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Study on root architecture of aerobic rice under intercropping system in different land configuration

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Abstract
Roots are essential for plant growth and development because it provides anchorage to the plant and growing substrate, promote water and nutrient uptake from the soil, sense and respond to environmental signals such as biotic and abiotic stresses. Rice has a shallow root system and requires more water to produce better yield. A deep root system is necessary to acquire water and nutrients from the relatively wet deep soil layer in order to achieve the consistent yield under aerobic conditions. A field investigation was carried out during *rabi* season of 2020-21 at farmer's field at Periya Mittahalli village, Karimangalam block, Dharmapuri district, Tamil Nadu, India. The experiment was laid out in factorial randomized block design with three replications. The factor I comprised of beds and channel and raised bed system and factor II consists of sole crop of rice, rice + greengram (2:1), rice + blackgram (2:1) and rice + cowpea (2:1). Encouraging results was obtained under rice + pulse intercropping system in aerated condition, with the maximum plant height (59.6 cm), more root length and root shoot ratio was recorded in beds and channel of land configuration. Higher root weight (2.60, 2.34 and 5.22 g plant^{-1}) and root volume (9.62, 15.69 and 19.51 cc) was register in raised bed configuration. Among the intercropping system, rice alone produced taller plants (71.6 cm), root length (11.29, 16.28 and 20.33 cm), root weight (2.96, 3.88 and 6.07 g plant^{-1}) and root volume (10.91, 17.04 and 21.48 cc) at active tillering, panicle initiation and harvest than all other intercropping treatments. Rice + blackgram intercropping system recorded the higher rice equivalent yield (6084 Kg ha^{-1}) and system profitability (147 ₹. ha^{-1}day^{-1}).

Keywords: aerobic rice, intercropping, land configuration, root characters

1. Introduction
Rice is a water-loving crop that consumes more fresh water. It is an excessive water consumer, requiring 3000–5000 litres of water to produce one kilogramme of grain, about twice as much as any other cereal crop. Rice contributes about 45 per cent of the total worldwide cultivable irrigated area, whereas irrigated fields produce about only 57 percent of harvested rice. Furthermore, rice farming consumes around 85% of total irrigation water. Agriculture uses 84 per cent of water extracted from surface or subterranean sources in Asia, primarily for flooded rice is threatened by the worldwide water problem (Subramanian *et al.*, 2008) [9]. India produces 24 per cent of the world's rice which is grown on 43.6 million hectares with a total production of 118.8 million tonnes and an average productivity of 2.72 tonnes ha^{-1} (Indiastat, 2020) [2]. India is anticipated to 25 per cent of water supply-demand gap and the extensive use of groundwater for rice cultivation, while groundwater table is decreasing in all of India's main rice-growing states (Sharma *et al.*, 2018) [8].
Aerobic cultivation of rice is an emerging technology designed to enhance water use efficiency in rice production by cultivated in non-puddled, non-flooded fertile soils. Nearly 50 per cent of water usage has been reduced, 64-88 per cent of higher water productivity, 55 per cent of labour saving and 28 - 44 per cent of higher gross return in aerobic rice situation than lowland rice (Bouman and Tuong, 2001) [1]. Aerobic rice offers growing of short-duration pulses in rice intercropping system is a recent breakthrough to meet out the need for pulses and food grains despite reducing agricultural land (Subramanian *et al.*, 2020) [10]. By using this approach with conserved water will efficiently use for enhance food grain production, in turn improve the benefits for the farmers. Similarly, it boosts the country cropping intensity by repurposing conserved water to produce other crops over the present level of 142 per cent.
Roots play a fundamental role for growth and development, they anchor the plant to its growing substrate, facilitate water and nutrient uptake from the soil, and sense and respond to environmental signals such as biotic and abiotic stressors. In comparison to other crops, rice has relatively compact and shallow root structure.

Rice's capacity to survive spells of water deprivation is determined by variations in root growth and architecture. The architecture of rice root system is determined by adventitious root development and lateral root branching on each adventitious root (Phule *et al.*, 2019) [5]. As a result, in order to achieve a stable yield under aerobic conditions, a deep root system is required for obtaining water and nutrients from the comparatively moist deep soil layer. In light of the foregoing, this research is being conducted in order to determine the suitable land architecture in intercropping system for aerobic rice production.

