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Research Article

Effects of irrigation regimes and brown manuring on physiological parameters and yield of direct seeded rice (TRY 3) under sodic soil condition

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Abstract
Direct seeded rice (DSR) production has been recognised as a more efficient way for conserving both labour and water. However, in regards to irrigation and brown manuring (BM), DSR has gotten relatively little attention. Hence, a field study was conducted to findout the effect of irrigation and brown manuring on physiological characters and yield of DSR (TRY 3) under sodic soil condition. The experiment was laid out in a split plot design and each replicated thrice. The main plots consist of irrigation after 10 cm (M_1) and 15 cm (M_2) depletion of field water tube and irrigation after the disappearance of ponded water (M_3). The sub plots consist of *sesbania* BM at 15 (S_1), 20 (S_2) and 25 kg ha^{-1} (S_3), PE Pretilachlor at 0.45 kg ha^{-1} *fb* PoE Bispyribac sodium at 25 g ha^{-1} + hand weeding (HW) on 45 DAS (S_4), HW (S_5) and weedy check (S_6). Results revealed that higher SPAD value was recorded under M_3 which was on par with M_1. Among sub plots maximum SPAD value was recorded with S_5 followed by S_4 and S_2. Treatment M_2 recorded maximum proline content. There is no significant difference found in relative water content (RWC). However, higher RWC content was observed in M_3. At the same time, higher grain and straw yield were recorded under M_3 with S_5, followed by M_1 with S_5. However, due to a large amount of water required and the higher labour costs associated with hand weeding, M_1 with S_2 was the best choice for increasing DSR productivity.

Keywords: Brown manuring, Field water tube, Grain yield, Physiological characters, *Sesbania*

INTRODUCTION

Rice is an important food crop for more than half of the world's population, predominantly in South and South-east Asia, and it occupies roughly 11% of the world's agricultural land, ranking second in terms of coverage (Tumrani *et al*., 2015; Haque *et al*., 2021). Rice is grown on around 45 million ha in India, with a total production of 124 million tonnes and productivity of 2717 kg ha^{-1}, accounting for 40% of the country's total food grain (https://www.indiastat.com.elibrarytnau.remotexs.in). Transplanting is a traditional rice growing method that is still used in many rice-growing regions. But major operations such as nursery preparation and maintenance, plucking out seedlings, transportation, distributing seedlings to the main field, and transplanting account for 30-40% of the overall cost of cultivation. Direct seeded rice is a feasible alternative to traditional transplantation rice, with the ability to save water, reduce labour requirements, minimize greenhouse gas (GHG) emissions, and safeguard farmers' livelihoods. Rice cultivation is becoming increasingly concerned about water conservation. Because demand for staple crops like rice will rise as the world's population grows, necessitating increased freshwater sources for rice irrigation (Norton *et al*., 2017). Due to climate change, growing industrialization, and urbanization, water for agricultural purposes is becoming increasingly limited. Rice cultivation, which makes indiscriminate use of ground water, causes the water table to drop and raises the expense of water pumping. When compared to other crops, rice has extremely low water use efficiency. Water shortage will affect 15–20 million hectares of irrigated rice in Asia by 2025 (Kumar and Rajitha, 2019). To deal with the worldwide water shortage, several alternative planting strategies have been used. Alternate wetting and drying (AWD) by using a field water tube is another effective way to preserve irrigation water for long-term rice production by drying and flooding rice fields on a regular basis. Also, loss owing to weeds has been observed to be between 50 to 60 percent under DSR conditions (Singh *et al*., 2020). Weeds are a key restraint in the DSR habitat. If weeds are properly controlled, direct seeding using pre-germinated rice seed in puddled state might be an effective approach to tackle these challenges. In agriculture, weed is controlled by many ways. However, in today's agriculture field, adopting an eco-friendly strategy to weed management is more suggested to safeguard natural resources such as soil flora and fauna, as well as humans and animals, in a holistic manner. Brown manuring is just a "no-till" variation of green manuring, in which the crop is desiccated before flowering using a herbicide rather than being cultivated (Tanwar*et al*., 2010). *Sesbania* may be cultivated with rice to reduce weeds as a bioherbicide because it is an aquatic and fast-growing plant. The dead *sesbania* is left to remain on the field with the main crop without being incorporated or ploughed until its residue decomposes in the soil, providing organic manure as well as weed suppression through its shadow impact. It also reduces soil moisture evaporation and contributes 20-35 kg N ha^{-1} to the soil, improving its physicochemical and biological properties as well as the rhizospheric environment without considerably raising cultivation expenses. So, to solve these issues, the present research was undertaken to determine the extent of irrigation regimes and brown manuring in direct seeded rice (TRY 3).

