Research Article

Assessment of Physiological Effects of Rice under Different Methods of Transplanting and Irrigation Management Practices

R. Sureshkumar[1]* and B.J. Pandian[2]

[1]Department of Agronomy, TNAU, Coimbatore-641003, Tamil Nadu, India
[2]Water Technology Centre, TNAU, Coimbatore-641003, Tamil Nadu, India

Abstract

A Field experiment was carried out at research farm, AC and RI, Coimbatore during *rabi* season 2015-2016 to assess the physiological effects of rice under different methods of transplanting and irrigation management practices. The experiment was laid out in strip plot design with three replications. The treatments comprised of four different method of transplanting *viz*., machine transplanting with 30 cm x 14 cm (M_1), 30 cm x 18 cm (M_2), SRI transplanting (25 cm x 25 cm) (M_3) and conventional transplanting (20 cm x 10 cm) (M_4), respectively in main plots and four method of irrigation management practices in sub plots *viz*., continuous submergence of 5 cm (I_1), cyclic irrigation management (I_2), SRI irrigation management (I_3) and Field water tube irrigation management (I_4). The results of this study showed that the positive impact of higher photosynthetic rate and specific leaf weight; lower transpiration rate and proline content of leaves were observed with SRI method of transplanting and SRI irrigation management practice.

Keywords: Field water tube irrigation, Machine transplanting, Physiological parameter, SRI irrigation, SRI transplanting

***Correspondence**
Author: R. Sureshkumar
Email: suresh2k589@gmail.com

Introduction

Rice is grown mainly as a wetland crop by transplanting seedlings into puddled fields. Conventional transplanting is the most common practice of rice cultivation in South and South East Asia. Transplanting of rice is very labour intensive and at least 30 man days are required to transplant one hectare. The typical system of low land rice cultivation in puddled soils discourages the labour to attend the field operations. Generally, rice growers face the problem of skilled labour shortage at the time of transplanting which results into delayed transplantation, low plant population and eventually low yield [1]. Often, the peak labour demand coincides with release of water from canals leading to labour shortage in canal command area [2]. Urbanisation, migration of labour from agriculture to non-agriculture sector and increased labour costs are seriously threating the cultivation of crops in general and rice in particular [3]. It is essential to reduce the factor by adopting the appropriate transplanting techniques for rice production to control the competitive prices in local and international markets. Therefore, there is need of alternative methods to replace manual transplanting to tackle the problem of high cost of production and labour scarcity in puddled rice. The mechanical rice transplanting is an alternate and promising option, as it saves labour, ensures timely transplanting and also contributes to higher grain yield.

Rice is one of the greatest water user among cereal crops, consuming about 80% of the total irrigated fresh water resources in Asia. In Asia, with relatively more suitable growing conditions for rice, production has declined due to increasing water stress [4]. Therefore, it is important to cut down water supply for rice cultivation but without affecting rice yield. The Food and Agricultural Organization (FAO) estimates that rice crop consumes about 4000-5000 liters of water per kg of grain production. So there is an imperative need to find ways to reduce water use, while maintaining high yields in rice cultivation. Since water for rice production has become increasingly scarce water saving is the main issue in maintaining the sustainability of rice production when water resources are becoming scarce [5]. There are a number of alternatives to continuous flooding of rice. One approach which can be used is intermittent irrigation or alternate wetting and drying (AWD). Instead of keeping rice fields continuously flooded, the adoption of AWD methods means that irrigation water is applied to fields to restore flooded conditions on an intermittent basis, only after a certain number of days have passed since the disappearance of ponded (standing) water [6].

The reduction of relative water content in leaves under water stress condition, nevertheless soil water status at saturated or more did not affect relative water content [8]. Water stress affects photosynthesis (Pn) rate which supports to a reduction of Pn rate in plants grown under AWD conditions but saturated or above water condition did not affect Pn rate, transpiration rate [7]. In the other case, photosynthetic rate of flag leaf was significantly higher in plants growing at wider spacing than in the more closely spaced plants [8]. SRI had a significantly higher specific leaf weight (SLW) (134.16 g m^{-2}), net photosynthetic rate (23.15 µmol m^{-2} s^{-1}) than in recommended management practices (12.23 µmol m^{-2} s^{-1}) [9]. Hence, the present investigation was taken up to study the effect of different method of transplanting and irrigation management on physiological parameters of rice.

