

# Root Growth, Nutrient Uptake and Yield of Medicinal Rice Njavara under Different Establishment Techniques and Nutrient Sources

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## ABSTRACT

Field experiments with medicinal rice Njavara were conducted at Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala during summer of 2007 and 2008. The experimental design was split plot with three replications. The treatments consisted of four establishment techniques *viz.*, System of Rice Intensification SRI (M<sub>1</sub>), Integrated Crop Establishment Method (ICM) (M<sub>2</sub>), Package of practices (PoP) (M<sub>3</sub>) of Kerala Agricultural University and Conventional Management Practices (CMP) (M<sub>4</sub>) in main plot. Three nutrient sources *viz.*, (1) organic, 2) integrated use of organic and inorganic, 3) chemical fertilizers only) were used under different establishment techniques. Root dry matter production was determined at weekly intervals and plant nutrients uptake was determined by calculating from the product of dry matter, straw dry weight, grain yield and percentage of nutrients. Results revealed that at early stages (4 - 6 WAT/WAS) (Weeks after transplanting/Weeks after sowing), root dry matter production hill<sup>-1</sup> was in the order of SRI > ICM > CMP > PoP which changed to SRI > ICM > PoP > CMP from 7<sup>th</sup> week onwards. Maximum root dry matter (at 9<sup>th</sup> WAS/WAT) was recorded in SRI (0.51/0.50 g·hill<sup>-1</sup> in 2007/2008). The total nutrients uptake (N, P, K, Fe, Mn and Zn) in conventional management practices was significantly higher than other establishment techniques. Among the nutrient sources, higher total (N, P, K, Fe, Mn and Zn) uptake by crop was recorded under integrated nutrient source than organic and inorganic sources.

**Keywords:** Njavara Rice; Establishment Techniques; Nutrient Sources; Root Growth; Total Nutrient Uptake; Yield

## 1. Introduction

Rice is an important crop and will continue to play a vital role in food security for millions of people in India. The future of Indian food security and foreign exchange through rice exports will also largely depend on desired production and productivity. Opportunities are great for attaining high yield in rice through proper agronomic management practices, low cost mechanization in seeding, weeding and suitable establishment techniques [1]. Njavara is widely used in the Ayurvedic System of Medicine, especially in treating Panchakarma. Njavara as a special cereal, has the properties to rectify the basic ailments affecting circulatory, respiratory and the digestive systems.

The water and nutrient uptake ability of plants highly depends on the root architecture [2], while the root system directly affects the amount of water available to crop. Most of crops largely rely on stored water into the soil

profile. The root systems of rice consist of seminal and nodal roots with first- and higher-order lateral roots. The rootlength can penetrate from 70 to 80 cm in soil. However, the lowland rice has got a shallow and compact root system, most of which is distributed in the top 15 cm of soil [3]. The soil moisture has a profound impact on root growth, viability, functionality and plant growth [4]. The deep extensive root enhances water utilization in the deeper soil profile, which is considered to be an important trait of drought resistance in plants. The present study was to investigate the developmental phenology of Njavara root growth and its nutrient uptake under different establishment techniques and nutrient sources.

## 2. Materials and Methods

### 2.1. Site and Soil Description

Field experiments were conducted for two consecutive

years *i.e.*, summer/third crop/puncha season of 2007 and 2008 at Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala. The soil was acidic in reaction (5.5 pH), high in organic carbon content (1.23%), medium in available nitrogen (261.9 kg·ha<sup>-1</sup>), available phosphorus (22.0 kg·ha<sup>-1</sup>) and available potassium (140.2 kg·ha<sup>-1</sup>) status.

## 2.2. Experimental Treatments and Design

The experiment was laid out in a split plot design with three replications. The establishment techniques in main plot were SRI (System of Rice Intensification) (M<sub>1</sub>), ICM (Integrated Crop Establishment Method) (M<sub>2</sub>), PoP (Package of Practices) (M<sub>3</sub>) (Recommendation of Kerala Agricultural University) as well as the Conventional Management Practices (M<sub>4</sub>) and nutrient sources *viz.*, organic sources (S<sub>1</sub>), integrated nutrient sources (S<sub>2</sub>) and inorganic sources (S<sub>3</sub>) in sub plot.

