Selection of Cultivars for Direct Seeding in Rice Based on the Development of Root System Analysis

Won, Jong Gun
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

Hirahara, Yuuiti
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

Yoshida, Tomohiko
Laboratory of Crop Science, Faculty of Agriculture, Kyushu University

https://doi.org/10.5109/24246

出版情報：九州大学大学院農学研究院紀要. 43 (1/2), pp.31-37, 1998-11. Kyushu University
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **43** (1·2), 31–37 (1998)

Selection of Cultivars for Direct Seeding in Rice Based on the Development of Root System Analysis

Jong Gun Won, Yuuiti Hirahara and Tomohiko Yoshida

Laboratory of Crop Science, Faculty of Agriculture,
Kyushu University, Fukuoka 812–8581, Japan
(Received, May 25, 1998 and accepted August 7, 1998)

This study was carried out to develop a useful method for selection of promising cultivars for direct seeding cultivation based on the development of root system analysis. To select cultivars at the early stage for root system with lodging resistance, transparent polyethylene seed pack growth pouch (SPGP) was used. Among the root parameters of SPGP seedlings, only root thickness of F4 lines was positively correlated with pushing resistance of field test (r=0.46**). The root thickness of SPGP also had a positive correlation with root thickness of field test (18 Days After Seeding : r=0.348*, 30 DAS : r=0.512**, respectively). Root thickness of SPGP, 18 DAS and 30 DAS seedlings in field were positively correlated with panicle weight (r=0.336**, r=0.298*, r=0.341**, respectively). Therefore, we can also select panicle weight type by root thickness of SPGP. In path analysis, the direct effect of root thickness of SPGP on pushing resistance occupied 63% (0.289) of total coefficient of correlation (0.458). However, that of 18 DAS seedlings of field test on pushing resistance occupied only 39% (0.1255) of total correlation coefficient (0.3189), and the direct effect of 30 DAS seedlings was negative. From these results we concluded that the root thickness of SPGP could be a very useful selection index for lodging resistance in direct seeding cultivation.

INTRODUCTION

Under the UR and WTO worldwide trading system, in the early future, free trade of agricultural products will be faced inevitably in Japan and Korea. Practically, the prices of rice as a principle food in these countries are expensive and about 3,5 times more compared to those of foreign rice markets. To overcome these situations, much attention has been paid on cultivation method, such as direct seeding, which can reduce production cost, save labor and increase international competition. However, there are many problems in the direct seeding cultivation in rice. For the establishment of this method, the development of adaptable rice cultivar to high planting density with lodging tolerance, effective seedling stand at low temperature, weed control, irrigation management, and so on are necessary.

Even though the history of study on direct seeding cultivation was long, the area of cultivation has not been increased because of the instability of the yield. Lodging of rice plant is a major problem, which reduces rice yield in unfavorable weather conditions in direct seeding cultivation. Lee *et al.* (1991) reported that lodging of rice plant at milky stage decreased grain yield 34% in Korea. Lodging was divided into four types and, among them, two types of lodgings, root lodging and culm breaking, mostly occurred in direct seeding cultivation (Seko, 1954). Miyasaka (1970) concluded in his report that root strength at ripening stage had a close relationship not only with root lodging but also with culm breaking lodging. Most researches on lodging of rice plant have involved the relationship between lodging and root system. Lodging tolerance of rice in direct seeding cultivation was affected by root thickness, root distribution and dry weight of root (Miyasaka, 1970; Ogata and Matsue, 1996; Terashima *et al.*, 1995). Ogata and Matsue (1996) reported that selection of high lodging tolerance cultivars adapted to direct sowing culture was possible without direct sowing by taking an accurate measurement of pushing resistance under transplanting culture.

Literatures of cultural practices of direct seeding cultivation are extensive. However, only a few studies have reported on development of adaptable cultivars for direct seeding cultivation. The objectives of this study are : 1) to develop a useful method for selection of promising cultivars with suitability for direct seeding cultivation at early seedling stage, 2) to study the relationship between this method and the agronomic traits of direct seeded rice in field.

MATERIALS AND METHODS

1. Seed pack growth pouch method

The breeding F4 lines used in this study were kindly provided from Fukuoka Agricultural Research Center (Table 1.). Several check cultivars are also tested. To select promising lines at the early stages for root system with lodging resistance, transparent polyethylene seed pack growth pouch (SPGP) was used. One–folded Kim–papertowel was inserted into SPGP and pre–sprouted seeds were placed on the upside of the SPGP. We used two types of SPGP : 1. Following the Kujira's method (Kujira, 1991), the low part of SPGP was intact and 30 ml hyponex was injected per SPGP ; 2. As a modified method by us, the low part of SPGP was cut off and soaked into a bed which contained hyponex. The experimental design at each method was completely randomized design with six replications. Hyponex was diluted by 5000 times (N–10ppm) and adjusted to pH 5. Then, they were grown under dark condition at 20°C and root length, root angle, root thickness and number of roots were measured at 18 days after germination.

