Madras Agric. J., 101 (1-3): 47-50, March 2014

Grain Filling is Positively Correlated with Root Activity in Aerobic Rice Under Different Irrigation Methods

K. Vanitha*, S. Mohandass and S. Chellamuthu
Water Technology Centre
Tamil Nadu Agricultural University, Coimbatore - 641 003

Field experiments were conducted using two rice genotypes with differential root activity. The genotype, TNRH 180 rice hybrid performed better with higher root activity than the variety PMK (R) 3 in both dry and summer season. Connecting irrigation methods, sub-surface drip irrigation at 125 % PE water level treatment maintained enhanced root activity at all the phenophases studied. The grain filling rate was positively correlated with root activity expressed as α-naphthylamine oxidation ability (RA) per gram of fresh root (RA), RA per spikelet (RA grain RA per sink capacity (RA). It is inferred that RA could be an effective parameter that can be sink grain altered to improve grain filling and test weight in rice for enhanced productivity in surface and sub-surface drip irrigated conditions.

Key words: Surface and sub-surface drip, Aerobic rice, Grain filling, Root activity.

The α-naphthylamine oxidase activity of rice roots, an index of the oxidation status in the rhizosphere region (Ota, 1970), was significantly correlated with the growth stages. Root oxidation activity of rice declined in the later growth stage in flooded culture (Samejima *et al.*, 2004; Zhang *et al.*, 2009). Ando *et al*. (1983) showed that K deficiency had low O availability and higher α-napthylamine oxidation activity. Thus, several reports indicated that adequate K nutrition is very much important in maintaining the oxidizing power of rice roots (Kirk and Bajita, 1995).

Root oxidizing power reduced the radiation use efficiency (Horie *et al.*, 1997) and also the nitrogen accumulation rate (Samejima *et al.*, 2004) especially, at later growth stages. However, aeration of the soil by intermittent drainage could minimize the decline in root oxidation activity during the reproductive stage of the flooded rice culture (Yang *et al.*, 2004; Zhang *et al.*, 2008).

Moderate soil drying significantly increased, whereas, severe soil drying reduced root oxidation activity at the late grain filling stage (Zhang *et al.*, 2008), indicating that a moderate soil drying in alternate wetting and drying method of irrigation benefited, while severe soil drying harmed root activity. Vanitha (2008) observed an increased oxidizing power of the aerobic rice roots with the drip fertigation practice. The aim of this study was to assess whether the grain filling rate is positively correlated with root activity in aerobic rice under surface and sub-surface drip irrigation.

Materials and Methods

Field experiments were conducted in the Field No. D6 (dry season, 2009 and summer, 2010) of the wetland farm (11º N, 77 º E and 426.72 m above MSL) at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The experimental plots were dry ploughed and harrowed. Raised flat beds were formed and laid out with double channels around all the plots to prevent subsoil lateral water flow. Before sowing, the wet seeds were treated with the *Pseudomonas fluorescens* biofungicide at the rate of 200 g 10 kg^{-1} of seeds and sown in the field for all the treatments. Sprouted and treated seeds were dry-sown by hand dibbling at 3 cm depth in rows of 20 cm apart at seeding rate of 30 kg ha^{-1} using two genotypes; pipeline hybrid (TNRH 180) and PMK (R) 3 spaced at 20 x 10 cm. Installation of drip system, from sub-main, in-line laterals were laid at a spacing of 0.8 m with 4 lph emitters spaced at 0.6 m such that one lateral could cover four rows of 20 cm each. In case of sub-surface drip irrigation, the laterals were buried to a depth of 10 cm in the soil. The treatment details are shown in Table 1 and 2.

Rice root activity was determined by measuring oxidation of alpha-naphthylamine(α-NA) (Ota, 1970).One gram of fresh root was transferred into a 150 mL flask containing 50 mL of20 mg L^{-1}α-NA. The flasks were incubated for 2 hour at room temperature in an end-over-endshaker. After incubation, the aliquots were filtered and 2mL of aliquot was mixed with 1mL$NaNO_3$ (1.18 mmolL^{-1}) and 1mLsulphanilic acid and the resulting color was measured byspectrophotometer and values were expressed as μg g^{-1} h^{-1}.

Besides root activity, derived parameters such as root activity per grain (RA_{grain}) and root activity per sink capacity (RA_{sink}) were calculated based on the following formulae as suggested by Xu-hua and Nong-rong (2005).

