RESEARCH ARTICLE

EVALUATION OF RICE BASED CROPPING SEQUENCES FOR WATER SCARCE CONDITIONS OF PARAMBIKULAM ALIYAR COMMAND AREA OF TAMIL NADU

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ABSTRACT

Field experiments were conducted at Coconut Research Station, Aliyarnagar during 2016 – 2019 to assess the performance of rice-based cropping sequences for water-scarce conditions of the Parambikulam Aliyar Project Command area of Tamil Nadu. Five cropping sequences viz., rice–sesame (T1), rice–groundnut (T2), rice–sunflower (T3), rice–castor (T4) and rice–black gram (T5) were experimented adopting Randomized Block Design with each sequence replicated four times. Results revealed that compared to the other non-legume sequences experimented, the contents of KMnO4-N and organic carbon in the post harvest soil, productivity of rice and economic efficiency were higher in rice–black gram followed by rice–groundnut sequence. Rice–castor sequence recorded the highest land utilization efficiency of 76.7 % and was the lowest in rice–black gram sequence (53.4 %). Rice equivalent yield was the highest on sequential cropping with sunflower (5755 kg ha-1) followed by groundnut (5028 kg ha-1). Production efficiency was the highest in rice–groundnut (47.5 kg ha-1 day-1) followed by rice–castor (42.5 kg ha-1 day-1) systems. Net returns and benefit-cost ratio were higher in rice–sunflower and rice–black gram and rice–groundnut sequences followed by rice–groundnut and was the lowest in rice–sesame sequence. In terms of soil fertility, system productivity and economic returns, rice–sunflower, rice–black gram and rice–groundnut systems are highly remunerative for water-scarce conditions of Parambikulam Aliyar Command Area of Tamil Nadu.

Key words : Rice; Cropping Sequence; Rice Equivalent Yield; Net Returns; Production Efficiency; Economic Efficiency.

INTRODUCTION

Rice and wheat are the two important cereals that witnessed India to a dramatic switch over of food grain export in the 1990s from mere self-sufficiency in the 1980s. Rice has been the companion of humankind for more than 8000 years providing staple food to 2.5 billion people which may escalate to 4.6 billion by 2050 (Lampe, 1995). In India, its acreage spreads over 44.5 million hectares constituting 34 % of the area under food crops and 42 % under cereals, with a total production of 117.47 million tonnes and productivity of 2639 kg ha-1. In Tamil Nadu, this domesticated crop is cultivated over 17.22 lakh hectares with a production of 64.54 lakh metric tonnes and productivity of 3748 kg ha-1 (GoTN, 2019). Rice production in the tropics is sensitive to climatic factors like temperature, rainfall, and solar radiation affecting the crop in various ways during different stages of its growth (Yoshida, 1978). The adverse impacts of climate change on rice production systems have been increasing over recent years (Matsushima et al., 1966).

Rice is a profligate user of water, and more than five tonnes of water is required to grow one kilogram of rice. The water use efficiency of rice is only 3.7 kg/ha/mm (Subbian et al., 2000), which is far less compared to the other predominant field crops known. Coimbatore is one of the agriculturally important districts of Tamil Nadu in which the majority of the agricultural lands are benefitted from the Parambikulam Aliyar Project (PAP), which is a major interstate multipurpose irrigation project. Rice, coconut, groundnut and vegetables are the principal crops of the command area with a total ayacut of 1.74 lakh hectares. Rice–rice-green manures is the predominant cropping system practised for ages by the farmers of the Anaimalai belt of PAP command because of the unprecedented irrigation water from the Aliyar reservoir. However, during 2016 and the years followed, the mean annual rainfall of the...
region was 59.4% less than the average annual rainfall of 808 mm, which posed a significant impediment for rice cultivation. Several thousand acres of agricultural lands were kept barren for want of irrigation water. In the event of monsoon failure, Aliyar reservoir can support only one rice crop (Kharif) per year and the rice growers incur huge losses by sacrificing the second Rabi rice crop. Besides water scarcity, continuous rice cropping also resulted in other problems like a relatively low response of nitrogen (N) fertilizers and slow mineralization rates as stated by Cassman et al. (1995) and Olk and Cassman (1995). Occurrence of second-generation problems such as over-mining of soil nutrients, the decline in factor productivity, reduction in profitability, lowering of ground-water table and build-up of pests including weeds, diseases and insects has been reported in continuous rice-rice cropping system (Ray et al., 2009) signifying the importance of crop diversification. Due to the introduction of short and medium duration rice varieties, multiple cropping and the diversification of rice-based cropping system is possible with the inclusion of pulses, oilseeds and vegetables and this has been found more beneficial, providing enhanced productivity of the system and improved soil fertility status than cereal–cereal sequence (Kumpawat, 2001 and Sravan et al., 2015), in alleviating the poverty, employment generation, ensuring balanced food supply, and improving productivity and sustainability of the cropping systems (Sravan and Murthy, 2018).