Table 1. F4 lines and check cultivars used in this study.

Lines and cultivars	Pedigrees
No. 1–50	Aoinokaze//Lemont/Hinohikari
No. 51–80	Yumehikari//Lemont/Hinohikari
Aoinokaze	Check cultivars
Hinohikari	
Lemont	
Kosihikari	

2. Field test

We used the same F4 lines and check cultivars at the experiment 1. The experiment was conducted at the field of Kyushu University in 1996. The rice seeds were hand–seeded directly on plots in wet condition, which measured 7.8×2.8 m with two replications in early June. Each entry was seeded in one row at 25 cm between rows. The basal dressing was applied at a rate of 5, 5, 5 g/m^2 of N, P_2O_5 and K_2O, and twice top–dressed at a rate of 3, 3, 3 g/m^2 and 1.5, 1.5, 1.5 g/m^2. At 18 days after seeding (DAS), 3 plants per entry were sampled to measure root length and root thickness. One month after seeding we also measured the longest root length and the thickness of root. After then we thinned to eight seedlings for one entry at 10 cm seedling interval. The root length was real measurement but root length and thickness were relative evaluation which rated into three degrees. The root angle was measured for the area where 90% of roots were included.

Prior to harvest, average five plants per entry were measured for culm length, panicle length, panicle number and pushing resistance. Culm length was measured from the base of the plant to the base of panicle, panicle length was from the base to the tip of panicle. At maturity, panicles were hand harvested. After one week of drying, the weight of panicles were measured. The measurement of pushing resistance was conducted as shown by Terashima *et al.* (1992).

RESULTS AND DISCUSSION

It may be effective if we can select promising cultivars at seedling stages for some agronomically important characters. Ogata and Matsue (1996) reported the possibility of early selection at 18 days seedling stage, and suggested that the crown root thickness of seedlings at 18 DAS had a positive correlation with the crown root thickness and pushing resistance of the plant in 15 days after heading. Kujira (1991) showed the method and the application for measuring root system by using SPGP, and mentioned the convenience and effectiveness of the investigation for root systems.

In this study, we used two types of SPGP, Kujira's method (A) and modified method (B). Root length, root angle, root thickness and number of roots in different SPGPs were shown in Table 2. In a comparison of root characteristics by the SPGP, there were some differences between method A and method B. To clarify which method was closer to the field conditions, the root thickness of SPGPs was subjected to compare to that of field test (Table 4). Among the root parameters of SPGP, only root thickness was significantly correlated with pushing resistance (r=0.46) in field (Table 5). Therefore, we used root thickness as an indicator for the evaluation.

Table 2. Comparison of the root characteristics between Kujira's(A) and modified method(B).

Cultivars	Root length (mm)		Root angle (°)		Root thickness*		Root number	
	A	B	A	B	A	B	A	B
F4 lines**	64.7	62.4	56.1	62.8	1.62	1.73	3.7	3.9
Aoinokaze	54.5	81.3	43.3	21.7	1.33	1.67	3.2	2.8
Lemont	35.7	33.1	52.5	55.0	2.83	2.67	3.2	3.0
M–302	82.7	68.8	33.3	37.5	2.17	2.17	3.0	4.2
Hinohikari	62.3	51.4	48.3	59.2	1.17	2.00	3.3	4.5
Kosihikari	76.2	66.0	47.5	53.3	1.33	1.83	3.3	4.0
Yumehikari	74.7	75.6	44.2	33.3	2.00	2.17	3.5	3.7

* Degree : 1 (thin) –3 (thick). ** Average of F4 lines.

Table 3 also showed the correlations of root thickness by two SPGP methods and that in field test. For the F4 lines, the root thickness in method A was significantly correlated with the root thickness of 30 DAS seedling (r=0.34) and pushing resistance (r=0.39) in field test. On the other hand, root thickness in method B's was significantly correlated not only with that of 30 DAS seedling (r=0.45) but also with that of 18 DAS seedling (r=0.44) in field test. However, for the check cultivars, only root thickness in method B's was significantly correlated with the root thickness of 30 DAS seedling in field test

Table 3. Coefficient of correlation between root thickness in field and that in method A and method B.