*Corresponding author

Total grain number (TGN, No. m^{-2}) = Spikelet No. m^{-2}

Sink capacity (SC, g m^{-2}) = TGN * Individual grain weight (g $grain^{-1}$)

Total root activity (TRA, µg m^{-2} h^{-1}) = Root fresh weight * Root oxidation power

Root activity $grain^{-1}$ (RA_{grain}, µg $grain^{-1}$ h^{-1}) = TRA / TGN

Root activity g^{-1} of sink (RA_{sink}, µg g^{-1} h^{-1}) = TRA / SC

The data collected were subjected to statistical analyses in the Factorial Randomized Block Design for Dry Season (2009) and Summer (2010)using ANOVAPackage (AGRES version 7.01) following the method of Gomez and Gomez (1984).Correlation coefficient ('r') of the chosen parameters were also worked out using SPSS (15.0) package.

Results and Discussion

Oxidizing power of roots, a key factor for root activity, is closely related to the activities of source (leaves) and sink (grain) during grain filling. In the present investigation, the values of oxidizing power of roots were greatly influenced by the moisture regimes and irrigation method, with the values decreasing from tillering to maturity. During Dry Season (2009), the root activity was found decreasing from active tillering (AT)130.3 tograin filling (GF) 75.3. Across the stages, the mean values of the genotypes were 109.3 and 92.9 µg g^{-1} h^{-1} for TNRH 180 and PMK (R) 3 respectively (Table 1). However, significantly increased values of 143.9 µg g^{-1} h^{-1} was recorded by TNRH 180 in comparison with the variety, PMK (R) 3 (116.6) especially at AT stage. Similar trend was observed for other stages of panicle initiation (PI), flowering (FF) and grain filling stage (GF). For the irrigation treatments, the mean values ranged between 83.5 (I_2) and 116.0 µg g^{-1} h^{-1} (I_6). The treatment I_6 showed its statistical supremacy at all the sampling stages of AT (152.3), PI (125.2), FF (100.9) and GF (85.7). Interactive effects of genotypes x irrigation treatments showing statistical significance at all the four stages of sampling indicated that the combined effect of G_1 x I_6 was superior to the rest of the combinations at all phenophases studied and the values being 165.1, 137.0, 106.0 and 89.7 µg g^{-1} h^{-1} at AT, PI, FF ad GF stages respectively.

During Summer (2010), among different stages analysed, higher oxidizing power of roots was noticed at AT (118.5) followed by PI (104.4), FF (82.5) and GF (60.9) stages (Table 2). Increased values of 132.6, 115.6, 90.1 and 73.8 µg g^{-1} h^{-1} were shown for TNRH 180 at AT, PI, FF and GF stages respectively, which were significantly superior to that of PMK (R) 3 at the respective stages. For the irrigation treatments, I_5 was found to be the better performer at all stages of analysis with higher oxidizing power noticed at AT (133.1) than the rest of the treatments. Similar trend was observed in the rest of the stages also. Interaction of genotypes x irrigation treatments indicated that the combined effect of G_1 x I_5 was statistically superior to the rest of the interactive treatments at all phenophases studied. The values of the said interaction were 145.1, 125.4, 101.0 and 86.1 µg g^{-1} h^{-1} at AT, PI, FF and GF stages respectively.

Table 1. Root activity (µg g^{-1} h^{-1}) at chosen growth stages as influenced by drip fertigation treatments in two rice genotypes, dry Season (2009)

Treatment	AT	PI	FF	GF	Mean	Treatment	AT	PI	FF	GF	Mean
Genotypes						G_1I_1	150.7	125.2	100.4	85.0	115.3
G_1	143.9	126.0	89.4	77.8	109.3	G_1I_2	110.2	115.1	70.5	66.4	90.6
G_2	116.6	96.3	85.6	72.8	92.8	G_1I_3	158.3	130.8	99.3	85.9	118.6
Mean	130.3	111.1	87.5	75.3		G_1I_4	145.5	120.7	85.6	71.8	105.9
Irrigation						G_1I_5	122.9	122.4	75.8	70.3	97.9
I_1	148.8	112.2	95.5	81.6	109.5	G_1I_6	165.1	137.0	106.0	89.7	124.5
I_2	99.9	98.1	71.0	65.0	83.5	G_1I_7	154.6	130.5	88.4	75.8	112.3
I_3	142.7	118.9	94.7	82.0	109.6	G_2I_1	146.8	99.1	90.5	78.2	103.7
I_4	128.2	105.6	85.4	71.0	97.5	G_2I_2	89.5	81.0	71.5	63.5	76.4
I_5	107.6	103.8	76.7	67.5	88.9	G_2I_3	127.1	107.0	90.1	78.0	100.6
I_6	152.3	125.2	100.9	85.7	116.0	G_2I_4	110.8	90.4	85.1	70.2	89.1
I_7	132.4	114.3	88.6	74.7	102.5	G_2I_5	92.3	85.2	77.5	64.7	79.9
Mean	130.3	111.1	87.5	75.3		G_2I_6	139.5	113.3	95.8	81.6	107.6
G SEd	0.85	0.72	0.56	0.49		G_2I_7	110.2	98.1	88.7	73.5	92.6
CD (0.05)	1.74	1.48	1.16	1.00		Mean	130.3	111.1	87.5	75.3	
I SEd	1.59	1.35	1.06	0.91		G x I SEd	2.24	1.91	1.49	1.28	
CD (0.05)	3.26	2.77	2.17	1.86		CD (0.05)	4.61	3.92	3.07	2.64	

