Response of rice cultivars to aerobic condition

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Abstract

In many countries, including Thailand, rice is largely grown in rainfed condition, where the soil is waterlogged for only some of the time during the growing season. However, there is limited understanding of how rice cultivars adapt to aerobic soil. The objective of this work was to compare the performance of a rainfed cultivar (KDML105), an upland cultivar (Kae Noi) and a high yielding cultivar bred for irrigated lowlands (Chainat 1) in well drained and waterlogged soil. The rice was grown for 3 weeks and their performace assessed in root and shoot length, root and shoot dry weight, aerenchyma appearance and nutrient content. Shoot concentrations of nitrogen and phosphorus indicated limited supply in all three cultivars and in both well drained and waterlogged soil. Aerenchyma development was affected by soil water differently in the different cultivars. Kae Noi and KDML105 developed more aerenchyma in their root in waterlogged than in well drained soil, while Chinat 1 had more aerenchyma in aerated soil. The effect of this difference on plant growth and nutrient uptake was not measurabale at 3 weeks. In general the rice grew better in waterlogged than in well drained soil. The main exception was Kae Noi which exhibited increased root elongation in well drained soils. Otherwise there were limited differences among the three rice cultivars in their response to aerated soil at the seedling stage.

Media summary

Rice plants generally grow less well in aerated soil than in waterlogged soil. No major difference was observed among an upland, a rainfed and an irrigated rice cultivar in their adaptation to aerated soil during the seedling stage.

Keywords

Rice, Cultivars, Rainfed, Waterlogging, Well-drained soil, Aerenchyma

Introduction

Rice cultivated areas are classified by water supplies as rainfed or irrigated. Overall, rice yield in rainfed condition is often less than 50 % of the irrigated rice. The rainfed rice region lacks irrigation water and usually experiences discontinuous waterlogging of the soil during crop growth. The amount and timing of water supply in rainfed rice ecosystem are considered to be the most severe constraints to productivity (Widawsky and O' Toole, 1990; Zeigler and Puckridge, 1995). Rainfall and nutrition influence rice yield by directly affecting the physiological process involved in vegetative growth and grain production. Intermittent flooding and drying of the soils depresses availability of several nutrients for rice uptake, and low nutrient supply will limit the potential yield (Bell *et al*., 2001). Rainfed rice is grown under both lowland and upland conditions. Lowland rice is direct seeded or transplanted in bunded fields and soils are often puddled by plowing at water saturated conditions. Upland rice is always direct seeded and usually grown in unbunded fields of often naturally well-drained soils without surface accumulation of water. Hence understanding the adaptations of rice cultivars to change in water regime may suggest nutrient management technologies or rice breeding strategies that increase productivity in well-drained and waterlogged soil conditions. The present experiment aimed to examine responses of root and shoot growth and nutrient accumulation of upland and lowland rice cultivars to waterlogged and well drained soil conditions.

Methods

Two different water regimes were imposed on three rice cultivars. Two water regimes were waterlogging and well drained for 3 weeks. Three rice cultivars were Kae Noi (upland), Chainat 1 (irrigated lowland), and KDML105 (rainfed lowland). There were 3 replicates. Four days after germination, five seedlings were transplanted into each pot, which was lined with a plastic bag, and contained 5 kg of soil mixed with 5 kg of coarse sand. At harvest maximum root and shoot length, root and shoot dry weight, total root volume, aerenchyma appearance and nutrient contents were assessed. Maximum root length was measured as the longest undamaged root. Maximum shoot length was measured from the base of stem to the tip of terminal leaf blade. Root and shoot dry weights were measured after oven drying at 70^{o}C for 48 hour. Aerenchyma appearances (%) were measured on samples of adventitious roots. A sample of 3 root tips (5 cm in length) was collected from pot (1 root tip/plant) for examination of aerenchyma development on cross sections scanned under a compound microscope. Shoot and root samples were analyzed for N (Kjeldahl method), P (molybdovanado-phosphoric acid method) and K content (atomic absorption spectrophotometer).

Results and discussion

Shoot concentrations of nitrogen and phosphorus (Table 1) indicated limited supply in all three cultivars and in both well drained and waterlogged soil (Reuter et al., 1997).