	F4 lines		Check cultivars	
	A	B	A	B
Root thickness of 18 DAS[1)]	0.22	0.44*	0.10	0.17
Root thickness of 30 DAS	0.34*	0.45*	0.93	0.95*
Pushing resistance	0.39*	0.41*	0.77	0.70

1) DAS : days after seeding.
* Significant at the 0.05 probability level.

Table 4. Germination, root length, root thickness, growth traits and pushing resistance under field condition.

Trsits	F4 (1–50)	F4 (51–80)	Aoinokaze	Lemont	M–302	Hinohikari	Kosihikari
Germination date (days)	4.1	4.3	6.3	5.3	4.3	3.8	4.0
Root length (mm)*	43.3	39.7	37.0	28.1		60.7	69.2
Root thickness (mm)*	0.6	0.6	0.5	0.6		0.6	0.7
Root length (mm)**	70.8	72.4	61.8	68.2		65.8	67.2
Root thickness (mm)**	0.69	0.71	0.60	0.92		0.67	0.72
Culm length (cm)	89.1	82.4	79.5	72.6	83.1	90.6	89.9
Panicle length (cm)	20.0	19.2	20.7	24.2	22.2	18.9	19.5
Number of panicles	12	12	17	13	21	14	22
Panicle weight (g/panicle)	3.03	3.01	3.11	4.44	3.58	2.60	3.55
Pushing resistance (g/panicle)	168.3	150.1	164.8	241.4	126.9	116.0	112.0

* Investigated at 18 days after seeding in field.
** Investigated at 30 days after seeding in field.

(r=0.95). It indicated that the modified method was more effective than Kujira's method for the root system analysis in SPGP.

Seed germination, root thickness at 18 DAS and 30 DAS seedling, heading date, culm length, panicle length and number of panicles in field test were shown in Table 4. The fastest germination was observed in Hinohikari, the latest was in Aoinokaze and Lemont. The thickest root was observed in Kosihikari at 18DAS and Lemont at 30 DAS seedling but the thinnest was observed in Aoinokaze at both points of investigation. Heading date of M–302 and Kosihikari was earlier by 10–13days than that of other cultivars. Culm length was longer in Hinohikari, Kosihikari and F4 1–50 lines but in Lemont and L–202 this character was shorter. M–203, L–202 and Kosihikari had much more panicles. F4 lines and Lemont had relatively fewer panicles. Panicle length and panicle weight were highest at Lemont and lowest at Hinohikari. In pushing resistance, Lemont was strongest, whereas M–302 and Hinohikari were weakest.

Correlations between pushing resistance and root parameters measured in SPGP and in field test were presented in Table 5. The correlation was obtained separately in F4 lines and check cultivars. Among the root parameters of SPGP seedlings, only root thickness of F4 lines was positively correlated with pushing resistance in field (r=0.46*). On the contrary, root length of cultivars was negatively correlated with pushing resistance. Among root parameters in field, root thickness of both 18 and 30 DAS seedlings of F4 lines was positively correlated (r=0.32*, r=0.28*, respectively) with pushing resistance. The root thickness of cultivars was not significantly correlated with pushing resistance because of the small d.f. number, though high values of 0.73 and 0.76 were obtained for 30 DAS in field and SPGP. It indicated that the root thickness of rice plant was closely related with lodging resistance, and this relationship is very useful and practical in rice breeding program for the selection of cultivars suitable for direct seeding cultivation. Table 6 showed that the root thickness of SPGP had a positive correlation with root thickness in field test (18 DAS : r=0.348, 30 DAS : r=0.512), indicating that the

Table 5. Coefficient of correlation between pushing resistance and root parameters.

		F4 lines	Cultivars
18 DAS[1] (field test)	Root length	0.11	−0.93
	Root thickness	0.32*	−0.24
30 DAS (field test)	Root length	0.30*	0.23
	Root thickness	0.28*	0.73
SPGP[2]	Root length	0.01	−0.82
	Longest root length	0.00	−0.81
	Root angle	0.09	0.15
	Root thickness	0.46*	0.76
	Root number	−0.08	−0.79

1) DAS : days after seeding.
2) SPGP : seed pack growth pouch.
* Significant at the 0.05 probability level.