MATERIALS AND METHODS

Experimental site

The field experiment was carried out at a farm field located at Anbil Dharmalingam Agricultural College & Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, during *Samba* season (September-January), 2021 to study the effect of irrigation regimes and brown manuring on physiological characters and yield of direct seeded rice (TRY 3) under sodic soil condition. Experimental soil was alkaline in nature (pH-8.7), sandy clay-loam in texture, moderately drained, and classified as *Vetric Ustropept*. Available nitrogen, phosphorus and potassium were estimated by Alkaline permanganate (Asija and Subbiah, 1956), Colorimetric (Olsen *et al*., 1954) and Flame photometer method (Stanford and English, 1949). These results revealed that the initial soil status of the experimental field was low in nitrogen (218 kg ha^{-1}), medium in phosphorus (14.3 kg ha^{-1}) and high in potassium (288.3 kg ha^{-1}).

Weather and climate

The experimental site was located at 10^{o} 45' N latitude, 78^{o} 36' E longitude and at an altitude of 85 m above MSL. Data collected from the Anbil Dharmalingam Agricultural College & Research Institute meteorological observatory indicated that total rainfall received during cropping season (September 2021–January 2022) was 985.4 mm in 44 rainy days. Mean maximum and minimum temperature was 32.5^{o}C and 23.2^{o}C, respectively. Mean relative humidity was 86.9 % (Morning) and 59.5 % (Evening). Mean bright sunshine hours and evaporation per day were 5.4hours and 7.4 mm, respectively. Mean wind velocity was 3 km per hour.

Experimental details

The experiment was laid out in a split plot design with three main plots and six sub-plots replicated thrice. The main plot treatments consisted of M_1-Irrigation after 10 cm depletion of field water tube, M_2-Irrigation after 15 cm depletion of field water tube and M_3-Irrigation after disappearance of ponded water. The sub-plot treatments consisted of S_1-Brown manuring with *sesbania* at 15 kg ha^{-1}, S_2-Brown manuring with *sesbania* at 20 kg ha^{-1}, S_3-Brown manuring with *sesbania* at 25 kg ha^{-1}, S_4-PE Pretilachlor at 0.45 kg ha^{-1} *fb* PoE Bispyribac sodium at 25 g ha^{-1} + HW on 45 DAS, S_5-Hand weeding and S_6-Weedy check. Medium duration variety TNAU Rice TRY 3 was used as the test variety. The sowing of DSR in well puddled and levelled field was done by using a paddy drum seeder at row spacing of 20 cm. The irrigation level was maintained by using a field water tube. When the land was irrigated, the quantity of irrigation was measured by Parshall flume for each plot. For brown manuring purpose, *sesbania* seeds were broadcasted uniformly after sowing the rice seeds as per treatment and Bispyribac sodium at 25 g ha^{-1} was sprayed at 30 DAS to knock down the *sesbania*. At the panicle initiation stage, the proline and relative water content was estimated using the method of Bates *et al*.

(1973) and Barrs and Weatherly (1962), respectively. SPAD readings were recorded using Chlorophyll Meter (SPAD 502) at panicle initiation stage. The harvested plants were manually threshed, and each plot yield was sun-dried, cleaned, winnowed, and weighed separately. Grain yield was calculated at a moisture content of 14 percent and expressed in kg ha^{-1}. The data collected from the field experiment was statistically analyzed following the procedure given by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Effect of irrigation regimes and brown manuring on physiological parameters

The readings from the SPAD metre have a good correlation with leaf greenness and N content in the crop; therefore they may be used to assess leaf chlorophyll concentration indirectly. The SPAD value (Fig.1) was significantly (5%) increased in irrigation after the disappearance of ponded water (M_3) (48.8) and it was on par with irrigation after 10 cm depletion of field water tube (M_1) (48.1), while a lower value was registered in irrigation after 15 cm depletion of field water tube (42.5). Among the sub-plot treatments, higher SPAD value was observed with hand weeding (S_5) (53.8). It was followed by BM with *sesbania* at 20 kg ha^{-1} (S_2) (51.7) and was on par with PE Pretilachlor at 0.45 kg ha^{-1} *fb* PoE Bispyribac sodium at 25 g ha^{-1} + HW on 45 DAS (S_4) (51.5). Lower SPAD value was recorded in weedy check treatment (S_6) (34.8). This might be due to *sesbania,* which helped preserve greater chlorophyll content by substituting nitrogen and other plant nutrients in rice (Islam *et al*., 2019). According to Ramesh *et al*. (2002), SPAD readings and direct wet seeded rice grain yield have a strong relationship.

