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RESEARCH ARTICLE

Impact assessment of water efficient rice production technology on farmers' field

G Selvarani[1], E Subramanian[2]*, A Sathishkumar[3], J Selvi[4], C Aathithyan[3] & S Selvakumar[3]

[1]Department of Agricultural Extension and Rural Sociology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai 625 104, Tamil Nadu, India

[2]ICAR- Krishi Vigyan Kendra, Tamil Nadu Agricultural University, Madurai 625 104, Tamil Nadu, India

[3]Department of Agronomy, Agricultural College and Research Institute (AC&RI), Tamil Nadu Agricultural University, Madurai 625 104, Tamil Nadu, India

[4]ICAR- Krishi Vigyan Kendra, Tamil Nadu Agricultural University, Thirupathisaram 629 901, Kanyakumari Dt., Tamil Nadu, India

*Email: esubramanian@tnau.ac.in

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Abstract

The experiments were conducted during *kharif* season of 2018 and 2019 at farmers' fields, Madurai in the Southern Zone of Tamil Nadu to find out the water efficient rice production technology. The experiment consisted of six crop establishment treatments *viz.,* direct planting system, drum seeding, system of rice intensification (SRI), aerobic rice, drip irrigated rice and conventional planting system. The rice variety ASD 16 was used and the experiments were arranged in a randomized block design with four replications. Among the water efficient techniques, drum seeding registered the higher grain yield (5650 kg ha^{-1}), which was comparable to the direct planting system (5592 kg ha^{-1}). The system of rice intensification produced the grain yield of 5025 kg ha^{-1}. The conventional method of transplanting produced higher yield than SRI. Interestingly, the water productivity was higher in aerobic rice (6.92 kg/ ha mm^{-1} of water) despite its lower yield. Around 49.6 % water can be saved by means of aerobic rice when compared to conventional method of rice cultivation. Hence, the water efficient methods like drum seeding and direct planting systems are recommended for canal irrigated areas, while aerobic rice is suitable for water scarcity regions, turn irrigation systems and well irrigated areas to enhance water use efficiency and sustain rice farming.

Keywords

aerobic rice; drum seeding; SRI; water efficient; water productivity

Introduction

Rice is life, as it represents not only a staple food and a source of livelihood but also plays a crucial role in the environment, supporting biodiversity and the web of life. Rice consumes about 90 % of the freshwater resources in Asia used for agriculture. Rice is grown under irrigated (55 %) and rainfed lowland (25 %) ecosystems, both of which depend on fresh-water resources (1, 2). In view of these demands and constraints, the question is - does rice need standing water for optimum production? Flooding technique in rice is used as management tool, not a specific requirement (3). Rice is unique in the sense that transplanted paddy requires a lot of water for land preparation. Can we explore alternatives that reduce this component? Rice can grow and withstands in diverse agro-ecosystems, varying from rainfed upland conditions to deep-water flooded conditions. Direct sowing of sprouted seeds onto puddled soil holds special significance in modern production systems, as it saves time, labour and energy while increasing profitability by reducing turnaround time and avoiding arduous operations like nursery preparation and manual transplanting. This shift from transplanting to direct seeding, offers opportunities to improve water-use efficiency in rice culture by reducing the irrigation inflow requirements during land preparation (4, 5).

The System of Rice Intensification (SRI), developed at Madagascar, has been reported to increase grain yields and save water due to the synergistic effects of adopting various cultivation practices simultaneously. The term “Aerobic rice” refers to high yielding rice grown in non-puddled and non-flooded aerobic soil (6). Aerobic cultivation entails the growing of rice in aerobic soil, with the use of external inputs such as supplementary irrigation and fertilizers, aiming for higher yield. Aerobic rice differs significantly from conventional flooded rice as it reduces water consumption and methane emissions. Unlike conventional methods, it requires effective weed management due to the absence of continuous water coverage. Additionally, aerobic rice develops a deeper root system, enhancing drought tolerance but potentially leading to lower yields compared to traditional flooded cultivation. The growing scarcity of fresh water is gradually driving a shift from traditional rice production systems to wet seeding and dry seeding, particularly in water-scarce irrigated lowlands. For instance, in regions like South Asia, including India and Bangladesh, farmers are increasingly adopting dry direct seeding to cope with declining water availability. Similarly, in China and Southeast Asian countries, wet direct seeding is being promoted as an alternative to conventional transplanting due to labor shortages and water constraints. Various State Agricultural Universities and Research Station have conducted considerable research on irrigation water management in rice. The research has yielded results of many water saving techniques in rice.

