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

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Field experiments with medicinal rice Njavara were conducted at Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala during summer 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_1), Integrated Crop Establishment Method (ICM) (M_2), Package of practices (PoP) (M_3) of Kerala Agricultural University and Conventional management practices (CMP) (M_4) in main plot. Three nutrient sources *viz*., ((i) organic, (ii) integrated use of organic and inorganic, (iii) chemical fertilizers only were used under different establishment techniques. Root dry matter production was determined at weekly intervals and plant nutrients uptake was determined separately by calculating from the product of dry matter, straw dry weight, grain yield and percentage of nutrients. The result revealed that at early stages (4-6 WAT/WAS) (Weeks after transplanting/Weeks after sowing), root dry matter production hill^{-1} was in the order of SRI >ICM > CMP > PoP which changed to SRI > ICM > PoP > CMP from 7th week onwards. Maximum root dry matter (at 9th WAS/WAT) was recorded in SRI (0.51/0.50 g hill^{-1} 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, highest total (N, P, K, Fe, Mn and Zn) uptake by crop was recorded under integrated nutrient source than organic and inorganic sources.

Key words: Njavara rice, establishment techniques, nutrient sources, root growth, total nutrient uptake, yield

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 (Budhar, 2011). Njavara is widely used in the Ayurvedic system of medicine, especially in Panchakarma treatment. Njavara as a special cereal, has the properties to rectify the basic ills affecting our circulatory, respiratory and the digestive systems.

The water and nutrient uptake ability of plants highly depends on the root architecture (Lynch, 1995), while the root system directly affects the amount of water available to crop. Most of crops largely rely on stored water in the soil profile. The root systems of rice consist of seminal and nodal roots with first- and higher-order lateral roots. The roots length can penetrate from 70 to 80 cm in soil. However, the lowland rice has got a shallow and compact root system, most of which are distributed in the top 15 cm of soil (Morita *et al*, 1995). The soil moisture has a profound impact on root growth, viability and functionality and thus plant growth (Huang, 1999). 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. Keeping all the above in view, the present investigation was undertaken to study the developmental phenology of Njavara root growth and its nutrient uptake under different establishment techniques and nutrient sources.

Materials and Methods

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^{-1}), available phosphorus (22.0 kg ha^{-1}) and available potassium (140.2 kg ha^{-1}) status. The experiments were laid out in a split plot design with three replications by fitting the establishment techniues in main plot *viz*. SRI (System of Rice Intensification) (M_1), ICM (Integrated Crop Establishment Method) (M_2), PoP (Package of Practices) (M_3) (Recommendation of Kerala Agricultural University) as well as the Conventional Management Practices (M_4) and nutrient sources *viz*., organic sources (S_1), integrated nutrient sources (S_2) and inorganic sources (S_3) in sub plot. Eight, twelve and eighteen days old seedlings as per treatments were transplanted at the rate of 1, 2

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and 3 seedlings per hill at 20x20 cm, 20x20 cm and 15x10 cm spacings in SRI, ICM and PoP treatments, respectively. In conventional management practices, pre germinated seeds were broadcasted on the same day. Nutrient management recommendation of Package of Practices: Crops KAU (2007) of Kerala Agricultural University was adopted i.e 5t FYM + 40:20:20 kg NPK ha^{-1}. Full FYM + 2/3 N + Full P + ½ K were applied as basal. 1/3 N + ½ K were applied at panicle initiation. In the organic treatments 40:20:20 kg NPK ha^{-1}were supplied through FYM, rock phosphate and wood ash. In integrated nutrient management treatments, 40: 20: 20 kg NPK ha^{-1} 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^{-1}, respectively.

Results and Discussion

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 hill^{-1} was recorded at weekly interval from 4th WAT/WAS till physiological maturity. At the early stages (4-6 WAT/WAS) root dry matter production hill^{-1} was in the order SRI >ICM > conventional management practices > PoP which changed to SRI > ICM > PoP > conventional management practices from 7th week onwards (Table 1). Throughout the crop growth period, all the establishment techniques differed significantly from one another in root dry matter hill^{-1}. Increase in root dry matter occurred up to 9 WAS/WAT (Weeks after transplanting/Weeks after sowing). Higher root dry matter (at 9th WAS/WAT) was recorded in SRI (0.51/0.50 g hill^{-1} in 2007/2008) and it was 21/25% higher in 2007/2008 than ICM (0.42/0.60 g hill^{-1} in 2007/2008) and 31/32% higher in 2007/2008 than PoP (0.39/0.38 g hill^{-1} in 2007/2008) and 59/52% higher in 2007/2008 than conventional management practices (0.32/0.33 g 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 6th 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 7th 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. Planting of single seedling rather than in clumps helped to avoid root competition and promoted vigorous root growth (Uphoff and Randriamiharisoa, 2002). Anitha (2005) reported that following a wider spacing 25 x 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 have more physiological activity.

Table 1. Effect of Njavara rice establishment techniques and nutrient sources on root dry matter production (g hill^{-1})

Treatment	4th week		5th week		6th week		7th week		8th week		9th week		10th week		Physiological Maturity	
Management system	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
M_1 (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_2 (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_3 (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_4 (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	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (0.05)	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03
Nutrient source																
S_1 (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_2(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_3 (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	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In square planting with wider spacing, more 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 Shrirame *et al*., (2008).

