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Root Growth, Nutrient Uptake and Soil Enzyme Activity Influenced by Aerobic, System of Rice Intensification and Conventional Method of Irrigation in Rice

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ABSTRACT

Background: The plant roots pay a vital role in the uptake of water and nutrients. This experiment evaluated the changes in root growth and soil enzyme activity with respect to different rice cultivation methods.

Methods: The study was carried out during *Kuruvai* (July-November) 2022 at Wetlands farm, Tamil Nadu Agricultural University, Coimbatore. Experiments were carried out with five treatments *viz*., T_1- 100% Saturation under drip irrigation, T_2- 150% Saturation under drip irrigation T_3- 200% Saturation under drip irrigation, T_4- System of Rice Intensification (SRI), T_5- Conventional method.

Result: The result of the experiment shows that higher root growth, enzyme activity was observed in SRI method of rice cultivation. Higher grain yields were recorded in SRI method. It can be concluded that most favourable method of rice production.

Key words: Alkaline phosphatase, Dehydrogenase, Drip irrigation, Nutrient uptake, Yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important source of food for more than half of the world's population and 90% of the rice area worldwide is in Asia, which around 11% of the world's agricultural area and ranks second in terms of coverage (Haque *et al.*, 2021). Rice is cultivated in a wide spectrum of locations and under a variety of climatic conditions, ranging from the wettest areas in the world to the driest areas. Globally, India holds first position in terms of area and second largest producer after China. In India, rice has been an area of 45.7 million hectares with a total production of 124 million tonnes and the productivity was 2717 kg ha^{-1} (Indiastat, 2021-22). As the world population grows to 9.15 billion people by 2050, there will be an increasing demand for food, particularly rice (Crossette, 2010). The present and future food security of Asia and India depends on the irrigated rice production system (Saha *et al.*, 2015).

Higher amount of water is used in conventional method because puddling requires more water and the field is continuously flooded with 5 cm depth up to physiological maturity. In this method, the existence of flooded water creates more seepage, percolation beyond the root zone and loss of water through evaporation. Most of the Indian farmers are utilizing about 15,000 litres of water to produce one kg of rice (Kanmony, 2001). The requirement of water to produce one kg was two to three times more than other cereals such as maize and wheat (Singh, 2013; Subramanian *et al.*, 2020). Novel technologies which require less water compared to conventional flooding method *viz.* alternate wetting and drying and aerobic rice, allow paddy to be cultivated with significantly less water input and labour than rice that is typically flooded (Jabran and Chauhan, 2015; Jabran *et al.*, 2015). It can be adopted in the following situations: irrigated places where water is scarce or limited and under rainfed condition. 50–60% water saving in aerobic rice as compared to transplanted rice (Belder *et al.*, 2004). The System of Rice Intensification (SRI), a methodology for rice cultivation, is an agricultural breakthrough that is still being evaluated. (Uphoff *et al.*, 2011). This practice saves irrigation water by 25 to 50% and higher yields and more revenue than conventional rice. (Materu *et al.*, 2018). SRI enhances yield (Sinha and Talati, 2007; Senthilkumar *et al.*, 2008; Zhao *et al.*, 2009; Kahimba *et al.*, 2013), declines water requirement (Satyanarayana *et al.*, 2007) and raises input productivity. SRI method involves, transplanting of

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young seedling (14 days), single seedling (one seedling per hill), square planting (25 cm × 25 cm), *cono* weeding and intermittent irrigation (alternate wetting and drying). In contrast, conventional method of rice cultivation includes older seedlings (22 days), transplanting of 3 to 5 seedling per hill, closer spacing (20 cm × 10 cm) and flooded throughout the cropping period (Kediyal and Dimri, 2009). However, there is very minimum research evidence about the effects of water management on the root growth and nutrient uptake. This study was undertaken to study the impact of effects of different rice cultivation methods on root growth uptake of nutrients and soil enzymes.

MATERIALS AND METHODS

Experimental site

The present experiment was carried out during *Kuruvai* (July-November) 2022 at Wetland farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. (11 N latitude and 77°E longitude, 426.7 m above mean sea level). The region is located the Semi-Arid Tropics and belongs to the Western Agro-climatic zone of Tamil Nadu.