The main limitation is all programme have been conducted in research stations. Although, several water-saving practices have been proposed by the researchers, they are still in the early stages of adoption farmers. Hence, the proposed study was conducted to compare the different water saving rice production methods and its productivity and utility at farmer’s field through on farm testing by ICAR TNAU KVK, Madurai.

Materials and Methods

The experiments were conducted during kharif season of 2018 and 2019 at farmers’ fields in Madurai, located in the Southern Zone of Tamil Nadu, to find out the water efficient rice production technologies. The experiment consisted of six crop establishment treatments *viz.,* direct planting system, drum seeding, SRI, aerobic rice, drip irrigated rice and conventional planting system. The rice variety ASD 16 was used for the study. The experiment was laid out in a randomized block design with four replications. In the direct planting system, 40 kg ha^{-1} of sprouted seeds were broadcast in puddled fields. After 12 days, rotary weeder was used to thin the plant stand in swaths of rows 25 cm apart. After covering the area in one direction, the process was repeated in the opposite direction with the same width of swath. In drum seeding, sprouted seeds were line sown at 40 kg ha^{-1} using drum seeder at spacing of 20 cm between rice onto puddled soil. Whereas, in system of rice intensification the 15 days old seedlings were transplanted at 22.5 X 22.5 cm spacing. Seeds were soaked in water for 12 hours to enhance water absorption, which triggers the metabolic processes required for germination. The subsequent incubation for 10 hours helps initiate radicle emergence, ensuring uniform and rapid seedling establishment in the field

Sprouted seeds were line sown at a spacing of 20x10 cm spacing under aerobic conditions. In the drip-irrigated rice sprouted seeds were line sown manually by 20x10 cm spacing and laterels were laid out at 60 cm spacing with the discharge of 1.6 lit sec^{-1}. These methods were compared with the conventional transplanting of 22 days old seedling at 20x10 cm spacing. Need-based plant protection measures were taken to grow healthy rice. Irrigation was applied using a Parshall Flume and was periodically measured. The observation on plant growth parameters, yield attributes and yield were recorded. The data on various characters (growth parameters, yield attributes and yield) studied during investigation were statistically analyzed as suggested previously (7).

Wherever statistical significance was observed, the critical difference (CD) at a 5 % level of probability was calculated for comparisons. Non- significant comparison was indicated as ‘NS’. The correlation was analyzed using Grapes version 1.1.0 software (8).

Results and Discussion

Effect on growth attributes of rice

The short duration rice variety responded well to the different establishment methods (Table 1). Among the methods, better growth characters were noticed especially plant height in direct seeding method when compared to transplanting. Sprouted seeds were line sown at 50 kg ha^{-1} using a drum seeder at a spacing of 20 cm between rows onto puddled soil, which produced taller plant of 118.5 cm. This was comparable to the direct planting system at the flowering stage. The puddled conditions favored the growth of rice and resulted in taller plants in direct planting system and drum seed rice as reported earlier (9).

In contrast, non-puddled condition produced shorter plants as resulted in shorter plants in both aerobic and drip irrigated rice. The sprouted seeds were line sown at a spacing of 20x10 cm spacing under aerobic condition produced shorter plants at flowering stage. Similarly, Leaf Area Index (LAI) was higher under the drum seeding method when compared to other methods, which was comparable with direct planting system at flowering stage of the crop. Both aerobic and drip irrigated rice produced lower LAI than the conventional system of rice growing. Due to higher number of seeds sown on the soil in drum seeding and direct planting system the tiller production also higher at maximum tillering stage (10). Therefore, direct seeding produced more number of tillers per unit area when compared with system of rice intensification and conventional transplanting.

