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Root Morphological Characters at Several Distances from Irrigated Trench in Rice Varieties Grown under Rain-fed Conditioned Plots

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ABSTRACT

In rain-fed area, water deficit or drought stress is a serious limiting factor to rice production and yield stability, and root system with deep roots is one of the most important characters. This study aimed to identify which root morphological characters induce the advantage of the deep rooting between varieties. Six varieties consisting of two groups of ecosystems, upland: NERICA1, NERICA4, NERICA7, Yumenohatamochi, and lowland: Hinohikari and Koshihikari were grown under the rain-fed condition in the field of Kochi University. The results suggested the adaptability of NERICA varieties to the upland rainfed conditions, due to the development of roots into the deep soil layer. NERICA7 had lowest soil moisture content and had a higher root weight, root surface area, root length and the number of root branching in the deep soil layer at heading stage. NERICA7 also had higher value on dry weight, surface area and thickness in total amount of root morphological characters. Varietal difference of root surface area in the deep soil layer was related to both root length and thickness, and root length was involved with root branches. On the other hand, the varietal difference of total amount of root surface area was related not to the root length, but to the root thickness. This result suggested that the emergence of the thick roots (probably primary crown roots) allowed the roots to penetrate into the deep soil layer. Therefore, it is considered that the emergence of thick roots is an important trait for the deep rooting character.

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Keywords:
rice; irrigated-trench; root morphological characters; rain-fed

1. Introduction

The main obstacles to cultivation in rain-fed land are very low water availability and large fluctuations in groundwater content. This has an impact on stunted growth and development of plants, both physiological and morphological and biochemical processes so that crop production also decreases.

Maclean *et al.*, (2002) estimated that about one-third of the world's rice production area is a lowland rain-fed area and most are prone to drought. Addressing this issue should be an important part of a breeding program aimed at crop improvement. The adaptive mechanisms of plants in response to drought have been reported by several scientists (Fukai and Cooper, 1995; Nguyen *et al.*, 1997; Chapra and Sinha, 1998; Ndjiondjop *et al.*, 2010; Abdallah *et al.*, 2016). The rooting system is one of the important components of drought resistance. Among the root morphological characters, root length and root thickness are important characters associated with drought resistance in upland conditions (Ganapathy *et al.*, 2010).

Increasing the thickness of the roots can increase the resistance to drought because the roots can increase root length density, root surface area, and water uptake by producing more and larger root branches. In lowland rain-fed conditions, long root densities greater than 20 cm and rapid root responses to alter soil moisture levels in soil layers 10-20 and 20-30 cm are common root characters for drought resistant genotypes (Ingram *et al.*, 1994). However, roots are usually distributed in shallow soil layers in lowland rain-fed areas, possibly due to the presence of a hard and watertight soil layer that inhibits deep rooting. The groundwater extraction is confined to the soil layer where root penetration occurs. Thus, in lowland rain-fed with the presence of hard and watertight soil layers, the development of a root system above the coating is important for water absorption by plants (Kano-Nakata *et. al.*, 2013).

The root development has been evaluated under different soil moisture conditions in sloping system (Kameoka *et al.*, 2015) and sprinkler system (Kameoka *et al.*, 2016). In this study, we used furrow irrigation system to compare rice varieties under different soil moisture conditions.

Based on the description, we have conducted a set of research on root morphological change at several distances from irrigated-trench in six different rice varieties grown on rain-fed conditioned plots.

2. Materials and Methods

Six rice varieties consisting of two groups of ecosystems. The upland ecosystem consisted of the NERICA1 (N1), NERICA4 (N4), NERICA7 (N7), Yumenohatamochi (YH) rice varieties, and Hinohikari (HH) and Koshihikari (KH) rice varieties for the low land ecosystem. They were grown in plots under rain-fed condition in the experimental field of Kochi University, Monobe Campus, Kochi Prefecture, Japan.