Materials and Methods

A Field experiment was conducted during *rabi* season of 2015-2016 at Research Farm, Agricultural College and Research Institute, Coimbatore, Tamil Nadu. The experimental site is geographically located in the Western Agro Climatic Zone of Tamil Nadu at 11°N latitude, 77 °E longitude with an altitude of 426.7 m above mean sea level. The soil of the experimental site was clay loam in texture having alkaline pH (8.10) and medium organic carbon (0.62%), With regard nutrient status, the soil was low in available nitrogen (215.7 kg ha^{-1}), medium in phosphorus (15.8 kg ha^{-1}) and high in potassium (420.8 kg ha^{-1}), respectively. Rice variety CO (R) 50 with the duration of 135 days was used as test crop.

The experiment was laid out in strip plot design with three replications. The treatments comprised of four different method of transplanting *viz*., machine transplanting with 30 cm x 14 cm (M_1), machine transplanting with 30 cm x 18 cm (M_2), SRI transplanting with 25 cm x 25 cm (M_3) and conventional transplanting with 20 cm x 10 cm (M_4), respectively in main plots and four method of irrigation management practices in sub plots *viz.*, Farmer practice of continuous submergence of 5 cm throughout the crop period (I_1), Cyclic irrigation management of irrigating the field with 5 cm depth of irrigation one day after disappearance of previously ponded water (I_2), SRI irrigation management of irrigation given @ 2.5 cm depth after the formation of hair line cracks in the field upto panicle initiation stage and thereafter the irrigation was given immediately after the disappearance of previously ponded water (I_3) and Field water tube irrigation management of maintenance of 5 cm water level at panicle initiation stage and remaining period irrigation to 5 cm depth after 15 cm depletion of ponded water from ground level (I_4). In order to evaluate the effect of different method of transplanting and irrigation management practices on relative water content and proline content, the data were statistically analyzed using "Analysis of variance test". The critical difference at 5% level of significance was calculated to find out the significance of different treatments over each other [10]. The physiological parameters of specific leaf weight, relative water content, leaf gas exchange parameters and proline in leaves were calculated as per the standard procedure.

Specific Leaf Weight (SLW)

The SLW was arrived at by employing the formula suggested by [11] and expressed in g cm^{-2} at panicle initiation stage.

$$\text{SLW} = \frac{\text{Leaf dry weight (g)}}{\text{Total leaf area (cm}^2)}$$

Relative Water Content (RWC)

The RWC was estimated at panicle initiation stage by the formula given by [12] and expressed in per cent.

$$\text{Relative Water Content (\%)} = \frac{\text{Fresh weight (g)} - \text{Dry weight (g)}}{\text{Turgit weight (g)} - \text{Dry weight (g)}} \text{x } 100$$

Leaf Gas Exchange parameters

Leaf gas exchange measurements were performed using Portable Photosynthetic System (PPS) (Model LI-6400 of Licor inc., Lincoln, Nebraska, USA) equipped with a halogen lamp (6400-02B LED) positioned on the cuvette. Totally, three measurements were taken in the same leaf at panicle initiation stage. Leaves were inserted in a 3 cm^2 leaf chamber and PPFD 1200 µmol photons m^{-2} s^{-1} and relative humidity were set at 50-55%. The following gas exchange parameters were recorded *viz*., Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}), Stomatal conductance (mol H_2O m^{-2} s^{-1}), Transpiration rate (mmol H_2O m^{-2} s^{-1}) and Leaf temperature (°C).