2. Materials and Methods

The field experiment was carried out during the *rabi* season of 2020-21 at a farmer's field in Periya Mittahalli village, Karimangalam block, Dharmapuri district, Tamil Nadu, India, located at 12° 17 51 N latitude, 78° 12 55 E longitude and an altitude of 460 m above the mean sea level, respectively. The normal annual rainfall over the district varies about 760 mm to 910 mm and this area represents the north western agro-climatic zone of Tamil Nadu state. The soil was sandy clay loam with neutral pH (7.3), low in organic carbon (0.24%), medium in available nitrogen (177 kg ha^{-1}), available phosphorous (17.9 kg ha^{-1}) and available potassium (242 kg ha^{-1}). The experiment was laid out in a factorial randomized block design and replicated thrice. The factor I comprised of two land configuration methods, namely beds and channel and raised bed systems, and factor II consists of seven cropping systems, *viz.*, sole crop of rice, intercropping of rice and greengram (2:1), rice and blackgram (2:1), and rice and cowpea (2:1), sole crop of greengram, blackgram, and cowpea. Healthy and viable seeds of the ADT 39 rice variety were sown as a base crop at a spacing of 20 x 10 cm. On the same day, intercrops were sown as additive series with a ratio of 2:1. The intercrop varieties, *viz.*, greengram CO 8, blackgram VBN 8, and cowpea VBN 3, were used as test varieties. As per the recommendation, recommended dose of NPK were applied to rice in the form of urea, single super phosphate and muriate of potash. Entire P is applied as basal and N & K were applied as split application. Growth attributes of plants, roots (root length, root weight, root volume and root shoot ratio), were recorded periodically and system profitability, rice equivalent yield were worked out using standard procedure and formula of Willey, (1979).

Rice equivalent yield

$$\text{RYE} = \sum_{i=1}^{n} Y_i e_i$$

$$\text{e}i = \frac{\text{Pbc}}{\text{Pi}}$$

Where,
Yi – yield of *i*th crop
ei – equivalent factor
Pi – price of the *i*th crop
Pbc – price of the crop to which yield is converted

System profitability

$$\text{SP} = \frac{\text{Net return ha}^{-1}}{365}$$

The Fisher technique of analysis of variance (ANOVA) was used to statistically analyse the data gathered for various factors, as stated by Gomez & Gomez. The "F" test was used to calculate critical difference (CD) values at a significance level of 5%.

3. Results

3.1 Plant height

Plant height is the most important and directly influences to measure growth and development of plant. The plant height of aerobic rice was significantly prejudiced by different land configuration methods. In this present study, plant height at panicle stage reported in Table 1. Among the land configurations, raised bed recoded significantly taller plants than beds and channels system of planting at panicle initiation. The plant height (59.6 cm) was noted in raised bed and was followed by beds and channels (44.5 cm). With respect to intercropping system, the taller plant (71.8 cm) at panicle initiation were found in rice alone followed by rice + greengram (61.3 cm) and rice + blackgram (63.3 cm) was on par with each other. The shorter plants were recorded in rice + cowpea (47 cm) intercropping system.

Table 1: Land configuration and intercropping practices on Plant height (cm) and root length (cm) of aerobic rice

Treatments	Plant height (cm)	Root length (cm)		
	Panicle initiation	Active tillering	Panicle initiation	Harvest
Beds and channel	44.5	10.52	15.01	18.54
Raised bed	59.6	9.27	13.18	16.76
SEd	1.129	0.476	0.128	0.627
CD=0.05	2.423	0.674	0.276	1.345
Rice alone	71.8	11.29	16.28	20.33
Rice + Greengram	61.3	9.86	14.43	17.34
Rice + blackgram	63.3	10.10	14.73	17.32
Rice + cowpea	47.0	8.35	10.92	15.6
SEd	1.597	1.023	0.182	0.886
CD=0.05	3.426	1.446	0.391	1.902