Seeds were sown directly on May 23, 2016 at a rate of 5 seeds per hill (Bhowmik *et. al.*, 2012), with a spacing of 30 x 10 cm on a plot measuring 2.6 m x 4.1 m. Fertilizer (N:P:K = 14:14:14, 40 kg ha^{-1}) was applied at 29 days after sowing (DAS). The irrigation systems were made by a small dugout trench (5 cm wide, 15 cm deep) in the center of the plots, and were manually implemented by giving water to the trench once every two days, starting from 43 – 116 DAS, except for rainy days. Shoot samples were collected at heading and maturity periods with distance of 20, 40, 60 cm from the center trench, and separated into each organ. In addition, at heading stage, the remaining roots for each hill were extracted using a soil core (11.5 cm in diameter, 15 cm in height) separated for each 5 cm in depth. Root length, root surface area and root branching was determined using software (WinRHIZO, Regent). All the separated parts were dried in the oven at $80^{o}C$ for three days, and then the constant dry weight was measured. Soil moisture content with distance of 20, 40, 90 cm from the center trench was measured using soil moisture meter (TDR-100, FieldScout). An analysis of variance (ANOVA) and Tukey's honest significant difference (HSD) procedure using JMP for windows version 7.0 was performed to determine the response of variety and distance.

3. Results and Discussion

Soil moisture content was significantly higher in 20 cm than in 40 and 90 cm distance from trench crossing in the middle of each plots. There was a significant difference in soil moisture between varieties, and N7 had the lowest soil moisture content between varieties (Figure 1). This results suggested that water uptake of N7 was higher that another varieties. As Trillana *et al*. (2001) reported, lower soil moisture shown higher water uptake of IRAT13.

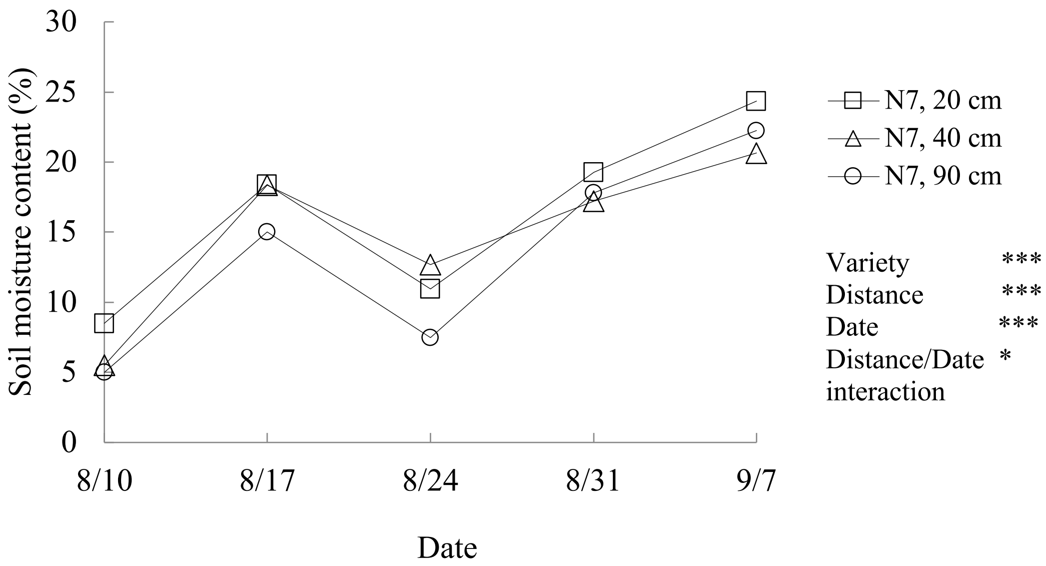

Figure 1. Soil moisture content condition at 20, 40 and 90 cm distance from NERICA7 (N7) plants. The symbols *and *** indicates significance at P<0.05 and P<0.001

Significant differences between varieties were shown in root morphological characters of the deep soil layer at heading stage, and upland rice varieties (N7, N4, N1, and YH) had a higher root weight, root surface area, root length and the number of root branching than those in lowland varieties (HH and KH) (Table 1). However, the effect of distance on root morphological characters was not significant. There was a significant interaction between the variety and distance on root weight, root surface area, root length and root branching, but not in root thickness and deep root length ratio. This suggests that the effect of the distance was different between varieties. Kono (1993) explains that the roots tend to penetrate deeply with a decrease in soil water content. The tendency to penetrate to the soil layer by nodal roots is known as the deep-rooted characteristics, which are governed by genetic factors. However, changes can occur in these characteristics, depending on soil factors, especially water conditions, even on the same cultivar. Nazirah (2008) also reported that the growth of each variety varies under the same environmental conditions because each variety has a different genetic ability to respond to its environmental conditions.