Sahrawat (2004) reported the importance of grain legumes in rice-based rotations to enhance the decomposition of accumulated organic matter as against the slow decomposition rate in continuously waterlogged rice soils. Evidence accumulate stating that inclusion of pulses, oilseeds and vegetables in the system is more beneficial than cereals after cereals, and such inclusion in a sequence changes the economics of the crop sequences (Patra et al., 1989; Gangwar et al., 2004; Ghosh et al., 2007 and Jat et al., 2012). The introduction of legumes and oilseeds can provide a sustainable production base to the continued rice mono-cropped system, which otherwise leads to a decline in total factor productivity. Hence, research has been envisaged on identifying low water requiring alternative crops that are highly productive, resource efficient, remunerative and sustainable, to fit into rice-based cropping system for the PAP command area of Tamil Nadu, based on soil fertility, system productivity and economic returns.

**MATERIAL AND METHODS**

Field experiments were conducted during 2016-2019 in Field Number A3 of Coconut Research Station, Aliyarnagar (10°29'449 N; 076°58'775 E) to elicit the impact of rice-based cropping systems on soil fertility, system productivity and on economic returns. The soil is sandy loam in texture, classified taxonomically as *Typic Ustropept*. The bulk density of the soil is 1.35 Mgm⁻³, particle density of 2.46 Mg m⁻³ and porosity is 45.2%. The pH of the experimental soil is 7.96 with an electrical conductivity of 0.33 dSm⁻¹. The major nutrients such as KMnO₄ N was 242 kg ha⁻¹, Olsen P of 14.4 kg ha⁻¹, NNH4OAc K of 246 kg ha⁻¹ indicating the low and medium status of the nutrients respectively. The organic carbon content of the soil was medium (5.2 g kg⁻¹). Experiment was conducted in a Randomized Block Design with each treatment replicated four times. Five rice-based cropping systems viz., rice–sesame (T₁), rice–groundnut (T₂), rice–sunflower (T₃), rice-castor (T₄) and rice–black gram (T₅) were evaluated for their production potential, soil fertility and economics. After the first crop of rice, without disturbing the plots, the field was prepared using a power tiller to optimum tilth and the sequential crops were raised adopting the crop management practices furnished in Table 1. The *Kharif* crop of rice was sown during the last week of June and harvested during October and the sequential crops were sown during October. During *Kharif*, the crop was irrigated to maintain a saturated moisture regime whilst *Rabi* crops were irrigated only at critical crop growth stages. Irrigation water was quantified through Parshall Flume placed in the field.