Experimental design

The present study was carried out using a Randomized Complete Block Design (RCBD) in which the rice cultivation methods were evaluated. Five treatments *viz*., T_1- 100 % Saturation, T_2- 150 % Saturation T_3- 200 % Saturation, T_4-SRI, T_5- Conventional method were selected for this study. Each treatment was replicated four times. Treatments T_1, T_2, T_3 involved the aerobic method with drip irrigation. T_1 was irrigated automatically based on the soil moisture sensor and then irrigation duration was calculated. Based on T_1 duration, T_2 and T_3 were irrigated 1.5x times and 2x times, respectively. T_4 was irrigated based on alternate wetting and drying and continuous flooding was done in conventional method (T_5).

Crop management

The rice variety CO 53 was used in this study. For the aerobic method dry seeds (75 kg ha^{-1}) were sown by hand dibbling at 3-cm depth with a spacing of 22.5 cm × 15 cm in a unpuddled condition. Fourteen days old seedlings were transplanted (one seedling hill^{-1}) in puddled field at 25 × 25 cm spacing in SRI. In the conventional method, transplanting (two to three seedling hill^{-1}) was done in a well puddled field on 22 DAS with a spacing of 20 × 10 cm. Pendimethalin at 1.0 kg *a.i*. ha^{-1} was applied as pre-emergence on 3 DAS followed by an early post emergence application of bispyribac sodium 25 g *a.i*. ha^{-1} on 25 DAS. Later, one hand weeding was done on 40 DAS in the aerobic method. For SRI and conventional method, pretilachor @ 1.0 kg *a.i*. ha^{-1} was applied as pre-emergence. Later, *cono* weeding was done at 10 days intervals, *i.e*., 25, 35 and 45 DAT in both directions in SRI. For conventional method, one hand weeding was done at 35 DAT. Recommended dose of fertilizer (150 :50: 50 kg N,P,K ha^{-1}) was applied as per the TNAU crop production guide. Irrigation was applied through drip as per the treatments based on the soil moisture sensor. In SRI, irrigation was provided at 2.5 cm height and allowed for 2-3 days and the next irrigation was given immediately when hairline cracks developed. In conventional method, irrigation was given at 2.5 cm height and stagnated in the entire field up to 10 days before harvest. The recommended agronomic practices and standard plant protection techniques were followed in all the treatments. Harvesting was done after the crop attained physiological maturity.

Observations

Soil enzymes activity analysis

Soil samples were collected at active tillering and flowering stage of rice. Soil dehydrogenase activity was estimated by spectrophotometer at 485 nm (Casida *et al.*, 1964) and alkaline phosphatase activity was estimated by spectrophotometer at 420 nm (Tabatabai and Bremner, 1969).

Nutrient uptake

Uptake of N, P and K were estimated in plants at harvest stage of the rice crop. The samples were dried at 70°C was recorded as dry weight. The samples were then ground to pass through a 250-meshsieve. Estimation of total nitrogen is done by Kjedahl distillation (Jackson, 1967), total phosphorous by Spectrophotometer (Jackson, 1967), total potassium by Flame photometery (Jackson, 1967). The uptake of N, P and K was measured by multiplying the concentration of each nutrient by the dry weight expressed in kg ha^{-1}.

Partial Factor Productivity (PFF)

Partial factor productivity is the ratio to the grain yield and amount of nutrient applied and it was calculated by following equation:

$$PFF = \frac{\text{Grain yield}}{\text{Amount of nutrient applied}}$$

Data analysis

Analysis of variance (ANOVA) was evaluated using SPSS 16.0 software and Fisher's Least Significant Difference at a significance of P d" 0.05 was used to compare the difference between means. Pearson correlation was used to measure the relationship between yield with various physiological parameters by using SPSS 16.0 software.

RESULTS AND DISCUSSION

Influence of different methods of rice cultivation on root growth and yield of rice

Root growth and yield was significantly influenced by different method of rice cultivation (Table 1). Length of root was increased from 60 DAS to 90 DAS. Among the cultivation methods, SRI observed longer roots (28.50 cm and 30 cm) on 60 DAS and 90 DAS respectively.

Comparatively aerobic rice recorded shorter root length. Similarly, root volume was increased 60 DAS to 90 DAS. Higher root volume (110 cc and 118 cc) was observed in SRI method of cultivation on 60 DAS and 90 DAS respectively. Rice is evolved from a semi-aquatic ancestor and thus has unique characteristics in root growth and suitable for wetland conditions. But these characters are varied based on cultivation methods. The significantly longer root length had been developed under SRI. Single seedling with wider spacing, regular *cono* weeding and alternate wetting and drying irrigation during the tillering stage resulted the higher root development in SRI method.