Table 1. Root morphological characters (plant-1) in the deepest soil layer only (10 - 15 cm deep)

Treatment		Dry weight (g)	Surface area (cm2)	Length (cm)	Branch	Thickness (mm)	Deep root length ratio (%)
Variety (V)	HH	0.06 c	57.4 c	990 bc	8226 bc	0.19 bc	16.2 ab
	KH	0.03 c	29.5 c	553 c	4750 c	0.17 c	10.8 b
	N4	0.15 b	109.7 b	1642 b	15433 b	0.22 ab	23.9 ab
	N1	0.17 b	116.6 b	1596 b	13432 bc	0.24 a	17.4 ab
	N7	0.30 a	196.8 a	2745 a	27371 a	0.24 a	29.6 a
	YH	0.10 bc	72.8 bc	1154 bc	11142 bc	0.20 abc	22.6 ab
Distance (D) (cm)	20	0.13 a	87.4 a	1212 a	10737 a	0.22 a	18.5 a
	40	0.14 a	102.1 a	1559 a	14736 a	0.20 a	21.2 a
	60	0.14 a	101.9 a	1569 a	14705 a	0.20 a	20.6 a
Variety		***	***	***	***	***	*
Distance		ns	ns	ns	ns	ns	ns
V x D		*	**	**	**	ns	ns

*Deep root length ratio was calculated as the ratio of root length in 10-15 cm soil depth to total root length. Value with same letter indicates not significant difference at 0.05 level. ns indicates not significant. *, ** and *** indicates significance at P<0.05, P<0.01 and P<0.001.*

Table 2. Total amount of root morphological characters (plant-1) for the three layers observed (0 - 15 cm deep)

Treatment		Dry weight (g)	Surface area (cm2)	Length (cm)	Branch	Thickness (mm)
Variety (V)	HH	0.60b	408 bc	6306 a	55841a	0.21 b
	KH	0.51b	319 c	5136 a	49282a	0.20 b
	N4	0.96ab	534 abc	6889 a	61167a	0.25 a
	N1	1.35a	748 ab	9332 a	77607a	0.26 a
	N7	1.40a	760 a	9406 a	84111a	0.26 a
	YH	0.79b	447 abc	5685 a	52416a	0.25 a
Distance (D) (cm)	20	0.92a	508 a	6346 a	54066a	0.25 a
	40	0.96a	558 a	7568 a	68787a	0.23 b
	60	0.93a	543 a	7463 a	67358a	0.23 b
Variety		***	**	*	ns	***
Distance		ns	ns	ns	ns	*
V x D		ns	ns	ns	ns	ns

*Value with same letter indicates no significant difference at 0.05 level. ns indicates not significant. *, ** and *** indicates significance at P<0.05, P<0.01 and P<0.001.*

Similarly, the significant difference between varieties in total amount of root morphological characters was observed, and upland varieties had higher value on dry weight, surface area and thickness than lowland varieties (Table 2). The effect of distance was significant only on thickness, and the root thickness in 20 cm was significantly higher than that in 40 and 60 cm. This result indicates that soil condition in 20 cm from the irrigated-trench suitable for the root development, especially for root diameter (thickness), and variety with thicker root was drought tolerance. Trillana *et al.* (2001) explained that root length density (RLD) and root diameter (thickness) are often used to characterize root system development of rice cultivar and under rainfed lowland condition, RLD in the 10-30 cm layer and the dynamic shedding of roots and root elongation were associated with drought tolerance.

Figure 2 showed root surface area sampled from the deep soil layer was significantly correlated with total root surface area. Root surface area plays an important role in water and nutrient uptake to support plant growth. Teo (1995) reported that an increase in root length also resulted in an increase in root surface area, thus providing a more open area for nutrient uptake. Gowda *et al*. (2011) also explained that the surface area is the size of the contact with the soil, the main determinant for water and nutrient uptake as the whole root system.