| S.No. | Particulars            | Rice  | Groundnut | Sunflower | Castor  | Sesame | Black gram |
|-------|------------------------|-------|-----------|-----------|---------|--------|-----------|
| 1.    | Variety                | C050  | C07       | C02 hybrid| YRC1    | 80-85  | 65-70     |
| 2.    | Duration (days)        | 130-135| 100-105   | 90-95     | 150-160 | 90-105 | 25-40     |
| 3.    | Seed Rate (kg ha⁻¹)    | 40    | 125       | 4.0       | 5.0     | 5.0    | 20.0      |
| 4.    | Land Configuration     | Flat Bed | Flat Bed | Ridges and Furrows | Ridges and Furrows | Flat Bed | Flat Bed |
| 5.    | Spacing                | (20 x 10) cm | (30 x 10) cm | (60 x 30) cm | (150 x 120) cm | (30 x 30) cm | (30 x 10) cm |
| 6.    | Planting method        | Transplanting | Dibbling | Dibbling | Dibbling | Sand mix | Broadcasting |
| 7.    | Fertilizer (NPK)/ha     | 150 – 50 - 50 | 25-50-75 | 60 – 90- 60 | 90 – 45-45 | 35-23-23 | 25-50-25 |
| 8.    | Special management practices | - | Gypsum @ 200 kg ha⁻¹ on 45 DAS | Borax spray @ 0.2 % at capitulum formation stage | - | MnSO₄ @85 kg ha⁻¹ | 2 % DAP spray on 30 and 45 DAS |
To elicit the differential effect of cropping sequences on soil fertility, soil samples were collected at the end of the first crop and sequential crops. Analyses viz., pH, electrical conductivity (Jackson, 1973), KMnO₄-N (Subbiah and Asija, 1956), Olsen P (Olsen et al., 1954), NH₄OAc – K (Stanford and English, 1949) and organic carbon content (Walkley and Black, 1934) were performed adopting the standard procedures. Economics of the cropping sequences were worked out on the basis of the market price of the product and other agro-inputs. Productivity of the cropping sequences was assessed based on rice-equivalent yield. Water use efficiency was computed as the ratio of yield obtained per unit of available water (Sinclar et al., 1984). Rice equivalent yield (kg ha⁻¹) was calculated employing the following formula

\[
\text{Rice Equivalent yield} = \frac{\text{Yield of the sequential crop (kg ha}^{-1}\text{)}}{\text{Price of the crop (Rs. kg}^{-1}\text{)}} \times \frac{\text{Price of rice (Rs. kg}^{-1}\text{)}}{\text{Organic carbon content (g kg}^{-1}\text{)}}
\]

Land use efficiency (LUE) was obtained by dividing the total duration of crops in an individual cropping system by 365 days (Chuang, 1973). Production efficiency values were obtained by dividing total production in sequence by the total duration of a cropping sequence (Tomar and Tiwari, 1990). Net returns were worked out as the difference between gross returns and the cost of cultivation. Economic efficiency (Perin et al., 1979) in terms of Rs. ha⁻¹ day⁻¹ was worked out by dividing the net returns of a cropping sequence by the total duration of the cropping sequence in a year. Pooled analysis was performed from the data accrued across three years and subjected to statistical scrutiny employing Gomez and Gomez (1984) and the results are discussed in detail based on the critical differences obtained.

**RESULTS AND DISCUSSION**

**Weather variables**

The weather variables recorded in the Agro Meteorological Observatory of Coconut Research Station, Aliyarnagar for the period 2014 – 2020 is presented in Table 2. The minimum temperature ranged from 21.5°C to 27.5°C and the maximum temperature from 35.3°C to 38.0°C in the said period.

| Year | Max. Temp. (°C) | Min. Temp (°C) | Rainfall (mm) | Relative Humidity (%) | Evaporation (mm) | Wind Velocity (kmph) |
|------|----------------|----------------|---------------|-----------------------|-----------------|---------------------|
| 2014 | 36.7           | 25.0           | 1054.9 (83)   | 90.8                  | 5.9             | 3.1                 |
| 2015 | 35.3           | 22.3           | 1073.7 (76)   | 92.4                  | 6.5             | 2.5                 |
| 2016 | 38.0           | 23.9           | 480.4 (31)    | 90.0                  | 8.0             | 4.0                 |
| 2017 | 36.8           | 24.2           | 748.1 (50)    | 93.4                  | 5.6             | 2.9                 |
| 2018 | 36.8           | 23.1           | 1085.5 (73)   | 96.8                  | 4.8             | 2.7                 |
| 2019 | 38.0           | 27.5           | 896.01 (67)   | 97.2                  | 9.0             | 4.4                 |
| 2020 | 37.5           | 21.5           | 684.9 (57)    | 94.2                  | 4.8             | 6.2                 |

Figures in parentheses represent the number of rainy days

Rainfall received during 2016 was 40.5% lesser than the mean annual rainfall of the region and the water levels in the reservoirs dropped down drastically forcing the farmers to abandon rice cultivation. The scenario reversed only during 2018 and thereafter again there was a dent in rainfall during 2020.