Among the crop establishment methods, drum seeding produced more number of primary, secondary tillers per unit area when compared with system of rice intensification and conventional transplanting. However, it produced lesser number of tertiary tillers. Even though, aerobic rice produced shorter plants and it produced more number of primary, secondary tillers per unit area, because the non-saturated soil conditions promote better root development and efficient nutrient uptake. The well-aerated root zone enhances the availability of oxygen, stimulating tiller formation. Additionally, reduced plant height allows more energy to be allocated toward tiller production rather than vertical growth. The yield of rice mainly depends upon primary and secondary tillers in short duration rice variety with less than 120 days (11). The tiller production in drip irrigated rice is lesser than the aerobic rice. The conventional system produced moderate primary (7.20) and secondary tillers (8.72). However, it produced lesser number of tertiary tillers. Better growth attributes of rice resulted in direct seeding produced higher Dry Matter Production (DMP) than the transplanting. Drum seeding on the puddled soil produced 6.32 t ha^{-1} of DMP at flowering and it was compared with direct planting system. Among the crop establishment methods, drip irrigated rice produced the lowest DMP.

Effect on yield attributes and yield of rice

Like tillers, the primary, secondary and tertiary panicles were counted for comparison and are depicted in Fig. 1. Among the crop establishment, drum seeding on puddled soil produced higher number of primary panicles (6.80) and it was comparable with direct planting system (6.51) whereas, Direct Planting System (DPS) produced more number of secondary panicles when compared with other establishment methods. Comparing aerobic rice with drip irrigated rice, aerobic rice produced higher number of primary and secondary panicles than the drip irrigated rice. System rice intensification produced more number of tertiary panicles with lesser grains than the other crop establishment methods (12).

Both drum seeding and direct planting system were equally effective to produce more number of panicles per unit area (Table 2). Among these, drum seeding was better than the direct planting system numerically. Aerobic rice recorded higher number panicles when compared with system of rice intensification. Interestingly, the system of rice intensification recorded the lowest number of panicles per unit area next to conventional transplanting. However, the yield attributed of rice especially panicle length and weight were higher in system of rice intensification methods and it was comparable with drum seeding and direct planting system. The aerobic rice produced shorter panicle with less weight when compared to other methods. Studies have shown that rice grown under the System of Rice Intensification (SRI) exhibits longer and heavier panicles due to improved root growth, better soil aeration and efficient nutrient uptake (13). Similarly, research on drum seeding and direct planting systems indicates comparable panicle traits due to uniform plant spacing and reduced competition (14). In contrast, aerobic rice often produces

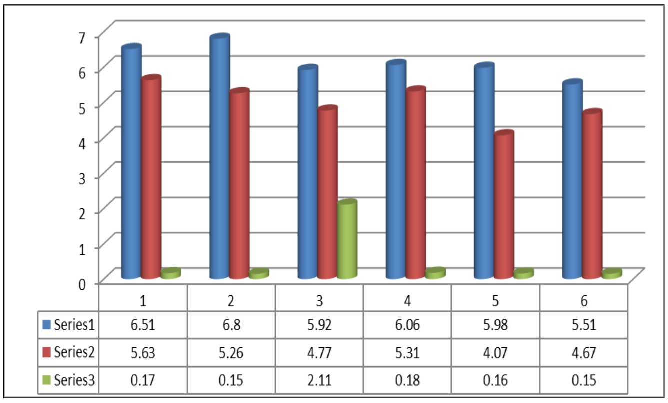

Fig. 1. Production of primary (Series 1), secondary (Series 2) and tertiary tillers (Series 3).