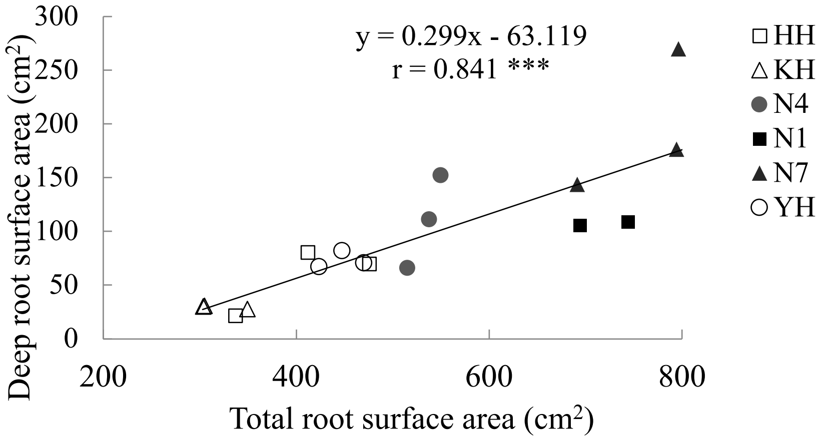

Figure 2. Relationship between total root surface area and deep root surface area at heading stage. The symbol *** indicates significance at P<0.001

Total shoot dry weight was not affected by the variety and distance at the heading stage (Table 3). However, the shoot dry weight in maturity stage was significantly different with varieties, and N4 showed a higher value than KH. This result suggests that N4 was a high-yielding genotype that expressed root plasticity. As stated by Menge *et al*. (2016) under moderate drought soil conditions where roots could penetrate into the deep soil layer, deep root development was greater in NERICA 4 than in NERICA 1, which contributed to maintaining dry matter production.

Table 3. Shoot dry weight (g plant^{-1}) at heading and maturity stage of seven rice varieties planted at three distances from its irrigated trench

Treatments		Shoot dry weight (g plant^{-1})	
		Heading	Maturity
Variety (V)	HH	13.4 a	20.0 ab
	KH	11.6 a	14.4 b
	N4	12.5 a	28.2 a
	N1	13.6 a	20.7 ab
	N7	12.5 a	19.6 ab
	YH	14.1 a	23.1 ab
Distance (D) (cm)	20	13.9 a	19.2 a
	40	13.2 a	21.6 a
	60	11.8 a	22.2 a
Variety		ns	*
Distance		ns	ns
V x D		ns	ns

*Value with same letter indicates no significant difference at 0.05 level. ns indicates not significant. * indicates significance at P<0.05.*

Kameoka *et al*. (2015) also conclude that the genotype that expressed root plasticity with root system developing in the soil portion where more soil moisture was available showed larger shoot dry weight than a genotype that showed root plasticity in the soil layer where soil moisture was less available. Similar response were also reported, the high-yielding cultivars whose shoot biomass at maturity in aerobic culture was greater than in flooded culture (Katsura *et al.*, 2010),

4. Conclusion

From the results, it can be concluded that NERICA varieties had the adaptability to the upland rainfed conditions, due to the development of roots into the deep soil layer. Varietal difference of root surface area in the deep soil layer was related to both root length and thickness, and root length was involved with root branches. On the other hand, the varietal difference of total amount of root surface area was related not to the root length, but to the root thickness. This result suggested that the emergence of the thick roots (probably primary crown roots) allowed the roots to penetrate into the deep soil layer. Therefore, it is considered that the emergence of thick roots is an important trait for the deep rooting character.

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References

Abdallah, E.H., Y. Musa, M. Mustafa, R. Sjahril and M. Riadi. (2016). Comparison between hydro- and osmo-priming to determine period needed for priming indicator and its effect on germination percentage of aerobic rice cultivars (*Oryza sativa* L.). AGRIVITA Journal of Agricultural Science. 38(3): 222-230. DOI: http://doi.org/10.17503/agrivita.v38i3.

Bhowmik, S.K., M.A.R. Sarkar and F. Zaman. (2012). Effect of Spacing and Number of Seedlings Per Hill on The Performance of *Aus* Rice cv. NERICA 1 under Dry Direct Seeded Rice (DDSR) System of Cultivation. J. Bangladesh Agril. Univ. 10(2): 191-195.

Chapra, R.K. and S.K. Sinha. (1998). Prospects of Success of Biotechnological Approaches for Improving Tolerance to Drought Stress in Crop Plants. Current Science. 74(1): 25-34.

Fukai, S. and M. Cooper. (1995). Development of Drought Resistance Cultivars Using Physio-Morphological Traits in Rice. Field Crops Research. 40: 67-86.