G_1 : TNRH 180 AT : Active tillering I_1 : Conventional irrigation I_5 : Sub-surface drip 100 %
G_2 : PMK (R) 3 PI : Panicle initiation I_2 : Surface drip 100 % I_6 : Sub-surface drip 125 %
FF : Flowering I_3 : Surface drip 125 % I_7 : Sub-surface drip 150 %
GF : Grain filling I_4 : Surface drip 150 %

However, the value was higher with moderate supply of water (125 % PE) than lower (100 % PE) and higher (150 % PE) water regimes. The oxidizing power at 125 % PE level was 32.5 and 12.4 per cent more in comparison with 100 and 150 % PE levels of drip irrigation respectively with special reference to AT stage. As quoted by Xu-hua and Nong-rong (2005), such increased root oxidizing power could slow down the decomposition of chlorophyll, maintain greater leaf area index and stimulate dry matter accumulation for grain filling. Besides, increased root oxidation activity, as observed with moderate water supply (125 % PE) especially through sub-surface drip system might be attributed to the improvement in oxygen supply to the root system with potential advantages for nutrient uptake (Stoop *et al.,* 2002; Yang *et al.*, 2004). It could also be possible that a greater photosynthetic rate of shoots in these scenario secured higher root activity by supplying sufficient amount of photosynthates to the roots.

Table 2. Root activity (µg g^{-1} h^{-1}) at chosen growth stages as influenced by drip fertigation treatments in two rice genotypes, summer, 2010

Treatment	AT	PI	FF	GF	Mean	Treatment	AT	PI	FF	GF	Mean
Genotypes											
G_1	132.6	115.6	90.1	73.8	103.0	G_1I_1	113.3	106.1	72.0	55.1	86.6
G_2	104.5	93.1	75.0	48.0	80.2	G_1I_2	122.3	111.7	83.5	75.4	98.2
Mean	118.5	104.4	82.5	60.9		G_1I_3	144.0	120.1	96.2	80.5	110.2
Irrigation						G_1I_4	136.0	115.3	92.5	70.1	103.5
I_1	101.8	91.0	66.0	45.1	76.0	G_1I_5	145.1	125.4	101.0	86.1	114.4
I_2	110.1	99.6	80.4	57.7	87.0	G_1I_6	134.9	115.0	95.1	75.6	105.1
I_3	128.6	110.9	89.9	67.9	99.3	G_2I_1	90.3	75.9	60.0	35.1	65.3
I_4	117.5	103.0	82.3	56.3	89.8	G_2I_2	97.9	87.6	77.4	40.0	75.7
I_5	133.1	115.2	93.0	73.9	103.8	G_2I_3	113.2	101.7	83.7	55.3	88.5
I_6	120.1	106.3	83.6	64.6	93.6	G_2I_4	99.1	90.8	72.1	42.6	76.1
Mean	118.5	104.4	82.5	60.9		G_2I_5	121.0	105.1	85.0	61.8	93.2
G SEd	0.83	0.73	0.58	0.44		G_2I_6	105.3	97.6	72.0	53.5	82.1
CD (0.05)	1.73	1.52	1.20	0.91		Mean	118.5	104.4	82.5	60.9	
I SEd	1.44	1.27	1.00	0.76		G x I SEd	2.04	1.79	1.42	1.07	
CD (0.05)	2.99	2.63	2.08	1.57		CD (0.05)	4.23	3.71	2.94	2.22	