Irrigation regimes and weed management practices significantly affect the proline content in leaves of rice at the panicle initiation stage (Fig. 1). Among the various irrigation and brown manuring practices, higher proline content was observed with irrigation after 15 cm depletion of field water tube (M_2) (1.51 μ mol g^{-1}) followed by irrigation after 10 cm depletion of field water tube (M_1) (1.36 μ mol g^{-1}). Lower proline content was recorded in irrigation after the disappearance of ponded water (M_3) (1.19 μ mol g^{-1}). Among the weed management practices, hand weeding (S_5) (1.43 g^{-1}) recorded higher proline content followed by BM with *sesbania* at 25 kg ha^{-1} (S_3) (1.42 μ mol g^{-1}). Plant tissues produce and accumulate free amino acids, particularly proline, as an adaptive response to drought. Increased proline levels may aid in maintaining the osmotic potential of the cell cytoplasm, which is critical for plant survival in stressful situations (Saha *et al*., 2016). It also serves as an enzyme protector, stabilizes protein structure and cell membranes, as well as a free radical scavenger and antioxidant (Kishor and Sreenivasulu, 2014). Proline build-up is a common indication of leaf dehydration and is linked to stress vulnerability (Hanson *et al*., 1977)

The balance between water availability to the leaf tissue and transpiration rate is reflected by RWC, which is an essential indication of water status in plants. Relative water content in the leaf was not significantly influenced by irrigation regimes and brown manuring practices (Fig.1). However, higher RWC was observed in irrigation after the disappearance of ponded water (92.8%). This was due to continuous rainfall during the panicle initiation stage, which rehydrates the plants in all treatments.

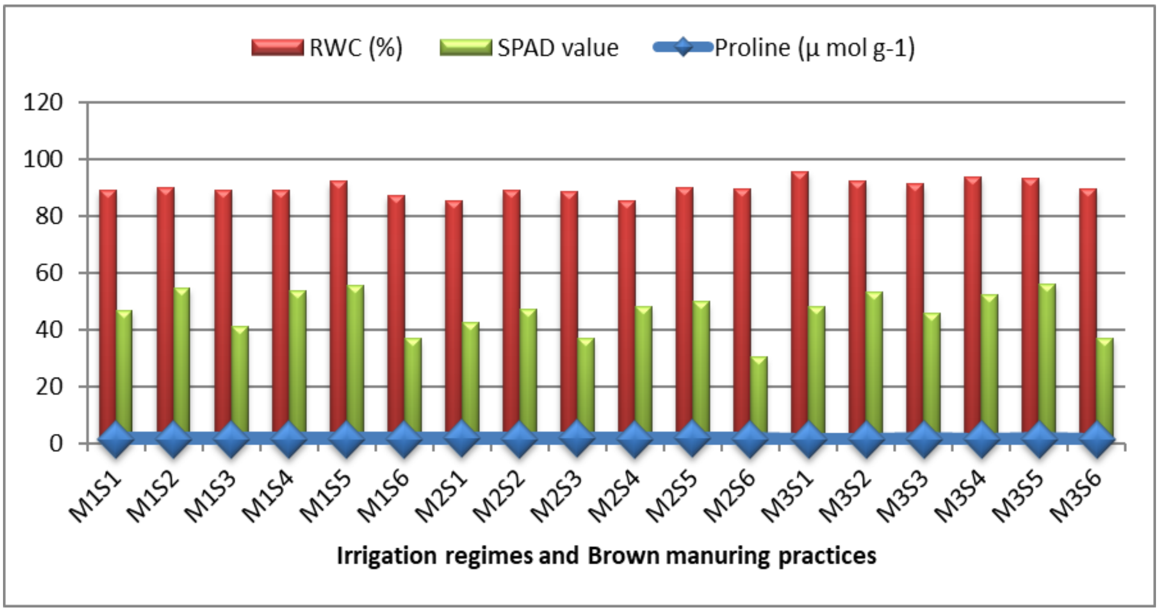

Fig. 1. *Effect of irrigation regimes and brown manuring practices on Relative water content (%), Proline (μ mol g^{-1}) and SPAD value*

Table 1. Effect of irrigation regimes and brown manuring on grain and straw yield of rice