## 2.3. Crop Husbandry

In SRI treatments single, eight day old seedlings were transplanted at 20 × 20 cm spacing. Four weedings with rotary weeder were given at 10 days interval starting from 10 DAT to panicle initiation (45 days). Soil was kept at field capacity up to panicle initiation and then onwards 5 cm standing water was allowed in the field till 10 days before harvesting. In ICM treatments two seedlings of 12 days age were transplanted at 20 × 20 cm spacing. Two rotary weedings on 10 and 20 DAT were given followed by one hand weeding on 35 DAT. A thin film of water was kept in the field till 10 days before harvesting. In PoP treatments three seedlings of 18 days age were transplanted at 15 × 10 cm spacing. Weed control was achieved through one manual weeding on 15 DAT and application of 2,4-D @ 1 kg a.i ha<sup>-1</sup> on 25 DAT. Water level was maintained at about 1.5 cm during transplanting. Thereafter it was increased gradually to about 5 cm. intermittent draining and reflooding was done. Field was drained 10 days before harvesting. In conventional management practices pre germinated seeds were broadcasted @ 80 kg·ha<sup>-1</sup>. A thin film of water was maintained up to 10 DAS after which water level was raised up to 5 cm and field was drained 10 days before harvest. Two manual weedings were done at 15 and 35 DAS.

## 2.4. Manures and Fertilizers

Nutrient management recommendation of Package of Practices: Crops (2007) of Kerala Agricultural University was adopted. For wet land local varieties the recommendation is 5t FYM + 40:20:20 kg NPK per ha. Full FYM + 2/3 N + Full P + 1/2 K were to be applied as basal.

1/3 N + 1/2 K were to be applied at panicle initiation. Three types of nutrient management were involved in the technical programme. In the organic treatments 40:20:20 kg NPK ha<sup>-1</sup> were supplied through FYM, rock phosphate and wood ash. 5t FYM ha<sup>-1</sup> was also applied. In integrated nutrient management treatments 40:20:20 kg NPK ha<sup>-1</sup> were supplied through urea, rock phosphate and muriate of potash along with 5t FYM. In the inorganic treatments NPK contribution by 5t FYM was calculated and they were supplied through urea, rock phosphate and muriate of potash. NPK was also applied at the rate of 40:20:20 kg·ha<sup>-1</sup> respectively.

## 2.5. Data Recording

### 2.5.1. Root Drymatter Production

Root biomass production from five sample plants collected from sampling area were recorded on dry weight basis and the average worked out at weekly interval from fourth week of transplanting/sowing till physiological maturity.

### 2.5.2. Plant Analysis

Sample plants collected from each plot at harvest were separated into straw and grain, sun dried, and then oven dried to a constant weight and the samples were ground, digested and used for analysis of nutrient content. Nutrient uptake was worked out using the following equation and expressed as kg·ha<sup>-1</sup>.

Nutrients	Determination methods
Nitrogen	Microkjeldahl method [5]
Phosphorus	Diacid extract estimated colorimetrically in a Spectronic-20 Spectrophotometer by Vanadomolybdophosphoric yellow colour method [5]
Potassium	Diacid extract method using Flame photometer [5]
Fe, Mn and Zn	Diacid extract method using atomic absorption spectrophotometer (Perkin Elmer model) [5]
Sulphur	Turbidimetric method using Spectronic-20 spectrophotometer [6]

$$\text{Nutrient uptake} = \frac{\text{Nutrient content} \times \text{Dry matter production}}{100}$$

### 2.5.3. Grain and Straw Yield

The net plot area was harvested individually, threshed, winnowed, dried, weighed and expressed in kg·ha<sup>-1</sup>. Straw harvested from each net plot was dried in sun and the weight expressed in kg·ha<sup>-1</sup>.