Proline in leaves

The method for the estimation of proline content was adopted from [13] with slight modifications. Samples were collected at panicle initiation stage and the collected leaves (1 g) were homogenized with 10 ml of 3 % sulphosalicylic acid and centrifuged at 3000 rpm for 10 minutes. Two ml of the supernatant was taken and 2 ml of glacial acetic acid and 2 ml of acid ninhydrin mixture were added. The contents were allowed to react at 100 ºC for 1 hr and then it is incubated on ice for 10 minutes to terminate the reaction. The reaction mixture was mixed vigorously with 4 ml toluene for 15-20 seconds. The chromophore containing toluene was aspired from the aqueous phase, warmed to room temperature and optical density was read at 520 nm. The proline content was determined from the standard graph prepared using commercially available proline in the concentration range of 20-100 µg.

Results and Discussion

Specific Leaf Weight

Data on specific leaf weight (SLW) shows that clear variation among different transplanting methods and irrigation management practices (**Figure 1**). Among all method of transplanting, SRI recorded higher specific leaf weight of 4.89 g cm^{-2} and lower value recorded in conventional transplanting method (4.27 g cm^{-2}). In different irrigation management practices, SRI irrigation management recorded higher specific leaf weight of 4.90 g cm^{-2} and lower value recorded in continuous flooding irrigation method (4.18 g cm^{-2}). The higher SLW in SRI management plants indicated thicker leaves as compared to the leaves grown under conventional and also this may be the reason for SRI management have received higher photosynthetic rate. These results in line with the findings of [4].

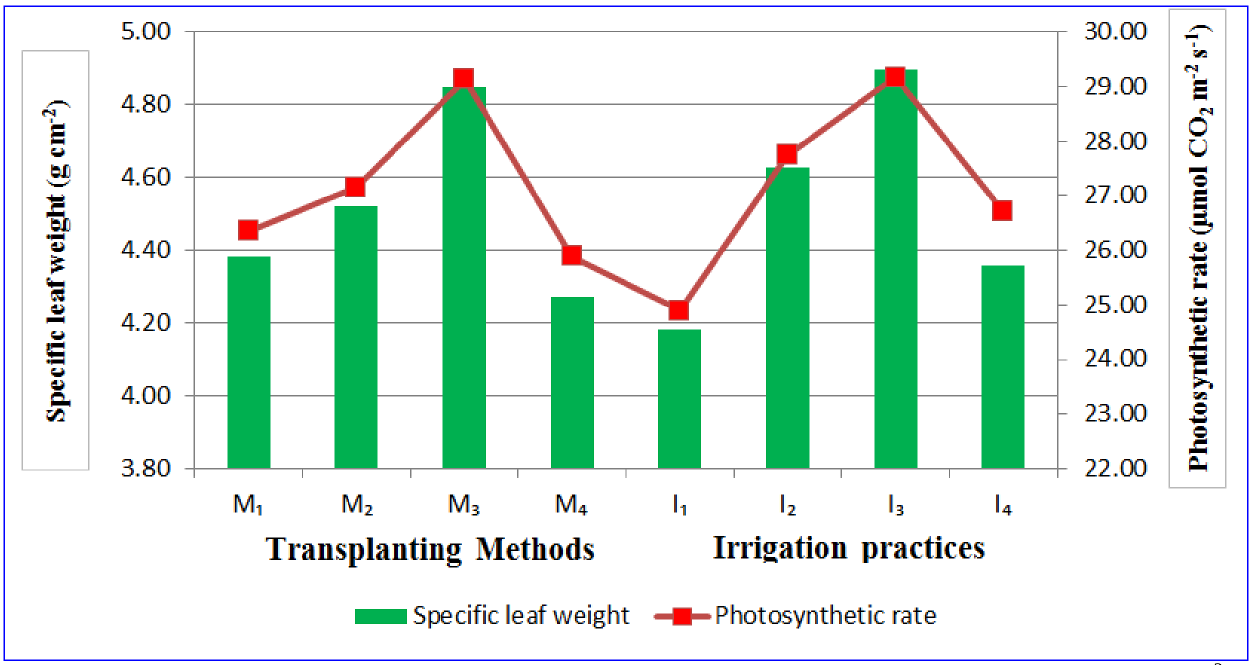

Figure 1 Effect of different transplanting methods and water management practices on Specific leaf weight (g cm^{-2}) and Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) of rice