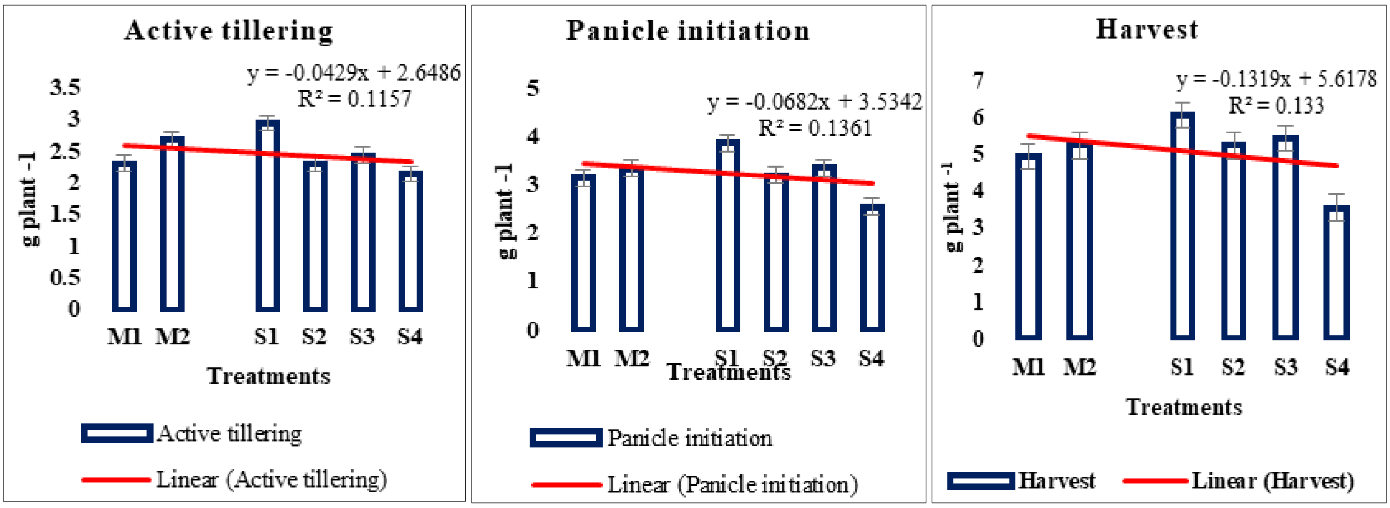
3.2 Root length

The root is the fundamental structure that allows the plant to absorb water and nutrients and it is a significant necessity for determining the plants growth and development. At active tillering, panicle initiation and harvest phases of different treatments, data on root length (cm) was pertained in Table 1.

The beds and channels land configuration exhibited longer roots of 10.52, 15.01 and 18.54 cm in three stages of growth. While shorter root lengths of 9.27, 13.18 and 16.76 cm were register in raised bed configurations. In intercropping system longer roots of 11.29, 16.28 and 20.33 cm were observed in rice alone of three phases of growth which followed by rice +

blackgram and greengram which was on par with each other.