### 2.5.4. Statistical Analysis

Data recorded during the field investigation were statis-

tically analyzed with split plot design method as suggested by [7] for test of significance. Wherever the treatment differences were found significant, the critical differences were worked out to 5 per cent probability level and the values furnished.

### 3. Results and Discussion

#### 3.1. Effect of Rice Establishment Techniques and Nutrient Source on Root Dry Matter Production

Root dry matter production in Njavara was significantly influenced by rice establishment techniques. Root dry matter  $\text{hill}^{-1}$  was recorded at weekly interval from 4<sup>th</sup> WAT/WAS till physiological maturity. At the early stages (4 - 6 WAT/WAS) root dry matter production  $\text{hill}^{-1}$  was in the order SRI > ICM > conventional management practices > PoP which changed to SRI > ICM > PoP > conventional management practices from 7<sup>th</sup> week onwards (**Table 1**). Throughout the crop growth period, all the establishment techniques differed significantly from one another in root dry matter  $\text{hill}^{-1}$ . Increase in root dry matter occurred up to 9 WAS/WAT (Weeks after transplanting/Weeks after sowing). Higher root dry matter (at 9<sup>th</sup> WAS/WAT) was recorded in SRI (0.51/0.50  $\text{g hill}^{-1}$  in 2007/2008) and it was 21/25% higher in 2007/2008 than ICM (0.42/0.60  $\text{g}\cdot\text{hill}^{-1}$  in 2007/2008) and 31/32% higher in 2007/2008 than PoP (0.39/0.38

$\text{g}\cdot\text{hill}^{-1}$  in 2007/2008) and 59/52% higher in 2007/2008 than conventional management practices (0.32/0.33  $\text{g}\cdot\text{hill}^{-1}$  in 2007/2008), respectively.

Increase in root dry matter in SRI and ICM may be attributed to increased aeration in soil due to stirring of soil by rotary weeder. Rotary weeder was operated four times in SRI treatments and two times in ICM treatments. Till 6<sup>th</sup> week, root dry matter production in conventional management practices was higher than that in PoP which may be attributed to the earlier establishment and root development in the broadcast crop. But from 7<sup>th</sup> week onwards root development occurred at faster rate in PoP compared to conventional management practices which might be due to availability of more space for individual hill under transplanted condition. This would have reduced the competition for nutrients and water as reported by [8] planting of single seedling rather than in clumps helped to avoid root competition and promoted vigorous root growth. [9] reported that following a wider spacing  $25 \times 25$  cm and early and frequent weeding using a mechanical weeder encouraged the proliferation of microorganisms that symbiotically enhanced the capacity of plants to produce more tillers, with vigorous and healthy root growth and a large number of panicles heavily laden with grains. Root development was least in conventional management practice which combined with least culm strength might have resulted in lodging of the crop. Less interplant competition would have enabled the plants to

**Table 1. Effect of rice establishment techniques and nutrient sources on root dry matter production  $\text{hill}^{-1}$ .**