Leaf Gas Exchange parameters

There were significant differences in flag leaf photosynthesis, stomatal conductance, transpiration rate and leaf temperature were observed with different method of transplanting and irrigation management practices at panicle initiation stage (Figure 1 and **Figure 2**). Among different method of transplanting, SRI recorded higher photosynthetic rate of 29.12 µmol CO_2 m^{-2} s^{-1} and lower transpiration rate (8.98 mmol H_2O m^{-2} s^{-1}), stomatal conductance (0.66 mol H_2O m^{-2} s^{-1}) and leaf temperature (30.38 °C). Among different irrigation management practices, SRI irrigation management practice recorded higher photosynthetic rate of 29.17 µmol CO_2 m^{-2} s^{-1} and farmers practice of continuous flooding to 5 cm recorded lower leaf temperature of 29.04 °C. whereas, lower transpiration rate (8.21 mmol H_2O m^{-2} s^{-1}) and stomatal conductance (0.61 mol H_2O m^{-2} s^{-1}) were observed with field water tube method of irrigation management.

This may be due to wider spacing in SRI management indicates that they were used water and nutrient sources more efficiently than conventionally managed continuously flooded rice. Photosynthetic rate of flag leaf was significantly higher in plants growing at wider spacing than in the more closely spaced plants. Similar result has been already reported by [8] and [14].

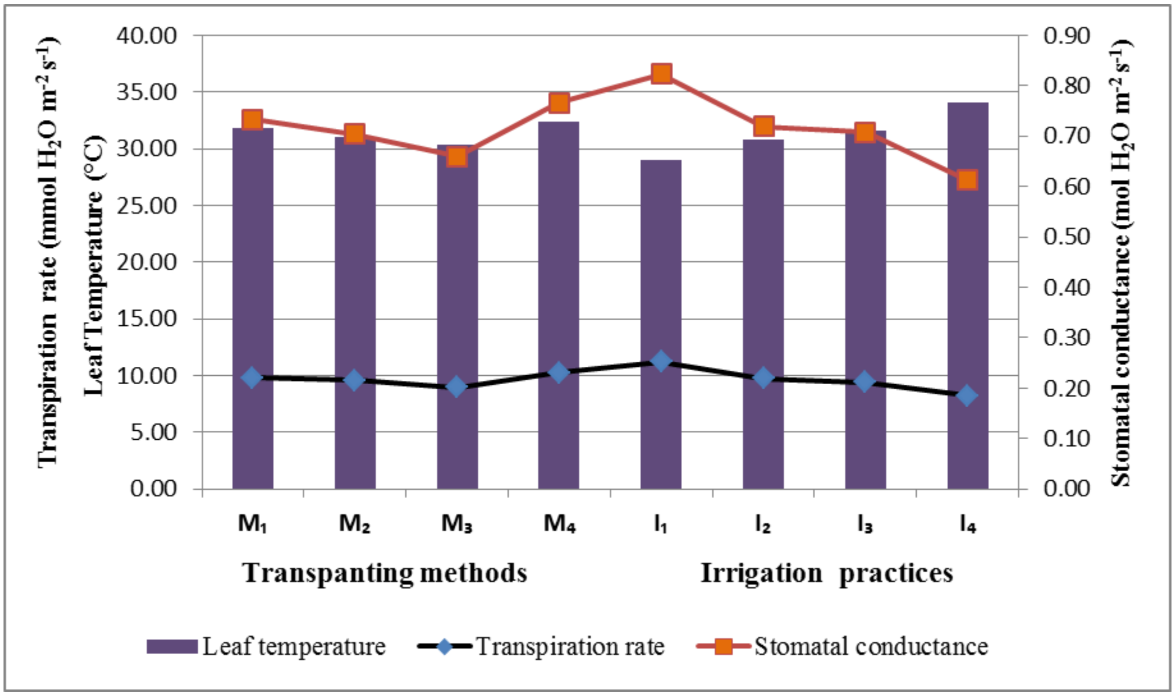

Figure 2 Effect of different transplanting methods and water management practices on Leaf Gas Exchange parameters of rice