AT :Active tillering G_1 :TNRH 180 I_3 :Surface drip 125 %
PI :Panicle initiation G_2 :PMK (R) 3 I_4 :Surface drip 150 %
FF :Flowering I_1 :Conventional irrigation (IW/CPE Ratio 1.00) I_5 :Sub-surface drip 125 %
GF : Grain filling I_2 :Conventional irrigation (IW/CPE Ratio 1.25) I_6 :Sub-surface drip 150 %

Thus, the result of present study implies that the root activity was greatly influenced by the genotypes and irrigation practices. The root activity was much higher with the hybrid culture and sub-surface system of drip irrigation. It is well known that rice grain sterility could result either from insufficient source of supply for grain filling or inappropriate grain filling dynamics (Zhong, 1995; Shen*et al*., 1997). Grain filling was affected by root activity (Xu-hua and Nong-rong, 2005), which was positively related to photosynthetic rate (Shi, 1984) and crop growth rate (Wang *et al*., 1993).

Changes in root activity under different drip biogation treatments

The mean data on root activity per gram of fresh root (RA_{fw}), root activity per grain (RA_{grain}) and root activity per sink capacity (RA_{sink}) are furnished in Table 3. It could be inferred that between genotypes, the hybrid culture possessed increased values for root activity per gram of fresh root (FF: 89.7 and GF: 75.8), root activity per grain (RA_{grain}) (FF: 0.59 and GF: 0.45) and root activity per sink capacity (RA_{sink}) (FF: 30.30 and GF: 23.14) in both the stages of observation. With regard to the water, scheduling irrigation at 125 % PE level registered greater root activity per gram of fresh root, RA_{grain} and RA_{sink} at heading stage (FF: 88.6, 0.60 and 27.85 respectively) than that of 100 or 150 % PE level. Irrespective of the genotypes / irrigation treatments, the values declined at GF stage. The sub-surface drip system was found to be advantageous for root activity per gram of fresh root at both the stages, but the values for RA_{grain} (0.64) and RA_{sink} (29.77) were better placed at heading (FF) stage only.

Table 3. Mean changes in root activity under different drip biogation treatments

Detail	Root activity $g^{-1}$of fresh root (µg g^{-1} h^{-1})		Root activity $grain^{-1}$ (µg $grain^{-1}$ h^{-1})		Root activity sink $capacity^{-1}$ (µg g^{-1} h^{-1})	
Genotype	FF	GF	FF	GF	FF	GF
TNRH 180	89.7	75.8	0.59	0.45	30.30	23.14
PMK (R) 3	80.3	60.4	0.53	0.44	21.98	18.32
Water Level						
100 % PE	73.8	66.2	0.59	0.43	20.30	28.06
125 % PE	88.6	72.8	0.60	0.51	27.85	24.00
150 % PE	84.9	66.6	0.56	0.45	26.03	20.42
Conventional	80.6	60.6	0.48	0.29	22.65	13.93
Drip system						
Surface	84.7	68.4	0.53	0.50	24.83	23.31
Sub-surface	88.5	73.3	0.64	0.50	29.77	23.01

(FF - Flowering; GF - Grain filling)

Grain filling strength was also positively correlated with root activity (Wang *et al*., 1992). It is further observed that filled grain percentage and 1000-grain weight were greater for the plants with higher root activity (Shi, 1984; Lu, 1987; Wang *et al*., 1993). Thus, increasing RA_{sink} would be an effective approach to improve grain filling and 1000-grain weight as opined by Wang *et al*. (1993). Besides, increased root activity slowed down the degradation of chlorophyll, maintained greater leaf area index and stimulated dry matter accumulation for grain filling(Ling and Ling, 1984). Such findings were also corroborated in the present study with special reference to the hybrid and sub-surface drip system of irrigation.

Correlation co-efficient between yield characters and root activity during ripening phase

Correlation analyses were made to evaluate the relationship between indices of root activity such as RA_{fw}, RA_{grain} , RA_{sink} and the grain yield spikelet sterility in two different genotypes at two different stages during ripening phase under different irrigation methods (Table 4). The relationship between sterility and root activity were comparatively less consistent for RA_{fw} and RA_{grain} in the GF stage. However, it has been highly consistent for RA_{sink} in both FF and GF stages. This implied that RA_{sink} could be more suitable in representing the root activity than RA_{fw} and RA_{grain}. The RA_{sink} is an integration of four factors such as root activity per gram of fresh root, fresh weight of roots, number of grains m^{-2} and grain size expressed as grain weight. This explained why it represented root better than the other two indices, though calculation of RA_{sink} would be more laborious than RA_{fw} and RA_{grain}. Therefore, as postulated by Xu-hua and Nong-rong, (2005),RA_{grain}would be an effective approach in improving grain filling and test