Table 1. Growth characters of rice as influenced by different crop establishment methods

Treatment	Plant height (cm)	LAI at flowering	Primary tillers	Secondary tillers	Tertiary tillers	Tiller $Plant^{-1}$	DMP at flowering t ha^{-1}
Direct planting system	115.3	5.94	7.33	8.99	2.03	18.35	6.25
Drum seeding	118.5	6.02	7.92	9.59	2.47	19.98	6.32
System rice planting	112.1	4.55	6.99	9.52	4.98	21.49	4.78
Aerobic rice	108.4	4.68	7.58	9.24	2.18	19.00	5.04
Drip rice	105.4	3.85	6.60	8.14	1.82	16.56	4.15
Conventional practice	110.2	5.25	7.20	8.72	1.96	17.88	5.50
SEd	**1.74**	**0.11**	**0.36**	**0.40**	**0.16**	**0.53**	**0.21**
CD(P=0.05)	**3.80**	**0.30**	**0.73**	**0.80**	**0.33**	**1.07**	**0.45**

Table 2. Yield attributes and yield of rice as influenced by different crop establishment

Treatment	Tillers m^{-2}	Panicle m^{-2}	Sterile tillers (%)	Panicle length (cm)	Panicle weight (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Direct planting system	568	411	27.64	22.5	2.34	5592	8854
Drum seeding	602	432	28.24	22.8	2.44	5650	8962
System rice planting	475	348	26.74	23.1	2.52	5025	8225
Aerobic rice	572	381	33.39	21.4	2.19	4854	7928
Drip rice	425	312	26.59	21.8	2.12	4254	6985
Conventional practice	515	375	27.18	22.3	2.38	5263	8654
SEd	**21.1**	**15.60**	**-**	**0.55**	**0.06**	**162.3**	**240.8**
CD(P=0.05)	**45.9**	**34.0**	**-**	**1.20**	**0.11**	**354.0**	**525.0**

shorter and lighter panicles, as observed in previous studies (15), which attribute this to limited water availability and greater oxidative stress in aerobic conditions.

Better growth characters with better yield attributes, resulted in higher yield of 5650 kg ha^{-1} under drum seeding and this was comparable with direct planting system which resulted in 5592 kg ha^{-1}. Both these methods are equally effective in producing higher yield when compare with other methods. Though higher values of panicle length and weight recorded in SRI method resulted in lesser yields when compared with the conventional transplanting. The aerobic rice recorded lesser yield when compared to SRI numerically and it was statistically on par with the system of rice intensification. Similar result was observed previously (16).

The most salient feature of aerobic rice in our study was the extremely low water input: the combined amount of rainfall and irrigation water from sowing to harvest was 625 mm (Fig. 2), compared with 1250 mm in transplanting and drum seeding (1050 mm). Compared with transplanted rice, water consumption in aerobic rice was lower than 50 %; water productivity was 60 % higher with yield reduction of 25 %. This study gave much novel ideas of crop -water relationships in aerobic rice. In terms of real water for aerobic, drum seeding and transplanted rice, about 92 %, 42 % and 40.6 % of water (including rainfall) was used for evapo-transpiration or consumptive purpose while remaining 8.0, 58.0 % and 59.4 % of water would have left the root zone as seepage and deep percolation flows, respectively. Because of its low water use with reasonable higher yield, aerobic rice has greater scope in areas where water availability is limited. Currently drum seeding and the direct planting system are more suitable for canal irrigated areas, where water and yield are the two face of the coin.

Correlation analysis

A correlation analysis was conducted to evaluate the relationship between tillers and grain yield in rice. The results indicated that grain yield showed a strong positive correlation with primary tillers (0.74), secondary tillers (0.64) and tertiary tillers (0.04) (Fig. 3). Additionally, correlation analysis was conducted to examine the relationship between growth and physiological parameters and grain yield in rice. The findings revealed a strong positive correlation of grain yield with plant height (0.92), LAI (0.97) and DMP (0.96) (Fig. 4).