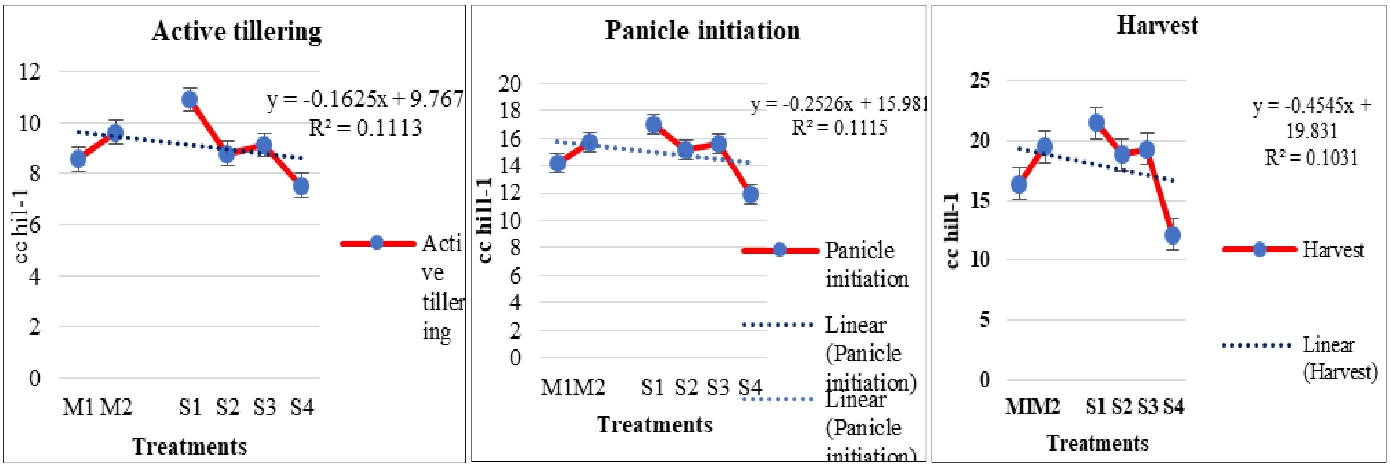
3.3 Root weight
The raised bed system of land configuration was recorded higher root dry weight of 2.60, 3.34, and 5.22 g at active tillering, panicle initiation and harvest stage than the beds and channels configuration (Figure 1). Rice alone generated the maximum root dry weight of 2.94, 3.88, and 6.07 g throughout all three development phases of the intercropping system followed by rice + blackgram and rice + greengram. The lower dry weight of 2.14, 2.55, and 3.55 g at AT, PI and harvest phases was registered with rice + cowpea intercropping system.



M1 – Beds and channels M2 – Raised bed
S1- Rice alone S2 – Rice + greengram
S3 – Rice + blackgram S4 – Rice + cowpea

Fig 1: Land configuration and intercropping practices on root dry weight (g) of aerobic rice

3.4 Root volume
The raised bed system of land configuration had the highest root volume of 9.62 cc at active tillering stage, 15.69 cc at panicle initiation and 19.51 cc at harvest stage compared to beds and channels of land configuration with 9.62, 15.69, and 19.51 cc all the three stages (Figure 2). Higher root volumes of 10.91, 17.04, and 21.48 cc were reported in rice alone during active tillering, panicle initiation, and harvest stage in intercropping techniques. It was followed by rice + blackgram intercropping method. Lowest root volume of 7.54, 11.89, and 12.14 cc was recoded in rice + cowpea intercropping at active tillering, panicle initiation, and harvest stages.



M1 – Beds and channels M2 – Raised bed
S1- Rice alone S2 – Rice + greengram
S3 – Rice + blackgram S4 – Rice + cowpea

Fig 2: Land configuration and intercropping practices on root volume (cc) of aerobic rice

3.5 Root shoot ratio
At active tillering, panicle initiation and harvest phases, the bed and channels system of land configuration was register higher root shoot ratios of 0.763, 0.504 and 0.232 than raised bed configurations of 0.707, 0.454 and 0.212 (Figure 3). Rice alone produced a greater root shoot ratio of 0.788, 0.378 and 0.238 than all other intercropping treatments combined at active tillering, panicle initiation and a lower root shoot ratio was observed in the rice + cowpea intercropping system.