Table 1. Nutrient concentration in the shoot of three rice cultivars when grown in waterlogged and well-drained soil for 3 weeks.

Cultivars	Soil conditions	
	Well drained	Waterlogged
Nitrogen (%)		
Kae Noi	2.91?0.29	2.27?0.08
Chainat 1	3.34?0.18	2.67?0.35
KDML 105	2.89?0.33	3.23?0.09
Phosphorus (%)		
Kae Noi	0.15?0.01	0.18?0.01
Chainat 1	0.17?0.00	0.16?0.01
KDML 105	0.13?0.01	0.17?0.01
Potassium (%)		

Kae Noi	3.09?0.09	3.68?0.09
Chainat 1	3.48?0.19	3.63?0.16
KDML 105	3.07?0.16	3.58?0.09

Development of the aerenchyma showed clear differences among cultivars in their responses to soil water (Figure 1). Kae Noi and KDML105 developed more aerenchyma in waterlogged soil than in well drained soil, while Chainat 1 was opposite by developing more aerenchyma in well drained than in waterlogged soil.

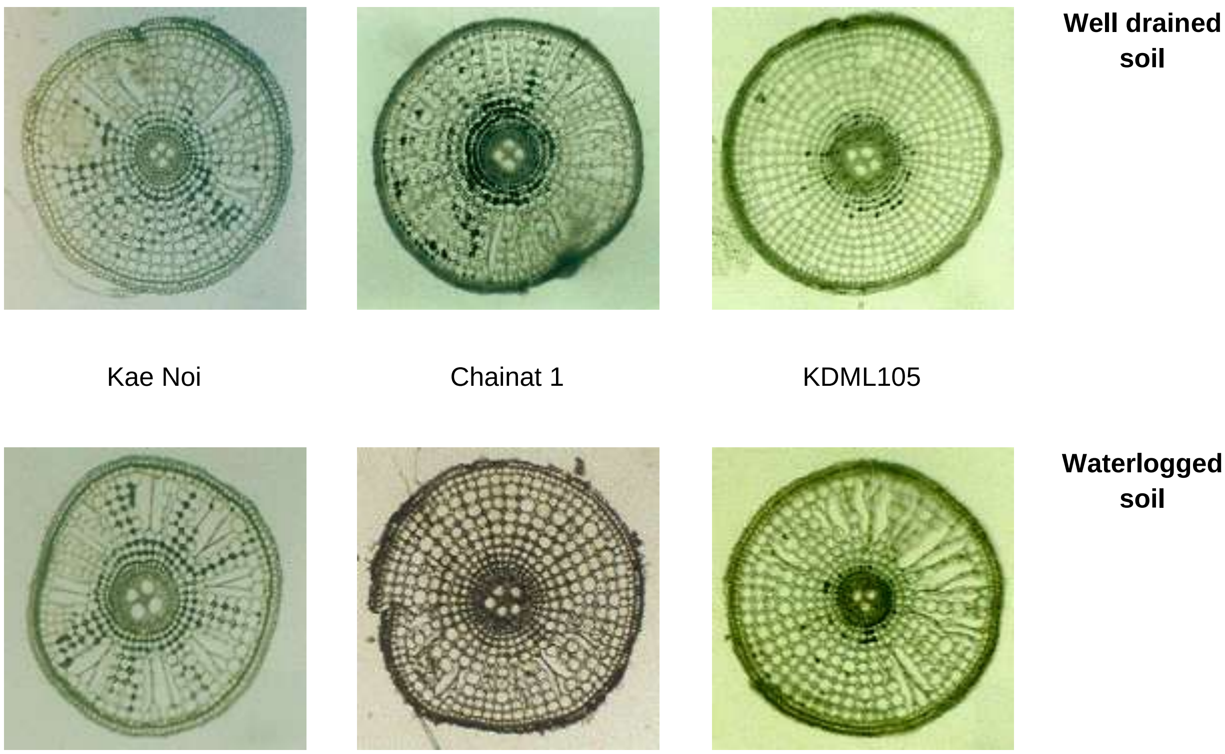

Figure 1. Aerenchyma appearance at 3 cm from root tip of three cultivars in waterlogged and well-drained soil conditions for 3 weeks.