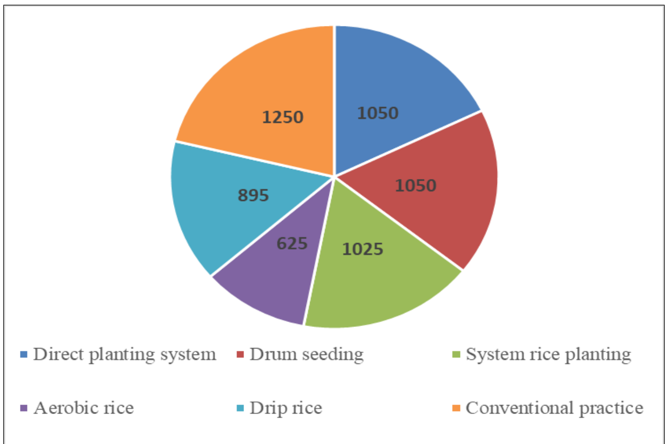

Fig. 2. Consumptive use of water (mm) in different establishment methods.

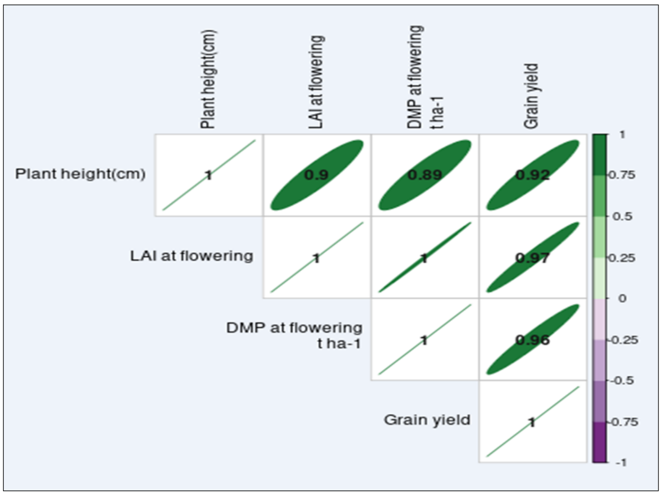

Fig. 3. Correlation between growth and physiological parameters versus grain yield.

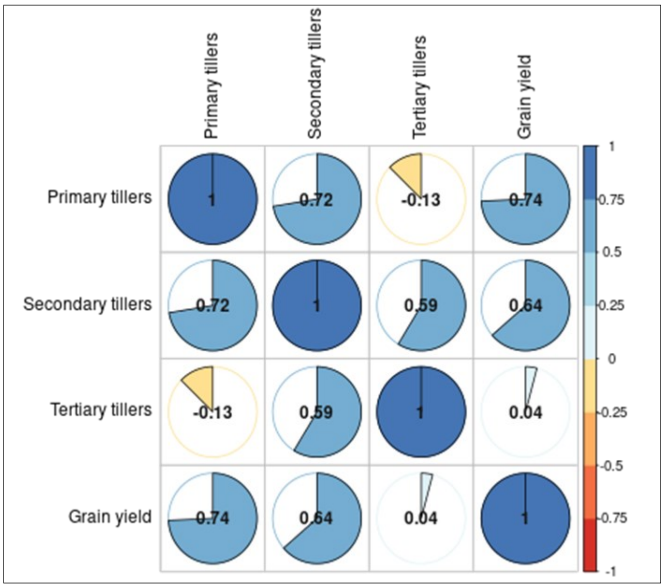

Fig. 4. Correlation between tillers and grain yield.

Conclusion

The system of rice intensification is known for higher yield, with a greater number of tiller and panicles per plant the suitability of this system for short duration rice varieties needs to be reassessed because of lower number of tiller and panicle per unit area. Hence, the water efficient rice production techniques of drum seeding and direct planting system can be followed in canal irrigated areas whereas aerobic rice can be followed in water scarcity, turn system of irrigation and well irrigated area for efficient water use and to sustain the rice farming at farmers field. However, special high-yielding aerobic rice varieties need to be developed and a lot of research is still needed to develop sustainable and viable aerobic rice systems.

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Authors' contributions

GS wrote the first draft of the paper. ES conceptualized, reviewed and edited the research paper holistically. AS, JS, CA and SS reviewed the paper and shared their inputs for upscaling. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: We do not have any conflict of interest to declare.

Ethical issues: None

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