Treatments	Root dry matter production $\text{hill}^{-1}$ (g)														Physiological Maturity	
	4 <sup>th</sup> week		5 <sup>th</sup> week		6 <sup>th</sup> week		7 <sup>th</sup> week		8 <sup>th</sup> week		9 <sup>th</sup> week		10 <sup>th</sup> week		2007	2008
Management systems	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
M <sub>1</sub> (SRI)	0.26	0.26	0.30	0.31	0.38	0.35	0.44	0.45	0.45	0.47	0.51	0.50	0.51	0.50	0.51	0.50
M <sub>2</sub> (ICM)	0.17	0.17	0.28	0.27	0.31	0.31	0.31	0.30	0.42	0.42	0.42	0.40	0.42	0.40	0.41	0.40
M <sub>3</sub> (PoP)	0.15	0.14	0.18	0.17	0.20	0.21	0.29	0.28	0.33	0.32	0.39	0.38	0.38	0.38	0.36	0.37
M <sub>4</sub> (CMP)	0.16	0.17	0.20	0.19	0.22	0.23	0.25	0.26	0.28	0.28	0.32	0.33	0.32	0.30	0.27	0.28
SEd	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.00</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>
CD (0.05)	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.02</b>	<b>0.01</b>	<b>0.02</b>	<b>0.02</b>	<b>0.02</b>	<b>0.02</b>	<b>0.03</b>	<b>0.02</b>	<b>0.02</b>	<b>0.03</b>
Nutrient sources																
S <sub>1</sub> (Organic)	0.19	0.19	0.24	0.24	0.28	0.28	0.33	0.33	0.37	0.38	0.41	0.40	0.41	0.40	0.40	0.39
S <sub>2</sub> (Integrated)	0.19	0.19	0.24	0.23	0.27	0.27	0.32	0.32	0.37	0.37	0.41	0.40	0.41	0.40	0.38	0.38
S <sub>3</sub> (Inorganic)	0.18	0.18	0.23	0.23	0.27	0.27	0.32	0.32	0.36	0.36	0.40	0.40	0.41	0.40	0.38	0.38
SEd	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.02</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.02</b>
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

SRI—System of Rice Intensification; ICM—Integrated Crop Establishment Method Package of Practices; PoP—Package of Practices of Kerala Agricultural University; CMP—Conventional Management Practices.

have more physiological activity. In square planting with wider spacing soil area was available for foraging leading to improved root characters *viz.*, root length, root volume and root dry weight resulting in more photosynthetic activity. This might be reason for higher root and straw dry matter in SRI. Similar result was reported by [10].

### 3.2. Effect of Rice Establishment Techniques and Nutrient Source on Nutrient Uptake

Nutrient uptake by grain, straw and total uptake by crop showed more or less the same trend in both seasons. The total nutrient uptake (N, K, Fe, Mn and Zn) were in the order CMP > PoP > SRI > ICM. Total P uptake was in the order CMP > SRI > PoP > ICM. Total uptake of all the nutrients in conventional management practices was significantly higher (20.42 kg·ha<sup>-1</sup> in 2007 and 2008 (N uptake), 1.93/2.20 kg·ha<sup>-1</sup> in 2007 and 2008 (P uptake), 25.98/28.56 kg·ha<sup>-1</sup> in 2007 and 2008 (K uptake), 0.99/1.06 kg·ha<sup>-1</sup> in 2007 and 2008 (Fe uptake), 1.00/1.08 kg·ha<sup>-1</sup> in 2007 and 2008 (Zn uptake) and 1.04/1.11 kg·ha<sup>-1</sup> in 2007 and 2008 (Mn uptake) than that in the other three establishment techniques (Tables 2 and 3). Uptake of all nutrients in PoP and ICM were at par and as well as that in SRI and ICM. [11] reported that total nutrient uptake in broadcast seeded flooded rice was higher than that in transplanted rice due to transplant shock, lower plant density and higher N losses in transplanted rice.

Nutrient sources showed significant influence on total

uptake by the crop (P, K, Fe and Zn) in both seasons. Nutrient sources showed no significant influence on total N, S and Mn uptake. Highest P uptake (1.82/1.89 kg·ha<sup>-1</sup>), K uptake (24.11/26.38 kg·ha<sup>-1</sup>), Fe uptake (0.93/1.00 kg·ha<sup>-1</sup>) and Zn uptake (1.02/1.06 kg·ha<sup>-1</sup>) by the crop (grain + straw) occurred. In integrated nutrient source and organic and inorganic source results were at par. [12] stated that integrated nutrient management is the best approach to supply adequate and balanced nutrients and increase crop productivity in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations. [13,14] reported that uptake of nutrients was improved by the application of integrated use of organic and inorganic fertilizer compared to RDF.