Relative Water Content

Relative water content (RWC) represents the ability of the crop to retain tissue water status under water stress and this is one of the most important indicators of plant water stress. RWC of leaves significantly differ with irrigation management practices but not significantly varied with different transplanting methods (**Table 1**). Among varies irrigation management practices, higher RWC recorded with continuous flooding (95.8%). Whereas, lower RWC observed with field water tube irrigation management practice. These results suggest the reduction of relative water content in leaves under such water stress condition, nevertheless soil water status at saturated or more did not affect relative water content. This is the reason the higher RWC treatment have lower leaf temperature. The similar findings were also observed by [15].

Table 1 Effect of different transplanting and water management practices on Relative Water Content (%) and Proline content (μmol g^{-1}) of rice

Treatment	Relative Water Content (%)						Proline content (μmol g^{-1})				
	M_1	M_2	M_3	M_4	Mean		M_1	M_2	M_3	M_4	Mean
I_1	96.6	97.2	98.2	95.8	**97.0**	I_1	1.41	1.39	1.31	1.37	**1.37**
I_2	90.2	89.5	95.4	87.5	**90.7**	I_2	1.48	1.42	1.50	1.58	**1.50**
I_3	88.4	89.8	88.2	84.3	**87.7**	I_3	1.59	1.57	1.53	1.74	**1.61**
I_4	85.2	86.6	85.5	82.3	**84.9**	I_4	1.66	1.63	1.58	1.80	**1.67**
Mean	**90.1**	**90.8**	**91.8**	**87.5**			**1.53**	**1.50**	**1.48**	**1.62**	
	M	**I**	**M at I**	**I at M**			**M**	**I**	**M at I**	**I at M**	
SEd	1.5	1.9	2.9	3.2			0.02	0.03	0.05	0.05	
CD (p=0.05)	NS	4.6	NS	NS			0.06	0.08	NS	NS	

Proline content in leaves

There was a clear variation of tissue proline content among method of transplanting and water management treatments (Table 1). Among different method of transplanting, higher proline content was recorded with conventional transplanting (1.62 µmol g^{-1}) and lower proline content was found with SRI method of transplanting (1.48 µmol g^{-1}). There were increases in the proline content in all AWD treatments, and the level of proline even increased with increasing the length of the period of suspension of irrigation. Upon increased soil moisture with continuous flooding, proline content in tissues decreased (1.36 µmol g^{-1}). Accumulation of free proline in the plant cells in response to onset of stresses is one of such mechanisms [16] and [17]. Mostajeran and Rahimi-Eichi [18] also observed higher amount of plant proline content in non-submerged rice and a positive correlation between free proline accumulation and drought tolerance. Singh *et al*. [19] mentioned that proline is a non-protein amino acid that forms in plant tissues when subjected to water stress and rapidly metabolized upon recovery from drought. This indicates the specific role of accumulated free proline in plant tissues acts as an osmolyte produced under water stress and plays a significant role in drought adaptation of plants.

Conclusion

The results of the experiment shows that the positive impact of higher photosynthetic rate and specific leaf weight; lower transpiration rate and proline content were observed with SRI method of transplanting and SRI irrigation management practice. These findings are useful for improving productivity of rice through selection of suitable method of transplanting with irrigation management practice based on resource availability.