Kae Noi in well drained soil had increased root length, while Chainat 1 and KDML105 root length was equal in both waterlogged and well drained soil conditions. However, root dry weights of all cultivars were not affected by soil water conditions (Table 2). Shoot dry weight and length of all cultivars was increased in waterlogged soil.

Table 2. Root and shoot growth of three rice cultivars when grown in waterlogged and well-drained soil conditions for 3 weeks.

Cultivars	Soil condition	F-test (LSD$_{0.05}$

	Well drained	Waterlogged	Mean	in brackets)	
Root length (cm)					
Kae Noi	34.7 Aa	26.6 Bb	30.7	Water	NS
Chainat 1	30.4 Aa	35.7 Aa	33.1	Cultivar	NS
KDML 105	29.7 Aa	29.1 Ba	29.4	WxC	*(6.3)
Mean	31.6	30.5			
Shoot length (cm)					
Kae Noi	43.3 Ab	52.3 Aa	47.8	Water	* (2.57)
Chainat 1	43.4 Aa	46.6 Ba	44.9	Cultivar	* (3.15)
KDML 105	44.5 Ab	55.2 Aa	49.9	WxC	* (4.45)
Mean	43.7	50.6			
Root dry weight (g/plant)					
Kae Noi	0.14	0.17	0.16	Water	NS
Chainat 1	0.12	0.18	0.15	Cultivar	NS
KDML 105	0.13	0.13	0.13	WxC	NS
Mean	0.13	0.16			
Shoot dry weight (g/plant)					
Kae Noi	0.22	0.36	0.29	Water	*(0.05)
Chainat 1	0.28	0.39	0.33	Cultivar	NS

KDML 105	0.26	0.34	0.30	WxC	NS
Mean	0.25 b	0.36 a			

ns = not significant and * significant at $p < 0.05$. The difference between means in the same row indicated by lower case letters and in the same column by upper case letters.

Contents of phosphorus and potassium in rice plants when grown in waterlogged soil were generally higher than in well drained soil. However, phosphorus contents in Kae Noi and KDML105 plants were higher in waterlogged soil, while those in Chainat 1 were not. Nitrogen contents in all cultivars were not affected by water soil conditions (Table 3).

Table 3. Nutrient contents of three rice cultivars when grown in waterlogged and well-drained soil conditions for 3 weeks.

Cultivars	Soil condition			F-test ($LSD_{0.05}$ in brackets)	
	Well drained	Waterlogged	Mean		
Nitrogen contents (mg/g plant)					
Kae Noi	2.34	2.67	2.50	Water	NS
Chainat 1	2.83	2.34	2.59	Cultivar	NS
KDML 105	2.45	2.78	2.62	WxC	NS
Mean	2.54	2.59			
Phosphorus contents (mg/g plant)					
Kae Noi	0.14 Bb	0.16 Aa	0.15	Water	*(0.01)
Chainat 1	0.16 Aa	0.15 Ba	0.15	Cultivar	NS
KDML 105	0.13 Bb	0.16 Ba	0.14	WxC	*(0.02)
Mean	0.14	0.16			
Potassium contents (mg/g plant)					

Kae Noi	2.61	3.03	2.82	Water	*(0.23)
Chainat 1	2.96	3.01	2.99	Cultivar	NS
KDML 105	2.76	3.06	2.91	WxC	NS
Mean	2.78 b	3.03 a			

ns = non significant and * significant at $p < 0.05$. The difference between means in the same row indicated by lower case letters. The difference between means in the same column indicated by upper case letters.

None of the differential responses to aerated soil between cultivars measured in this experiment suggested that the upland cultivar Kae Noi and rainfed cultivar KDML 105 are better adapated to aerated soil condition than the irrigated, wetland cultivar Chainat 1. Indeed the difference in phosphorus contents was in the opposite direction.

Conclusion

In the seedling stage, rice cultivars generally performed better in waterlogged than in well drained soil. No evidence of better adaptation to aerated soil in upland and rainfed cultivars has yet been found.

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