### 3.3. Effect of Rice Establishment Techniques and Nutrient Source on Yield

Higher grain yield was recorded in conventional management practices (M<sub>4</sub>) (1041.4/1038.4 kg·ha<sup>-1</sup> in 2007/2008) and was 16%/15% higher in 2007/2008 than PoP, 24%/26% higher in 2007/2008 than in SRI and 36%/37% higher in 2007/2008 than ICM (Table 4). The highest grain yield (928.7/920.5 kg·ha<sup>-1</sup> in 2007/2008) was obtained in integrated nutrient source (S<sub>2</sub>) which was followed by organic source (872.1/857.9 kg·ha<sup>-1</sup> in 2007/2008) and inorganic source (857.3/857.5 kg·ha<sup>-1</sup> in 2007/2008), respectively. Significant higher grain yield realized in conventional management practices could be attributed to the better growth and yield parameters

Table 2. Effect of rice establishment techniques and nutrient sources on N, P, K and S uptake ((kg·ha<sup>-1</sup>).

Treatments	N uptake (kg·ha <sup>-1</sup> )		P uptake (kg·ha <sup>-1</sup> )		K uptake (kg·ha <sup>-1</sup> )		S uptake (kg·ha <sup>-1</sup> )	
	2007	2008	2007	2008	2007	2008	2007	2008
<b>Management systems</b>								
M <sub>1</sub> (SRI)	16.56	15.54	1.57	1.53	20.47	20.93	1.85	1.71
M <sub>2</sub> (ICM)	14.62	14.08	1.44	1.36	17.99	19.67	1.76	1.58
M <sub>3</sub> (PoP)	17.45	16.71	1.56	1.56	21.09	23.47	1.93	1.95
M <sub>4</sub> (CMP)	20.42	20.42	1.93	2.20	25.98	28.56	2.46	2.22
<b>SEd</b>	<b>0.92</b>	<b>0.89</b>	<b>0.10</b>	<b>0.13</b>	<b>1.07</b>	<b>1.31</b>	<b>0.29</b>	<b>0.29</b>
<b>CD (0.05)</b>	<b>2.10</b>	<b>2.02</b>	<b>0.11</b>	<b>0.29</b>	<b>2.42</b>	<b>2.97</b>	<b>NS</b>	<b>NS</b>
<b>Nutrient sources</b>								
S <sub>1</sub> (Organic)	18.35	17.56	1.63	1.88	20.33	20.44	1.78	1.93
S <sub>2</sub> (Integrated)	15.90	15.78	1.82	1.89	24.11	26.38	2.05	2.21
S <sub>3</sub> (Inorganic)	17.55	16.73	1.42	1.44	19.72	22.65	1.77	1.86
<b>SEd</b>	<b>1.02</b>	<b>0.87</b>	<b>0.05</b>	<b>0.11</b>	<b>1.61</b>	<b>1.29</b>	<b>0.34</b>	<b>0.18</b>
<b>CD (0.05)</b>	<b>NS</b>	<b>NS</b>	<b>0.10</b>	<b>0.22</b>	<b>3.32</b>	<b>2.66</b>	<b>NS</b>	<b>NS</b>

**Table 3. Effect of rice establishment techniques and nutrient sources on Fe, Zn and Mn uptake ( $\text{kg}\cdot\text{ha}^{-1}$ ).**