References

[1] Aslam, M., Hussain, S., Ramzan, M. and Akhter, M. 2008. Effect of different stand establishment techniques on rice yields and its attributes. J. Anim. Pl. Sci., 18(2-3): 80-82.
[2] Singh, G., Singh, R. G., Singh, O. P., Kumar, T., Mehta, R. K., Kumar, V. and Singh, P. P. 2005. Effect of weed management practices on direct seeded rice (Oryza sativa) under puddled low lands. Indian J. Agron., 50(1): 35-37.
[3] Yadav, S. K., Singh, D. K. and Rani, M. 2014. Interaction effect of weed management practices, brown manuring and nitrogen levels on yield of direct seeded rice and growth of weeds. Green Farming, 5(1): 46-50.
[4] Tao, F. M., Yokozawa, Z., Zhang, Y., Hayashi, H. G. and Fu, C. 2004. Variability in climatology and agricultural production in China in association with the East Asia summer monsoon and El Niño South Oscillation. Climate Res., 28: 23-30.
[5] Arif, C., Setiawan, B.I., Mizoguchi, M. and Doi, R. 2012. Estimation of water balance components in paddy fields under non-flooded irrigation regimes by using excel solver. J. Agron., 11(2): 53-59.
[6] Zhang, H., Xue, Y., Wang, Z., Yang, J. and Zhang, J. 2009. An alternate wetting and moderate soil drying regime improves root and shoot growth in rice. Crop Sci., 49: 2246-2260.
[7] Okuma, E., Jahan, M.S., Munemasa, S., Ogawa, K., Watanabe-Sugimoto, M., Nakamura, Y., Shimoishi, Y., Mori I. C., and Murata, Y. 2011. Negative regulation of abscisic acid-induced stomatal closure by glutathione in Arabidopsis. J. Plant Physiol., 168: 2048-2055.
[8] Thakur, A. K., Rath, S., Roychowdhury S. and N. Uphoff. 2010a. Comparative Performance of Rice with System of Rice Intensification (SRI) and Conventional Management using Different Plant Spacings. J. Agron. & Crop Sci., 196: 146-159.
[9] Thakur, A. K., Uphoff, N. and Antony, E. 2010b. An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. Expl. Agric., 46(1): 77-98.
[10] Gomez, K.A and Gomez, A.A. 1984. Statistical procedures for agricultural research. (2nd Ed.), Wiley India Pvt Ltd., India.
[11] Garnier, E., Shipley, B., Roumet, C. and Laurent, G. 2001. A standardized protocol for the determination of specific leaf area and leaf dry matter content. Functional Ecol., 15: 688-695.
[12] Barrs, H. D. and Weatherley, P. E. 1962. A re-examination of relative turgidity for estimating water deficits in leaves. Aust. J. Biol. Sci., 15: 413-428.
[13] Bates, L. S., Waldren, R. P. and Teare, I. D. 1973. Rapid determination of proline for water stress studies. Plant Soil., 39: 205-207.

[14] Wahlang, B., Das, A., Layek, J., Munda, G. C., Ramkrushna, G. I. and Panwar, A. S. 2015. Effect of establishment methods and nutrient management on physiological attributes and water-use efficiency of rice (Oryza sativa) in a sub-tropical climate. Indian J. Agron., 60(4): 157-163.
[15] Khairi, M., Nozulaidi M., Afifah, M. A. and Jahan, S. 2015. Effect of various water regimes on rice production in lowland irrigation. Aus. J. Crop Sci., 9(2): 153-159.
[16] Vendruscolo, E. C. G., Schuster, I., Pileggi, M., Scapim, C. A., Molinari, H. B. C. and Marur C. J. 2007. Stress-induced synthesis of proline confers tolerance to water deficit in transgenic wheat. J. Plant. Physiol., 164: 1367-1376.
[17] Cattivelli. L., Rizza. F., Badeck, F. W., Mazzucotelli, E., Mastrangelo, A. M. and Francia, E. 2008. Drought tolerance improvement in crop plants: an integrated view from breeding to genomics. Field Crops Res., 10: 1-14.
[18] Mostajeran, A, Rahimi-Eichi, V. 2009. Effects of drought stress on growth and yield of rice (Oryza sativa L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. Am. Eurasian J. Agric. Environ. Sci., 5: 264-272.
[19] Singh, D. K., Sale, P. W. G., Charles, K. P. and Vijaya, S. 2000. Role of proline and leaf expansion rate in the recovery of stressed white clover leaves with increased phosphorus concentration. New Phytol., 146: 261-269.

Publication History

Received	11th May 2017
Revised	25th May 2017
Accepted	10th June 2017
Online	30th June 2017