Ganapathy, S., S.K. Ganesh, P. Shanmugasundaram and R.C. Babu. (2010). Studies on Root Traits for Drought Tolerance in Rice (*Oryza sativa* L.) under Controlled (PVC Pipes) Condition. Electronic Journal of Plant Breeding. 1(4): 1016–20.

Gowda, V.R.P., A. Henry, A. Yamauchi, H.E. Shashidhar and R. Serraj. (2011). Root biology and genetic improvement for drought avoidance in rice. Field Crops Research, 122, 1–13.

Ingram, K. T., F.D. Bueno, O.S. Namuco, E.B. Yamboo and C.A. Beyrouty. (1994). Rice Root Traits for Drought Resistance and Their Genetic Variation. In: Rice Roots: Nutrient and Water Use. G.J.D. Krik (ed.), IRRI, Philippines, pp: 67-70.

Kameoka, E., R.R. Suralta, S. Mitsuya and A. Yamauchi. (2015). Matching the expression of root plasticity with soil moisture availability maximizes production of rice plants grown in an experimental sloping bed with soil moisture gradients. Plant Production Science, 18(3): 267–276.

Kameoka, E., R.R. Suralta, S. Mitsuya and A. Yamauchi. (2016). Developmental Plasticity of Rice Root System Grown under Mild Drought Stress Condition with Shallow Soil Depth; Comparison between Nodal and Lateral roots, Plant Production Science.19(3): 411-419. DOI: 10.1080/1343943X.2015.1128094.

Kano-Nakata, M., V.R.P. Gowda, A. Henry, R. Serraj, Y. Inukai, D. Fujita, N. Kobayashi, R.R. Suralta and A. Yamauchi. (2013). Functional Roles of the Plasticity of Root System Development in Biomass Production and Water Uptake under Rainfed Lowland Conditions. Field Crops Research. 144: 288–296.

Katsura, K., M. Okami, H. Mizunuma and Y. Kato. (2010). Radiation use efficiency, N accumulation and biomass production of high-yielding rice in aerobic culture. Field Crop. Res. 117: 81-89.

Kono, Y. (1993). Soil Factor and Root Morphology, Morphological Responses to the Environment. In Science of The Rice Plant: Morphology. Eds., T. Matsuo and K. Hoshikawa, Tokyo: Food and Agriculture Policy Research Center, pp: 507-525

Maclean, J.L., D.C. Dawe, B. Hardy and G.P. Hettel. (2002). Rice Almanac. Third Edition. Los Baños (Philippines): International Rice Research Institute, Bouaké (Côte d'Ivoire): West Africa Rice Development Association, Cali (Colombia): International Center for Tropical Agriculture, Rome (Italy): Food and Agriculture Organization. 253 p.

Menge, D.M., E. Kameoka, M. Kano-Nakata, A. Yamauchi, S. Asanuma, H. Asai, M. Kikuta, R.R. Suralta, T. Koyama, T.T. Tran, J.D.L.C. Siopongco, S. Mitsuya, Y. Inukai and D. Makihara. (2016): Drought-induced root plasticity of two upland NERICA varieties under conditions with contrasting soil depth characteristics, Plant Production Science, DOI: 10.1080/1343943X.2016.1146908

Nazirah, L. (2008). Response Some Upland Rice Varieties to Water Distribution Intervals and Levels. Master Thesis, Graduate School of University of North Sumatera, Medan. (*in Indonesian*)

Ndjiondjop, Marie-Noelle, F. Cisse, K. Futakuchi, M. Lorieux, B. Manneh, R. Bocco and B. Fatondji. (2010). Effect of Drought on Rice (Oryza spp.) Genotypes According to Their Drought Tolerance Level. Second Africa Rice Congress, Bamako, Mali, 22–26 March 2010: Innovation and Partnerships to Realize Africa's Rice Potential.

Nguyen, H.T., R.C. Babu and A. Blum. (1997). Breeding for Drought Tolerance in Rice: Physiology and molecular genetics considerations. Crop Science 37, 1426–1434.

Teo, Y.H., C.A. Beyrouty, R.J. Norman and E.E. Gbur, (1995). Nutrient Uptake Relationship to Root Characteristics of Rice. Plant Soil 171: 297-302. https://doi.org/10.1007/BF00010285

Trillana, N., T. Inamura, R. Chaudhary and T. Horie, (2001). Root System Development in Two Rice Cultivars during Stress Recovery and Plant Traits. Plant Prod. Sci 4(3): 155–59.