Treatments	Fe uptake ( $\text{kg}\cdot\text{ha}^{-1}$ )		Zn uptake ( $\text{kg}\cdot\text{ha}^{-1}$ )		Mn uptake ( $\text{kg}\cdot\text{ha}^{-1}$ )	
	2007	2008	2007	2008	2007	2008
<b>Management systems</b>						
M <sub>1</sub> (SRI)	0.74	0.75	0.76	0.81	0.78	0.81
M <sub>2</sub> (ICM)	0.65	0.69	0.68	0.73	0.70	0.74
M <sub>3</sub> (PoP)	0.78	0.83	0.81	0.88	0.84	0.88
M <sub>4</sub> (CMP)	0.99	1.06	1.00	1.08	1.04	1.11
<b>SEd</b>	<b>0.05</b>	<b>0.05</b>	<b>0.05</b>	<b>0.06</b>	<b>0.06</b>	<b>0.06</b>
<b>CD (0.05)</b>	<b>0.11</b>	<b>0.12</b>	<b>0.11</b>	<b>0.14</b>	<b>0.13</b>	<b>0.14</b>
<b>Nutrient sources</b>						
S <sub>1</sub> (Organic)	0.63	0.66	0.74	0.81	0.77	0.81
S <sub>2</sub> (Integrated)	0.93	1.00	1.02	1.06	0.91	0.97
S <sub>3</sub> (Inorganic)	0.81	0.83	0.68	0.76	0.85	0.87
<b>SEd</b>	<b>0.10</b>	<b>0.13</b>	<b>0.04</b>	<b>0.05</b>	<b>0.10</b>	<b>0.12</b>
<b>CD (0.05)</b>	<b>0.26</b>	<b>0.22</b>	<b>0.09</b>	<b>0.11</b>	<b>NS</b>	<b>NS</b>

**Table 4. Effect of rice establishment techniques and nutrient sources on yield attributes of Njavara rice.**

Treatments	Number of tillers $\text{m}^{-2}$		Grain yield ( $\text{kg}\cdot\text{ha}^{-1}$ )		Straw yield ( $\text{kg}\cdot\text{ha}^{-1}$ )	
	2007	2008	2007	2008	2007	2008
<b>Management systems</b>						
M <sub>1</sub> (SRI)	96.0	95.5	1235	1210	840.8	821.6
M <sub>2</sub> (ICM)	146.7	146.7	1126	1115	764.7	756.2
M <sub>3</sub> (PoP)	591.1	587.8	1338	1324	897.3	899.7
M <sub>4</sub> (CMP)	981.4	976.4	1685	1697	1041.4	1038.4
<b>SEd</b>	<b>4.02</b>	<b>2.16</b>	<b>15.68</b>	<b>15.43</b>	<b>9.41</b>	<b>9.28</b>
<b>CD (0.05)</b>	<b>9.10</b>	<b>4.88</b>	<b>35.47</b>	<b>34.89</b>	<b>21.29</b>	<b>20.99</b>
<b>Nutrient sources</b>						
S <sub>1</sub> (Organic)	454.7	450.7	1285	1266	872.1	857.9
S <sub>2</sub> (Integrated)	452.0	451.5	1494	1496	928.7	920.5
S <sub>3</sub> (Inorganic)	453.9	452.7	1258	1246	857.3	857.5
<b>SEd</b>	<b>3.96</b>	<b>2.16</b>	<b>14.26</b>	<b>34.89</b>	<b>9.25</b>	<b>9.06</b>
<b>CD (0.05)</b>	<b>NS</b>	<b>NS</b>	<b>29.42</b>	<b>28.59</b>	<b>19.10</b>	<b>18.71</b>

realized in this treatment compared to other establishment techniques. Significant growth characters like leaf number per plant, leaf area index and tiller number per unit area might have resulted in increased photosynthesis and production resulting of photosynthates which finally transformed into high number of panicles per unit area and thereafter higher relative accumulation of dry matter.

Straw yield also showed the same trend like grain yield in establishment techniques and nutrient sources.

#### 4. Conclusion

All the tillers produced in SRI were productive tillers and 91% of the tillers produced in ICM bore panicles. Uptake

of all the nutrients in conventional management practices was significantly higher than that in the other three establishment techniques. Highest total nutrient (P, K, Fe and Zn) uptake by crop (grain + straw) occurred in integrated nutrient source. Maximum root dry matter (at 9<sup>th</sup> WAS/WAT) was recorded in SRI and root development was least in conventional management practices which combined with least culm strength might have resulted in lodging of the crop. Tiller per unit area in SRI practices was found to be the minimum which limit the uptake of nutrients, while in case of conventional management practices it was found to be vice versa.

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