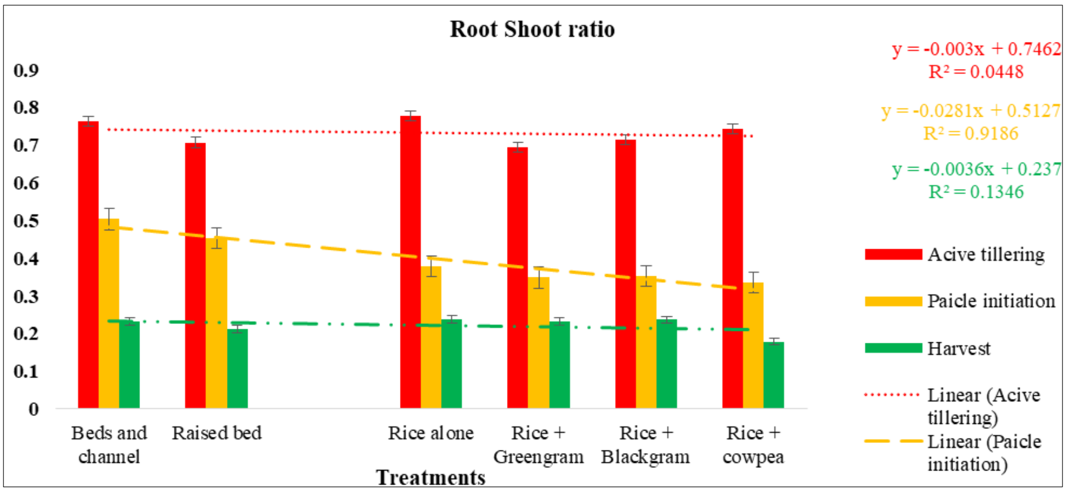


Fig 3: Land configuration and intercropping practices on Plant height (cm), Dry matter production and root length (cm) of aerobic rice

3.6 Rice equivalent yield

Data from the rice equivalent yield differs intentionally among the land configuration and intercropping system. In land configuration, maximum rice equivalent yield (5420 Kg ha^{-1}) was recorded in beds and channel land configuration than raised bed (4729 Kg ha^{-1}) system of land configuration (Figure 4). With respect to intercropping system rice + blackgram intercropping system recorded higher (6084 Kg ha^{-1}) rice equivalent yield over the other intercropping systems. Other than rice + cowpea intercropping system, all other systems are register higher REY.

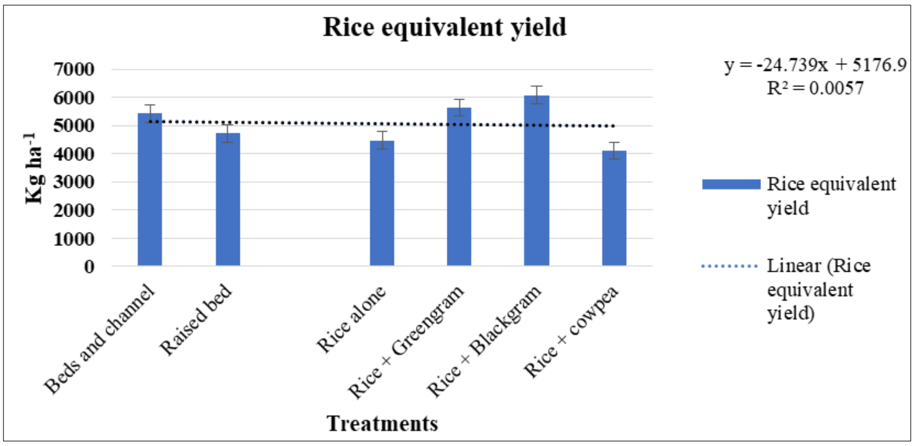


Fig 4: Land configuration and intercropping practices on rice equivalent yield (Kg ha^{-1}) of aerobic rice

3.7 System profitability

Data pertained from the land configuration of beds and channels had maximum system profitability (122 ₹. ha^{-1}day^{-1}) than raised bed configuration (89 ₹. ha^{-1}day^{-1}). Among the intercropping treatments, rice + blackgram in recorded the maximum system profitability (147 ₹. ha^{-1}day^{-1}) which was followed by intercropping of rice + greengram (129 ₹. ha^{-1}day^{-1}) intercropping system (Figure 5). Lowest system productivity (52 ₹. ha^{-1} day^{-1}) was registered in rice + cowpea system.