SRI method recorded significantly higher grain yield, straw yield and harvest index compared to other method of rice production. These results line up with Hidayati *et al.* (2016) and Geethalakshmi *et al.* (2011) where SRI method recorded higher grain yield. The stay-green characteristics of SRI plants during grain-filling contributed to higher grain yield. According to Thakur *et al.* (2011) the rice plant's enhanced morphological and physiological characteristics were the main factors of the increase in grain yield during SRI cultivation. Improved grain yield under SRI is mostly attributable to the synergistic benefits of changes in cultivation techniques, such as the use of young, single seedlings per hill, limited irrigation and frequent topsoil tillage (*cono* weeding) to promote aeration (Stoop *et al.*, 2002).

Influence of different methods of rice cultivation on enzymes activity of soil

Variation in soil alkaline phosphatase enzymes activities was recorded at 60 DAS (Fig 1) and 90 DAS (Fig 2) of rice crop. Among the different method of rice cultivation SRI method of rice cultivation significantly showed highest alkaline phosphatase activity at both stages of the rice crop as compare to conventional and aerobic method of rice cultivation and lowest dehydrogenase activity was observed in 100% saturation of aerobic rice cultivation.

Dehydrogenase activity of soil determined 60 at and 90 DAS of rice crop was presented in Fig 1 and 2. From the values it was clear that dehydrogenase activity of soil increased from 60 DAS to 90 DAS of rice crop. In respect to different method of rice cultivation, dehydrogenase activity in soil was maximum at 60 and 90 DAS in SRI method of rice cultivation as compare to other method of rice cultivation and lowest dehydrogenase activity was recorded under 100% saturation of aerobic rice.

In the SRI method, a healthy soil ecosystem has abundant plant nutrients, which develop plant root biomass, are more favourable for the growth of the microbial population for greater enzyme synthesis and also increase the availability of nitrogen. The soil enzyme activity decreased in aerobic method of rice cultivation may be caused by an unfavourable soil environment that prevents

Table 1: Influence of different methods of rice cultivation on root growth and yield of rice.

Treatments	Root length (cm)		Root volume (cc)		Grain yield	Straw yield	Harvest
	60 DAS	90 DAS	60 DAS	90 DAS	(kg ha^{-1})	(kg ha^{-1})	index
T_1 - 100%	16.43	18.23	30.00	32.12	2470	4885	0.34
T_2 - 150%	19.27	22.34	30.00	33.32	2779	4964	0.36
T_3 - 200%	22.01	25.23	50.00	55.23	3427	5152	0.40
T_4 - SRI	28.50	30.33	110.00	118.41	6011	8289	0.42
T_5 - Conv	24.21	27.53	80.00	84.32	5152	7586	0.40
SEd	0.96	1.06	3.35	4.08	243	339.8	-
CD (P= 0.05)	2.08	2.31	7.30	8.90	530	740.3	-

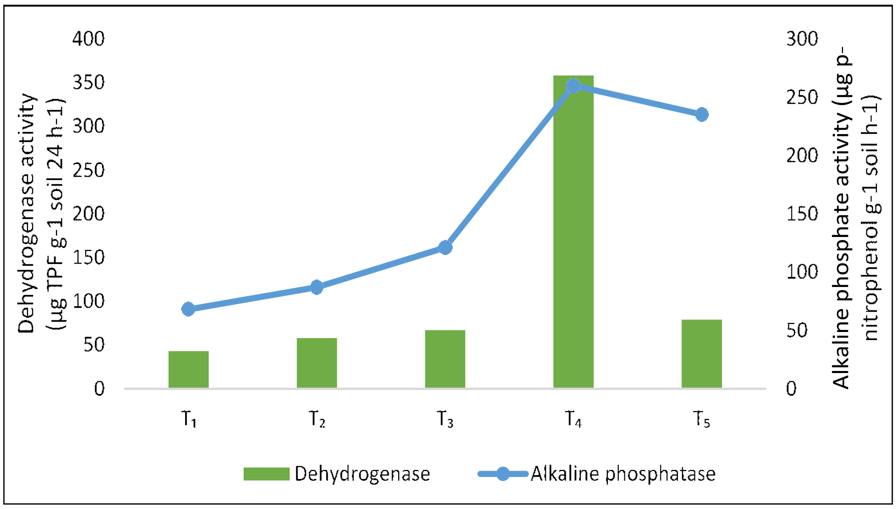

Fig 1: Influence of different methods of rice cultivation on enzymes activity of soil at 60 DAS.