**Table 2. Weather variables recorded at Coconut Research Station, Aliyarnagar**

**Table 3. Initial and post-harvest soil fertility status of paddy–oilseeds cropping sequence experiment**
Soil Fertility Status

The initial and post-harvest soil fertility status for the period 2016 – 2019 is presented in Table 3. Compared to the initial soil fertility status during 2016, soil reaction and electrical conductivity registered a mild increase in the post-harvest soil during 2019; however no significant variation was observed between the cropping sequences adopted. It is a natural corollary that the pH of the soil under submergence converges to neutrality (Kar et al., 1977 and Ponnamperuma, 1978) and hence sequential crops did not impact their influence on the pH of the post-harvest soil. Electrical conductivity did not register significant variation among the cropping sequences adopted.

Table 4. Growth attributes of rice in rice-based cropping sequence at harvest stage (2016 -19)

| Cropping system        | Plant height (cm) | Number of leaves per plant | Root length (cm) | Dry matter Production (kg ha\(^{-1}\)) |
|------------------------|-------------------|----------------------------|------------------|---------------------------------------|
| T\(_1\): Rice-Sesame   | 92.20             | 43                         | 15.85            | 10150                                 |
| T\(_2\): Rice-Groundnut| 89.75             | 41                         | 15.60            | 10200                                 |
| T\(_3\): Rice-Sunflower| 94.12             | 46                         | 14.33            | 10100                                 |
| T\(_4\): Rice-Castor   | 87.83             | 42                         | 15.75            | 10100                                 |
| T\(_5\): Rice–Black gram| 86.32             | 45                         | 15.90            | 10300                                 |
| Mean                   | 90.04             | 43                         | 15.49            | 10170                                 |
| S.ED.                  | 6.79              | 3.17                       | 1.17             | 760                                   |
| CD (P = 0.05)          | NS                | NS                         | NS               | NS                                    |

The content of KMnO\(_4\) -N was higher in the rice–black gram sequence followed by rice–groundnut and rice–sunflower sequences and was the lowest in rice–sesame sequence. The results are in proximity to the findings of Tamilezhai et al., (2018). The residual nitrogen benefits of legumes have been well documented by several workers (Ahmad et al., 2001; Wasim et al., 2015 and Kakraliya et al., 2018). In an experiment conducted to assess the residual nitrogen benefits to rice in farmers’ fields of North East Thailand, it was found that groundnut fixed 72-77 % of its nitrogen amounting to 150 – 200 kg N ha\(^{-1}\) in 106 – 119 days (Toomson et al., 1995).

In a trial on sequential cropping, nitrogen fixation by groundnut was significant and the residual N effect was higher on the succeeding rice crop (Senaratne and Ratnasinge, 1995). Although the availability of phosphorus and potassium did not show any statistical superiority among the treatments in the post-harvest soil, there was mining of potassium in the soil of rice-sesame sequence. As sesame is one of the heavy feeders of nutrients (Adisu et al., 2020), there is a depression in the soil fertility status of the post-harvest soil compared to the other sequences experimented with. Organic carbon content in the post-harvest soil was higher in rice-black gram, rice-groundnut and rice-castor cropping sequences owing to the recycling of stubbles in the above systems.

Growth and Yield attributes

Plant height of rice at harvest ranged from 86.32 cm to 94.12 cm, the number of leaves per plant from 41 to 46, root length from 14.33 to 15.90 cm and dry matter production from 10100 to 10300 kg ha\(^{-1}\) (Table 4). Although statistical parllance was observed among the cropping sequences on the
above parameters, the inclusion of black gram in the system resulted in increased dry matter production of rice crops. Diverse cropping sequences adopted did not bring noteworthy differences in a number of productive tillers per plant. However, numerically higher grain yield were recorded in rice-black gram system followed by rice-groundnut system (Figure 1). An array of evidence states that the inclusion of legumes in rice based cropping system increases the productivity of rice (Ahmad et al., 2001; Hegde, 2003; Kakraliya et al., 2018, Nath et al., 2019 and Ghosh et al., 2019). Introduction of a legume in rice-based cropping system has several advantages like biological nitrogen fixation which include nutrient recycling from deeper layers, minimizing soil compaction, increasing soil organic matter and breaking pest cycles (Sanford and Hairston, 1984; Wani et al., 1995). Thus in the present study, rice yield was higher in rice-black gram and rice-groundnut systems compared to the other non-legume sequences experimented. Growth of the sequential crops at harvest, yield attributes and yield are presented in Table 5. As the phenology, physiology, architecture, flowering and bearing habits of the sequential crops are different, their statistical comparison will be obsolete and hence presented per se.