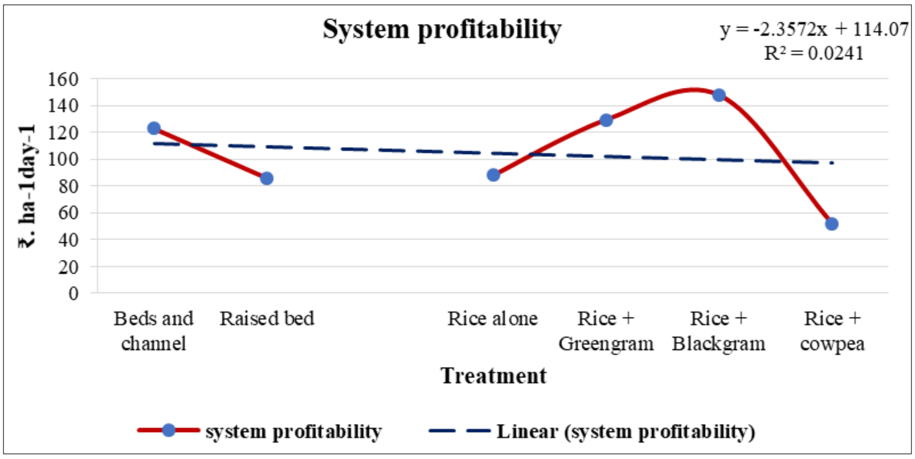


Fig 5: Land configuration and intercropping practices on System productivity (₹. ha^{-1} day^{-1}) of aerobic rice

4. Discussion

Plant growth is a measure of the crop's use of available resources. The land configuration and intercropping system had a substantial impact on the growth characteristics of aerobic rice plant height and dry matter accumulation at different stages of growth. Taller plants were found in the raised bed system among the various land configurations. When compared to beds and channels, plant height under raised beds grew by 25.4% at panicle initiation. The increased plant height in the raised bed was mediated by adequate soil moisture availability, particularly near the root zone (Prakesh *et al.*, 2020) [6]. In terms of intercropping methods, rice alone produced a taller plant during panicle initiation of aerobic rice than other intercropping systems. This might be owing to a lack of competition and excessive root growth (Mahalakshmi *et al.*, 2020) [3].

Root characteristics were discovered to be in agreement with soil moisture availability. At all phases of observation, beds and channel design result in the establishment of longer root lengths than to raised beds. At the harvest stage of aerobic rice, root length increased by 5 to 10% under beds and channel land configuration as compared to raised bed land configuration and similar trend to root shoot ratio this might be because water stress caused rooting depth to expand in order to acquire moisture from deeper layers of soil. Raised bed systems, in contrast to beds and channel systems, yielded 5 to 15% higher root volume and 5 to 6% higher root weight at all stages of crop development. The quantity of fibrous roots increased intensely in the raised bed system, resulting in increased root weight and root volume. By maintaining a better plant water status, sufficient soil moisture in the root zone has promoted normal physiological processes of plant and root cell division and cell multiplication, resulting in improved plant and root development (Mohanakeethi *et al.*, 2018) [4]. In comparison to intercropping system, rice alone had a greater root volume, root dry weight and root-shoot ratio. The findings of Xiao *et al*. (2010) [11] are consistent with this outcome.

The higher system profitability of rice + blackgram intercropping system was mainly due to an additional yield of intercrops as a bonus in intercropping system and higher yield of rice coupled with higher market price of components crops under the same intercropping system Sathishkumar *et al.* (2020) [7]. The system output is determined not just from the efficiency of its individual component crops, but also by how these crops compete with one another for light and space at any given time.

These observations are strengthened further by examining at the rice equivalent yield. Except for rice + cowpea, all intercropping systems exhibit significantly higher rice yield equivalent (RYE) ranging from 5.63 to 6.08 t ha^{-1} than rice alone. Rice + blackgram intercropping system resulted in a greater rice equivalent production. It is possible that this is owing to the intercropping system greater yield and market price, as well as better usage of agronomic resources for enhanced output. Similar findings have been reported by Mahalakshmi *et al.,* 2020 [3] and Subramanian *et al.,* 2020 [10].

5. Conclusion

In aerobic rice production, a well-developed root system is very essential for water and nutrient uptake. From the results it can be concluded that, rice alone or intercropping with blackgram and greengram along with raised bed system of planting aids in improved plant and root growth. Beds and channels method of planting and rice + blackgram or greengram was registered higher rice equivalent yield and system profitability.

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