Main/Sub plots	S_1	S_2	S_3	S_4	S_5	S_6	Mean
Grain yield (kg ha^{-1})							
M_1	3705	4058	3139	3925	4387	2933	3691
M_2	3487	3759	3005	3704	4083	2064	3350
M_3	3723	4235	3356	4005	4467	3020	3801
Mean	3603	4017	3211	3914	4267	2672	
	M	S	M at S	S at M			
SEd	63	87	151	150			
CD(p=0.05)	82.65	179	328	307			
Straw yield (kg ha^{-1})							
M_1	5450	5805	4902	5595	6452	4471	5446
M_2	5083	5226	4750	5294	5436	4207	4998
M_3	5518	6327	5012	6138	6549	4619	5694
Mean	5350	5786	4888	5676	6146	4432	
	M	S	M at S	S at M			
SEd	101	120	215	208			
CD(p=0.05)	277	245	473	425			

M_1: Irrigation after 10 cm depletion of field water tube, M_2: Irrigation after 15 cm depletion of field water tube, M_3: Irrigation after disappearance of ponded water, S_1: Brown manuring with *sesbania* at 15 kg ha^{-1},S_2: Brown manuring with *sesbania* at 20 kg ha^{-1}, S_3: Brown manuring with *sesbania* at 15 kg ha^{-1}, S_4: PE Pretilachlor at 0.45 kg ha^{-1} *fb* PoE Bispyribac sodium at 25 g ha^{-1} + HW on 45 DAS, S_5: hand weeding on 20and 45 DAS, S_6:Weedy check

Effect of irrigation regimes and brown manuring on grain and straw yield

The key criterion for measuring the efficacy of different treatments is grain and straw yield. In direct seeded rice, irrigation regimes and brown manuring practices were found to impact considerably on grain and straw yields (Table 1). Under irrigation regimes, higher grain and straw yields were recorded in irrigation after the disappearance of ponded water (3801 and 5694 kg ha^{-1}, respectively) and which was on par with irrigation after 10 cm depletion of field water tube (3691 and 5446 kg ha^{-1}, respectively). Under sodic soil conditions, conventional methods of irrigation leach out the Na ions in the root zone, favouring rice plants with less toxicity to Na ions (Abrol *et al*., 1985). Alternate wetting and drying at threshold level enhance air exchange between the atmosphere and the soil, resulting in soil organic matter mineralization and nitrogen mobilization owing to appropriate oxygen availability besides, it increases an ABA level which facilitates the grain filling of rice. This aids in the improvement of soil fertility and the availability of vital nutrients for rice plant development (Dong *et al*., 2012). Indeed lower yields were observed with irrigation after 15 cm depletion of field water tube (3350 and 4998 kg ha^{-1}, respectively).

Under severe moisture stress, the photosynthesis cycle is slowed owing to stomata closure, which reduces CO_2 absorption and protoplasm capacity to actively carry out photosynthesis. This has an impact on translocation and may impede end products. Whereas, among the sub-plots, significantly higher grain and straw yields were obtained with hand weeding (S_5) (4267 and 6146 kg ha^{-1}, respectively). This was followed by BM with *sesbania* at 20 kg ha^{-1}(S_2) (4017 and 5786 25 kg ha^{-1}, respectively) and it was on par with PE Pretilachlor at 0.45 kg ha^{-1} *fb* PoE Bispyribac sodium at 25 g ha^{-1} + HW on 45 DAS (S_4) (3914 and 6146 25 kg ha^{-1}, respectively). This might be due to the organic acids produced during the breakdown of brown manure crops were able to solubilize the nutrients that had been adsorbed and fixed in the soil, and the mineralization of key nutrients eased the deficiency of various nutrients in the soil (Kumar *et al*., 2022). Also it supplies the nutrients with a low C: N ratio. There was a substantial interaction effect. Grain and straw yield of direct seeded rice were maximum at irrigation after disappearance of ponded water with hand weeding followed by irrigation after 10 cm depletion of field water tube with hand weeding and it was on par with each other. Similar results were reported by Kumar *et al*. (2022). After 15 cm depletion of field water tube and weedy check treatment, lower yields were noted with irrigation.

Conclusion

The present study concluded that irrigation after the disappearance of ponded water and hand weeding was superior in terms of physiological parameters, grain and straw yield. It could be the best option with abundant resources. For sustainable agronomic management in direct seeded rice irrigation after 10 cm depletion of field water tube along with brown manuring with optimum seed rate of *sesbania* at 20 kg ha^{-1} could be the ideal option to improve the TRY 3 rice productivity under sodic soil conditions.

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Conflict of interest

The authors declare that they have no conflict of interest.

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