### Table 6. Rice Equivalent Yield, Land Use Efficiency and Production Efficiencies of cropping sequences in rice-based cropping system (2016 - 19)

| Cropping system       | REY of sequential crop (kg ha⁻¹) | Land Use Efficiency (%) | Production Efficiency (kg ha⁻¹ day⁻¹) | Economic Efficiency (Rs. ha⁻¹ day⁻¹) |
|-----------------------|----------------------------------|-------------------------|---------------------------------------|-------------------------------------|
| T₁: Rice-Sesame       | 1856                             | 57.5                    | 30.2                                  | 144.2                               |
| T₂: Rice-Groundnut    | 5028                             | 64.4                    | 47.5                                  | 269.2                               |
| T₃: Rice-Sunflower    | 5733                             | 60.3                    | 38.8                                  | 230.1                               |
| T₄: Rice-Castor       | 4004                             | 76.7                    | 42.5                                  | 162.1                               |
| T₅: Rice-Black gram   | 1867                             | 53.4                    | 40.3                                  | 280.0                               |
| S.Ed.                 | 1125                             | 2.64                    | 1.75                                  | 13.7                                |
| CD (P = 0.05)         | 2669                             | 7.19                    | 5.15                                  | 31.8                                |

### Land Use Efficiency and Production Efficiency

Rice equivalent yield and efficiencies of cropping systems are presented in Table 6. Rice equivalent yield was the highest in sunflower followed by groundnut and was the lowest in sesame, mainly due to the lower yield of sesame than the other sequential crops experimented with. Land utilization efficiency was the highest (76.7%) in the rice-castor system and lowest (53.4 %) in rice-black gram sequence, which is mainly attributed to the long duration of castor and short duration of black gram in the field. Similar results of rice-black gram cropping sequence recording lowest land utilization efficiency were recorded by Sanjoy and Monalisa (2007). Production efficiency was the highest in the rice-groundnut system followed by the rice-castor system and was the lowest in rice-sesame system. Economic efficiency was the highest in rice-black gram system (Rs. 280 ha⁻¹ day⁻¹), followed by rice-groundnut system (Rs. 269 ha⁻¹ day⁻¹).

### Table 7. Water Use Efficiency and Economics of rice in rice-based cropping sequences (2016 – 19)

| Cropping system       | Total water used (mm) | WUE (kg/ha.mm) | Cost of Cultivation (Rs/ha) | Gross returns (Rs/ha) | Net returns (Rs/ha) | B : C |
|-----------------------|-----------------------|----------------|----------------------------|-----------------------|---------------------|-------|
| T₁: Rice-Sesame       | 1150                  | 4.57           | 35000                      | 57396                 | 22396               | 1.64  |
| T₂: Rice-Groundnut    | 1150                  | 4.71           | 35000                      | 59411                 | 24411               | 1.70  |
| T₃: Rice-Sunflower    | 1150                  | 4.46           | 35000                      | 55688                 | 20688               | 1.59  |
| T₄: Rice-Castor       | 1150                  | 4.28           | 35000                      | 53088                 | 18088               | 1.52  |
| T₅: Rice-Black gram   | 1150                  | 5.22           | 35000                      | 59604                 | 24604               | 1.70  |
| Mean                  | 1150                  | 4.65           | 35000                      | 58437                 | 23437               |       |