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 the years. 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^{-1} in 2007 and 2008 (N uptake), 1.93/2.20 kg ha^{-1} in 2007 and 2008 (P uptake), 25.98/28.56 kg ha^{-1} in 2007 and 2008 (K uptake), 0.99/1.06 kg ha^{-1} in 2007 and 2008 (Fe uptake), 1.00/1.08 kg ha^{-1} in 2007 and 2008 (Zn uptake) and 1.04/1.11 kg ha^{-1} in 2007 and 2008 (Mn uptake) than that in the other three establishment techniques (Table 2 and 3). Uptake of all nutrients in PoP and ICM were on par and that in SRI and ICM were also on par. Nabheerong (1992) 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.

Table 2. Effect of Njavara rice establishment techniques and nutrient sources on N,P,K and S uptake ((kg ha^{-1})

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
Management system	2007	2008	2007	2008	2007	2008	2007	2008
M_1 (SRI)	16.56	15.54	1.57	1.53	20.47	20.93	1.85	1.71
M_2 (ICM)	14.62	14.08	1.44	1.36	17.99	19.67	1.76	1.58
M_3 (PoP)	17.45	16.71	1.56	1.56	21.09	23.47	1.93	1.95
M_4 (CMP)	20.42	20.42	1.93	2.20	25.98	28.56	2.46	2.22
SEd	0.92	0.89	0.10	0.13	1.07	1.31	0.29	0.29
CD (0.05)	2.10	2.02	0.11	0.29	2.42	2.97	NS	NS
Nutrient source								
S_1 (Organic)	18.35	17.56	1.63	1.88	20.33	20.44	1.78	1.93
S_2 (Integrated)	15.90	15.78	1.82	1.89	24.11	26.38	2.05	2.21
S_3 (Inorganic)	17.55	16.73	1.42	1.44	19.72	22.65	1.77	1.86
SEd	1.02	0.87	0.05	0.11	1.61	1.29	0.34	0.18
CD (0.05)	NS	NS	0.10	0.22	3.32	2.66	NS	NS

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

Treatment	Fe uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})		Mn uptake (kg ha^{-1})	
Management system	2007	2008	2007	2008	2007	2008
M_1 (SRI)	0.74	0.75	0.76	0.81	0.78	0.81
M_2 (ICM)	0.65	0.69	0.68	0.73	0.70	0.74
M_3 (PoP)	0.78	0.83	0.81	0.88	0.84	0.88
M_4 (CMP)	0.99	1.06	1.00	1.08	1.04	1.11
SEd	0.05	0.05	0.05	0.06	0.06	0.06
CD (0.05)	0.11	0.12	0.11	0.14	0.13	0.14
Nutrient source						
S_1 (Organic)	0.63	0.66	0.74	0.81	0.77	0.81
S_2 (Integrated)	0.93	1.00	1.02	1.06	0.91	0.97
S_3 (Inorganic)	0.81	0.83	0.68	0.76	0.85	0.87
SEd	0.10	0.13	0.04	0.05	0.10	0.12
CD (0.05)	0.26	0.22	0.09	0.11	NS	NS

Nutrient sources showed significant influence on total uptake by the crop (P, K, Fe and Zn) in both the years. Nutrient sources showed no significant influence on total N, S and Mn uptake. Highest P uptake (1.82/1.89 kg ha^{-1} in 2007/2008), K uptake (24.11/26.38 kg ha^{-1} in 2007/208), Fe uptake

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

Treatment	Number of tillers m^{-2}		Grainyield (kg ha^{-1})		Strawyield (kg ha^{-1})	
Management system	2007	2008	2007	2008	2007	2008
M_1 (SRI)	96.0	95.5	1235	1210	840.8	821.6
M_2 (ICM)	146.7	146.7	1126	1115	764.7	756.2
M_3 (PoP)	591.1	587.8	1338	1324	897.3	899.7
M_4 (CMP)	981.4	976.4	1685	1697	1041.4	1038.4
SEd	4	2	15	15	9	9
CD (0.05)	9	4	35	3	21	20
Nutrient source						
S_1 (Organic)	454.7	450.7	1285	1266	872.1	857.9
S_2(Integrated)	452.0	451.5	1494	1496	928.7	920.5
S_3 (Inorganic)	453.9	452.7	1258	1246	857.3	857.5
SEd	3	2	14	34	9	9
CD (0.05)	NS	NS	29	28	19	18

(0.93/1.00 kg ha^{-1} in 2007/2008) and Zn uptake (1.02/1.06 kg ha^{-1} in 2007/2008) by the crop (grain + straw) occurred in integrated nutrient source and organic and inorganic source were on par. Ayalew and Dejene (2012) 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. Mithun *et al.*, (2007) and Srinivasan and Angayarkanni, (2008) reported that uptake of nutrients was improved by the application of integrated use of organic and inorganic fertilizer compared to RDF.

Effect of rice establishment techniques and nutrient source on yield

Higher grain yield recorded in conventional management practices (M_4) (1041.4/1038.4 kg ha^{-1} in 2007/2008) which 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^{-1} in 2007/2008) was obtained in integrated nutrient source (S_2) which was followed by organic source (872.1/857.9 kg ha^{-1} in 2007/2008) and inorganic source (857.3/857.5 kg ha^{-1} in 2007/2008), respectively. Significantly higher grain yield realized in conventional management practices may be attributed to the significantly better growth and yield parameters realized in this treatment compared to other establishment techniques. Significantly higher growth characters like leaf number per plant, leaf area index and tiller number per unit area might have resulted in increased photosynthesis and production of photosynthates which finally transformed into significantly higher number of panicles per unit area and higher relative accumulation of dry matter in the panicles. Straw yield also showed the same trend like grain yield in establishment techniques and nutrient sources.

Conclusion

Even though Njavara did not respond to SRI and ICM to the same extent in tillering like other varieties, 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 9th 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, where in case of conventional management practices it found to be wise versa.

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