the growth of soil microorganisms, which in turn lowers soil enzymes activity (Lakshmi *et al.*, 2019; Midya *et al.*, 2021; Doni *et al.*, 2022). Kavitha *et al.* (2010) revealed that SRI system improves soil aeration and boosts microbial population counts, which raises the enzyme activity of dehydrogenase.

Influence of different methods of rice cultivation on nutrient uptake and partial factor productivity

Different methods of cultivation influenced the nutrient uptake in rice (Fig 3). Among different method of rice cultivation, the nutrient uptake of N, P and K significantly higher in SRI method as compare to other cultivation methods and it was followed by conventional method of rice cultivation. The lowest nutrient uptake of N, P and K was recorded in 100% saturation of aerobic rice cultivation. The partial factor productivity was higher in SRI method of cultivation and it was described in Fig 4. In SRI method, maintaining one seedling per hill favours in many ways during weeding time using a *cono* weeder greatly helps to remove weeds; mixing anaerobic and aerobic soil horizon portions and decomposing organic matter quickly. It ultimately increases the nutrient usage efficiency and dry matter production with the help of active feeding roots due to less competition on plants. Similar results reported by Sridevi and Chellamuthu (2012). By the action of *cono* weeding, the process of pruning roots has encouraged them to produce new active roots, which may have assisted in the nutrition absorption rate (Dass and Chandra, 2012; Kumar and Kumar, 2018). Due to the presence of both aerobic and anaerobic environments in the SRI method of cultivation, there may be a probable increase in the amount of nitrogen that is readily accessible to the rice crop, which is able to uptake more nutrients directly in an efficient manner with the help of nitrogen-fixing bacteria inside the plant root system (Barison, 2002; Zhao *et al.*, 2011). Additionally longer root systems help to access a more soil volume and to absorb more nutrients from various depths (Barison and Uphoff, 2011).

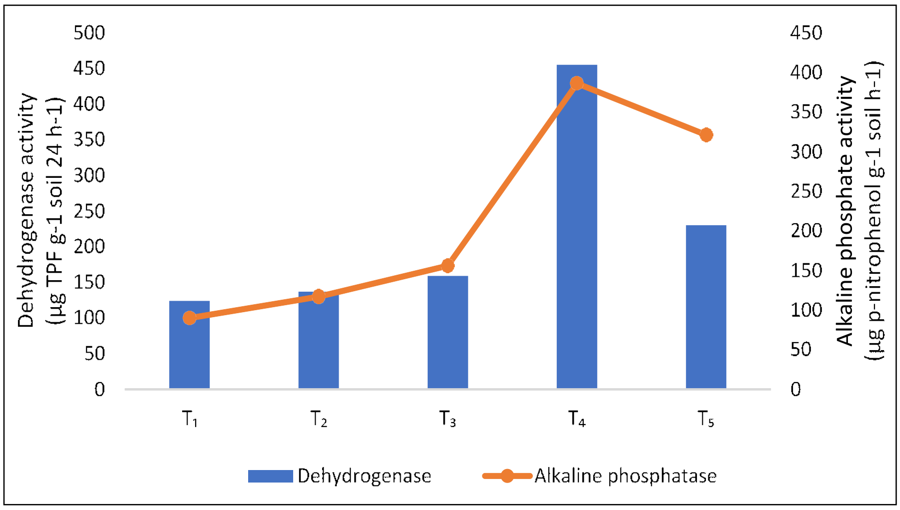

Fig 2: Influence of different methods of rice cultivation on enzymes activity of soil at 90 DAS.