### Water Use Efficiency and Economics

Total water consumed was computed by summing the irrigation water applied and the effective rainfall. Effective rainfall was calculated as fifty percent of the total rainfall during the cropping period. The highest water use efficiency of rice (5.22 kg ha⁻¹ mm⁻¹) was witnessed in rice-black gram cropping sequence followed by rice-groundnut (4.71 kg ha⁻¹ mm⁻¹) and rice-sesame (4.57 kg ha⁻¹ mm⁻¹) systems (Table 7) which may be attributed to the higher grain yields of rice obtained in the above systems. Sureshkumar and Pandian, 2017 recorded a water use efficiency of 6.7 kg ha⁻¹ mm⁻¹ in the SRI method of rice cultivation whilst lower WUE was recorded with a conventional method of rice cultivation.
Table 8. Water Use Efficiency and Economics of sequential crops in rice-based cropping sequences (2016 – 19)

| Cropping system          | Total water used (mm) | WUE (kg/ha. mm) | Cost of Cultivation Rs/ha | Gross returns Rs/ha | Net returns Rs/ha | B : C |
|--------------------------|-----------------------|-----------------|---------------------------|---------------------|------------------|-------|
| T<sub>1</sub>:Rice-Sesame | 580                   | 1.50            | 32000                     | 43500               | 11500            | 1.36  |
| T<sub>2</sub>:Rice-Groundnut | 380                   | 3.31            | 28036                     | 62850               | 34814            | 2.24  |
| T<sub>3</sub>:Rice-Sunflower | 420                   | 5.12            | 31500                     | 75250               | 43750            | 2.39  |
| T<sub>4</sub>:Rice-Castor  | 620                   | 2.36            | 28000                     | 43950               | 15950            | 1.57  |
| T<sub>5</sub>:Rice-Black gram | 350                   | 2.00            | 26000                     | 56000               | 30000            | 2.15  |

Although irrespective of cropping sequences, the cost of cultivation was the same for rice, gross returns were highest in rice-black gram system followed by rice-groundnut system because of the enhanced grain yield obtained in the above systems. Net returns and benefit-cost ratio was the highest in rice-black gram system followed by rice-groundnut system and was the lowest in rice-castor system compared to other systems. Patra et al. (1989) and Das and Bhanja (1996) also reported that the rice-black gram and rice-field pea relay cropping systems were the most remunerative relay cropping systems.

Table 9. Water Use Efficiency and Economics of rice-based cropping sequences (2016 – 19)

| Cropping system          | Total water used (mm) | WUE (kg/ha. mm) | Cost of Cultivation Rs/ha | Gross returns Rs/ha | Net returns Rs/ha | B : C |
|--------------------------|-----------------------|-----------------|---------------------------|---------------------|------------------|-------|
| T<sub>1</sub>:Rice-Sesame | 1730                  | 3.54            | 67000                     | 100896              | 33896            | 1.51  |
| T<sub>2</sub>:Rice-Groundnut | 1530                  | 4.36            | 63036                     | 122261              | 59225            | 1.94  |
| T<sub>3</sub>:Rice-Sunflower | 1570                  | 4.63            | 66500                     | 130938              | 64438            | 1.97  |
| T<sub>4</sub>:Rice-Castor  | 1770                  | 3.61            | 63000                     | 97038               | 34038            | 1.54  |
| T<sub>5</sub>:Rice-Black gram | 1500                  | 4.47            | 61000                     | 115604              | 54604            | 1.90  |

As far as the sequential crops are concerned, the highest water use efficiency was witnessed in sunflower (5.12 kg/ha mm) followed by groundnut (3.31 kg/ha mm) and the lowest was registered in sesame (Table 8). Net returns were the highest in the sunflower cropping system and the lowest was registered in rice-sesame system. Benefit–cost ratio was also the highest due to sequential cropping with sunflower followed by groundnut (Table 9).

CONCLUSION

Results indicated that of the cropping systems experimented with, rice-black gram and rice-groundnut systems are the most viable options for maintaining soil fertility, improving dry matter production and grain yield of the proceeding rice crop and economic efficiency of the sequences. Sequential cropping with sunflower followed by groundnut impacted its significance in registering higher rice equivalent yield, water use efficiency, net returns and benefit-cost ratio whilst the above parameters were the lowest in rice-sesame system. Amalgamating, the positive impact of the cropping sequences, rice-black gram, rice-sunflower and rice-groundnut cropping sequences can be recommended for water scarce conditions of Parambikulam Aliyar Command area of Tamil Nadu.

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