Table 4. Correlation co-efficient between yield characters and root activity during ripening phase (n=26)

Detail	Root activity g^{-1} of fresh root (µg g^{-1} h^{-1})		Root activity grain^{-1} (µg grain^{-1} h^{-1})		Root activity sink capacity^{-1} (µg g^{-1} h^{-1})	
	FF	GF	FF	GF	FF	GF
Grain yield	0.814**	0.416*	0.783**	0.465*	0.829**	0.538**
Sterility	-0.566**	-0.710**	-0.598**	-0.506**	-0.706**	0.617**

* Correlation is significant at 5 % level=
** Correlation is significant at 1 % level

weight in rice for enhancing rice productivity in the given irrigation scenario.

Conclusion

In the present investigation, the root activity was much higher with the hybrid culture and sub-surface drip irrigation. Grain filling is positively correlated with root activity in aerobic rice under surface and sub-surface drip irrigation.

Acknowledgement

The first author would like to thank the funding agency M/s. *Jain Irrigation Systems Ltd.* to carry out this research work.

References

Ando, T, Yoshida, S. and I. Nishiyama, 1983.Nature of oxidizing power of rice roots. *Plant Soil*., **72**: 57-71.

Horie, T., Ohnish, M., Angus, J.F, Lwein, L.G.Tsukaguchi,T. and Matano, T. 1997.Physiological characteristics of high yielding rice inferred from cross-location experiments. *Field Crops Res*., **52**: 55-67.

Kirk, J.D. and Bajita, J.B. 1995. Root-induced iron oxidation, pH changes and zinc solubilization in the rhizosphere of lowland rice. *New Phytol.,* **131**:129.

Ling, Q.H. and Ling, L. 1984. Studies on the functions of roots at different node positions and their relation to the yield formation in rice plants. *Sci. Agric. Sin.*, **5**: 3-10.

Lu, D.Z. 1987. Relationship between physiological heterosis of root and shoot system of hybrid rice Shanyou 6. *Chin. J. Rice Sci.,* **1**: 81-94.

Ota, Y. 1970. Diagnostic methods for the measurement of root activity in rice plant. *JARQ*., **5**: 1-6.

Samejima, H., Kondo, M., Ito, O., Nozoe, T, Shinano, T. and Osaki, M. 2004. Root-shoot interaction as a limiting factor of biomass productivity in new tropical rice lines. *Soil Sci. Pl. Nutrn.,* **50**: 545-554.

Shi, Q.H. 1984. Studies concerning the effect of root characteristics on the formation of yield in hybrid rice and large-panicle type varieties. *Acta Agric. Univ Jiangxi.* **2**: 71-80.

Vanitha, K. 2008. Drip fertigation and its physiological impact in aerobic rice (*Oryza sativa* L.) M.Sc. (Ag.) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore 641 003. India.

Wang, Y.L., Cai, J.Z., He, J.S., Chen, L., Xu, J.K. and Bian, Y. 1992: The relationships between spikelet-root-activity and grain filling and ripening in rice (*Oryza sativa* L.). *Acta Agron Sin.*,**18**: 81-88.

Wang, Y.L., Xu, J.K., Bian, Y. and Cai, J.Z. 1993. Effect on the grainfilling of spikelet-root activity and its analysis in rice (*Oryza sativa* L.).*J. Jiangsu Agric Coll.*, **4**: 11-16.

Xu-hua, Z. and Nong-rong, H. 2005.Rice grain chalkiness is negatively correlated with root activity during grain filling. *Rice Sci.,* **12**: 192-196.

Yang, C., Yang, L., Yang, Y. and Ouyang, Z. 2004. Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agric. Water Manage*., **70**: 67-81.

Zhang, Z., Zhang, S., Yang, J. and Zhang, J. 2008. Yield, grain quality and water use efficiency of rice under non-flooded mulching cultivation. *Field Crops Res*., **108**: 71-81.

Zhang, H., Xue, Y., Wang, Z., Yang, J. and Zhang, J. 2009. Morphological and physiological traits of roots and their relationships with shoot growth in super rice. *Field Crops Res*., **113**: .31-40.

Zhong, X.H. 1995. The relationship between chalkiness formation and filling dynamics of rice grains. *Acta Agric. Jiangxi.*, **7**: 55-60.

Received: March 21, 2013; Accepted: May 13, 2013