N & K application in 10 days intervals (T_5) and except control (conventional planting with 100 % recommended dose of fertilizers). The lowest harvest index (0.33) was recorded under conventional planting with 100 % recommended dose of fertilizers (T_1). Similar results were reported by Gowri [23], Oliver et al. [16] and Rahman and Bulbul [11]. It might be due to the increased yield in plants with higher irrigation regimes.

4. CONCLUSION

The field experimental results confirmed that through field water tube irrigation along with 75% level of application of nitrogen and potassium at 7 days intervals had saved 25% of nitrogen and potassium besides 34.7% of water without any yield penalty. Hence, this method can be used as an attractive method for sustaining the rice production under puddled transplanted rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Joshi B, Chaudhary A, Singh H, Kumar PA. Prospective evaluation of individual and consortia plant growth promoting rhizobacteria for drought stress amelioration in rice (*Oryza sativa* L.). Plant Soil. 2020;457(1-2):225-40.
2. Joshi R, Mani SC, Shukla A, Pant RC. Aerobic rice: water use sustainability. ORYZA An Int J Rice. 2009;46(1):1-5.
3. Caine RS, Yin X, Sloan J, Harrison EL, Mohammed U, Fulton T et al. Rice with reduced stomatal density conserves water and has improved drought tolerance under future climate conditions. New Phytol. 2019;221(1):371-84.
4. Maneepitak S, Ullah H, Datta A, Shrestha RP, Shrestha S, Kachenchart B. Effects of water and rice straw management practices on water savings and greenhouse gas emissions from a double-rice paddy field in the Central Plain of Thailand. Eur J Agron. 2019;107:18-29.
5. He G, Wang Z, Cui Z. Managing irrigation water for sustainable rice production in China. J Cleaner Prod. 2020;245:118928.
6. Carracelas G, Hornbuckle J, Rosas J, Roel A. Irrigation management strategies to increase water productivity in *Oryza sativa*

rice in Uruguay. Agric Water Manag. 2019;222:161-72.
7. Singh B, Mishra S, Bisht DS, Joshi R. Growing rice with less water: improving productivity by decreasing water demand. Rice Improv. 2021:(147-70).
8. Bouman BAM, Lampayan RM, Tuong TP. Water management in irrigated rice. Coping with water scarcity. Manila, Philippines: International Rice Research Institute. 2007:53.
9. Viets FG. Fertilizers and the efficient use of water. Adv Agron. 1962;14:223-64.
10. Faruki MRI, Ali MH, Saha RC, Roy AK. Effect of water saving technology through alternate wetting and drying for boro rice cultivation. J Agrofor Environ. 2011;5(1):11-4.
11. Oliver MMH, Talukder MSU, Ahmed M. Alternate wetting and drying for rice cultivation. J Bangladesh Agric Univ. 2008; 6(2):409-14.
12. Latif MA, Yamaji EIJI. A study on field water tube's effectiveness as a practical indicator to irrigate SRI. IJERD-Int J Environ Rural Dev. 2011;2(2):24-9.
13. Kulkarni S. Innovative technologies for water saving in irrigated agriculture. Int J Water Resour Arid Environ. 2011;1(3): 226-31.
14. Rahman MR, Bulbul SH. Effect of alternate wetting and drying (AWD) irrigation for Boro rice cultivation in Bangladesh. Agric For Fish. 2014;3(2):86-92.
15. Bhuiyan SI, Tuong TP. Water use in rice production: issues, research opportunities and policy implications. Paper presented at the Inter-Center Water Manag Workshop, 29-30 September 1995. Colombo, Sri Lanka: International Irrigation Management Institute. Geneva: World Health Organization; 1995.
16. Sato S, Uphoff N. Raising factor productivity in irrigated rice production: opportunities with the System of Rice Intensification. CAB Rev. 2007;54:2.
17. Chapagain T, Riseman A, Yamaji E. Achieving more with less water: alternate wet and dry irrigation (AWDI) as an alternative to the conventional water management practices in rice farming. J Agric Sci. 2011;3(3):3.
18. Satyanarayana A, Thiyagarajan TM, Uphoff N. Opportunities for water saving with higher yield from the system of rice intensification. Irrig Sci. 2006;25(2): 99-115.
19. Hameed KA, Mosa AJ, Jaber FA. Irrigation water reduction using System of Rice Intensification compared with conventional cultivation methods in Iraq. Paddy Water Environ. 2011;9(1):121-7.
20. Saini HS, Westgate ME. Reproductive development in grain crops during drought. Adv Agron. 1999;68:59-96.
21. Tao H, Brueck H, Dittert K, Kreye C, Lin S, Sattelmacher B. Growth and yield formation of rice (*Oryza sativa* L.) in the water-saving ground cover rice production system (GCRPS). Field Crops Res. 2006;95(1):1-12.
22. Lilley JM, Fukai S. Effect of timing and severity of water deficit on four diverse rice cultivars III. Phenological development, crop growth and grain yield. Field Crops Res. 1994;37(3):225-34.
23. Gowri S. Physiological studies on aerobic rice (*Oryza sativa* L.). M. Sc. (Ag.) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore. 2005; 641(003).
24. Crop production guide (CPG). Coimbatore: Tamil Nadu Agricultural University. 2020; 641 003.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/90232