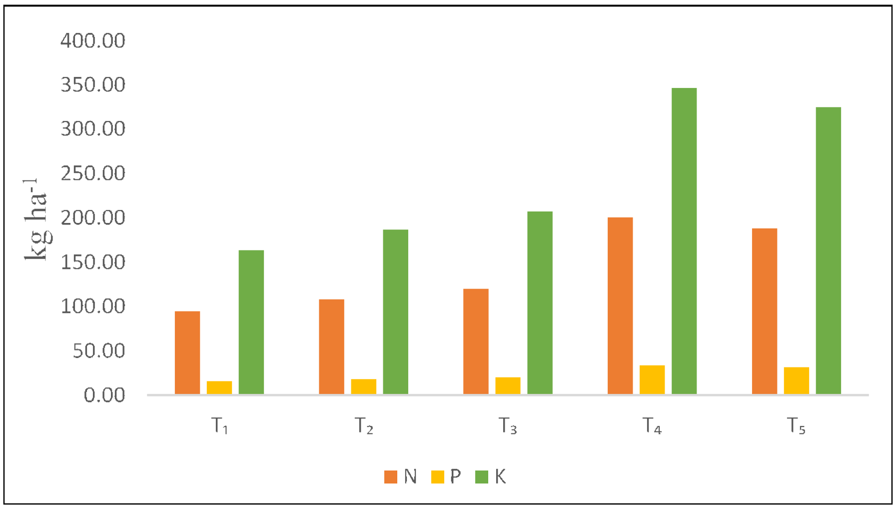

Fig 3: Influence of different methods of rice cultivation on nutrient uptake on rice (After harvest).

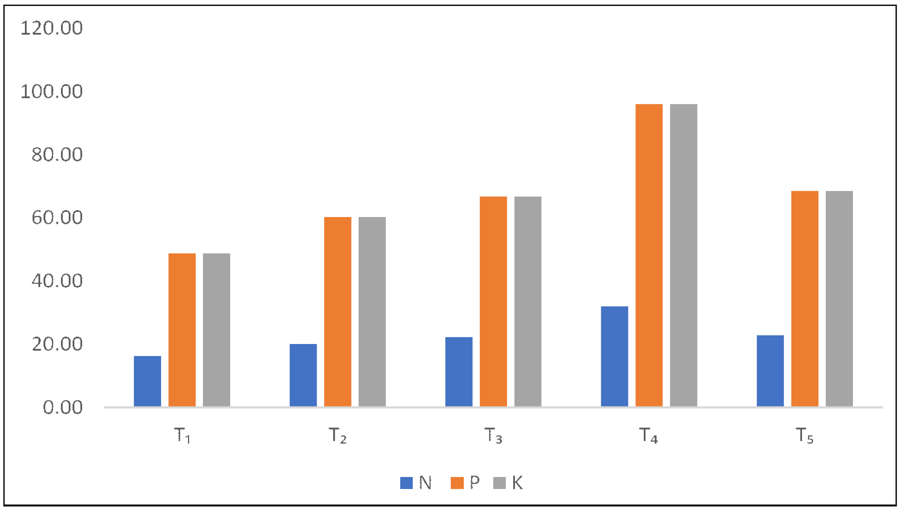

Fig 4: Influence of different methods of rice cultivation on partial factor productivity on rice (After harvest).

Table 2: Correlation between root growth, enzyme activity, nutrient uptake with respect to yield.

	Yield	RL	RV	Dase	Al. Pase	N uptake	P uptake	K uptake
Yield	1							
Root length	.924*	1						
Root volume	.934*	.928*	1					
Dehydrogenase	.957*	.833	.949*	1				
Alkaline phosphatase	.881*	.924*	.981**	.901*	1			
N uptake	.846	.920*	.961**	.861	.996**	1		
P uptake	.844	.919*	.961**	.860	.996**	1.000**	1	
K uptake	.846	.920*	.961**	.861	.996**	1.000**	1.000**	1

*.Correlation is significant at the 0.05 level (2-tailed).

**.Correlation is significant at the 0.01 level (2-tailed).

Relationship between root growth, enzyme activity, nutrient uptake with respect to yield

Significantly positive relation was observed between root growth and yield (Table 2). These results attributed to significant positive correlation with yield. Encouraging root growth improve the grain yield in the rice. Similarly, He *et al*. (2014) observed the positive correlation between root growth and yield.

CONCLUSION

System of Rice Intensification was able to achieve greater grain yield with less water. Alternate wetting and drying enables more vigorous root growth, greater root activity. Based on above results it can conclude that SRI method was most favourable method for rice cultivation.

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Conflict of interests

The authors declare that there is no competing interest.

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