SPGP and field test methods were comparable and we could use the SPGP method instead of field test for root system analysis. Some interesting matters were the relationship between root thickness and panicle weight. Root thickness of SPGP, 18 DAS and 30 DAS seedlings in field had a positive correlation (r=0.336**, r=0.296*, r=0.341**, respectively) with panicle weight. Therefore, we also might be able to select panicle weight type by root thickness. Panicle weight was highly positively correlated with pushing resistance. Kim and Vegara (1990) reported that the close spacing adaptability was higher in low-tillering cultivars than in high-tillering cultivars. Therefore a low-tillering cultivar with large panicles could be considered as an ideotype of direct seeded rice plant. Through this SPGP method we can preliminarily screen rice lines in laboratory, reduce the scale of population, and then save much labor in field.

Table 6. Coefficient of corrrelation among the root thickness, plant growth traits and pushing resistance among F4 lines.

	X1	X2	X3	X4	X5	X6
Root thickness of SPGP (X1)	1.000	0.348**	0.512**	0.015ns	0.336**	0.458**
Root thickness in field (18DAS)(X2)		1.000	0.378**	0.013ns	0.296**	0.319**
Root thickness in field (30DAS)(X3)			1.000	-0.151ns	0.341**	0.284*
Panicle number (X4)				1.000	-0.023ns	-0.156ns
Panicle weight (X5)					1.000	0.556**
Pushing resistance (X6)						1.000

*, ** Significant at the 0.05 and 0.01 probability level.

In this study, pushing resistance (as a response variable), and root thickness in SPGP and in field test (as predictor variables) were further studied using path analysis (Table 7). Differences were found between root thickness of SPGP and that of field test. The direct effect of root thickness of SPGP on pushing resistance occupied 63% (0.2887) of total correlation coefficient (0.4578), and the indirect effect via panicle weight was 37% (0.1691). However the direct effect of root thickness of field test on pushing resistance occupied only 39% (0.1255) of total correlation coefficient (0.3189), whereas the direct effect of 30 DAS seedlings in field was negative. It indicated that in selection strategies for optimizing rice lodging resistance in direct seeding cultivation, selection based on root thickness in SPGP was more effective than that in field. The indirect effect of root thickness via panicle weight was quite sizable and positive, and it explained the relationship between root thickness and panicle weight. All of them showed that the root thickness of seed pack growth pouch can be very important selection index for improving lodging resistance in direct seeding cultivation.

Table 7. Path coefficient analysis showing direct and indirect effects of 5 characters on pushing resistance in rice direct seeding cultivation among F4 lines.

	X1	X2	X3	X4	X5	Correlation
Root thickness of SPGP (X1)	0.2887	0.0437	-0.0413	-0.0025	0.1691	0.4576
Root thickness in field (18DAS)(X2)	0.1005	0.1255	-0.0307	-0.0022	0.1258	0.3189
Root thickness in field (30DAS)(X3)	0.1477	0.0478	-0.0807	0.0248	0.1455	0.2842
Panicle number (X4)	0.0045	0.0016	0.0122	-0.1641	-0.0099	-0.1558
Panicle weight (X5)	0.1140	0.0369	-0.0272	0.0038	0.3550	0.5558

________ direct effect for each character.

From these results we concluded that, among the root parameters, the root thickness of early stage seedling was closely related with pushing resistance in field. The root thickness of modified SPGP method had higher correlation with pushing resistance than that of field test and the direct effect on pushing resistance was also relatively higher than that of field test. It indicated that in selection strategies for optimizing rice lodging resistance in direct seeding cultivation, indirect selection based on root thickness in SPGP was more accurate and effective than that in field.

REFERENCES

Kim, J. K. and B. S. Vergara 1990 Tillering behavior of low and high tillering rices. *Korean J.Crop Sci.*, **35**: 512–517

Kujira, Y. 1991 Methods and applications for measuring root systems by using seed pack growth pouch– Varietal differences of roots systems in rice plant at the early stage. *Hokuriku Crop Sci.*, **26**: 31–34

Lee, M. H., J. O. Oh and R. K. Park 1991 Lodging mechanisms and reducing damage of rice plant. *Korean J. Crop Sci.*, **36**: 383–393

Miyasaka, A. 1970 Studies on the strength of rice root. II. On the relationship between root strength and lodging. *Proc.Crop Sci. Soc. Japan.*, **39(1)**: 7–14

Ogata, T. and Y. Matsue 1996 Studies on direct sowing culture of rice in Northern Kyushu. I. Evaluation of lodging tolerance. *Jpn. J. Crop Sci.*, **65(1)**: 87–92

Ogata, T. and Y. Matsue 1996 Studies on direct sowing culture of rie in Northern Kyushu. II. Evaluation of lodging tolerance by crown root thickness during seedling stage. *Jpn. J. Crop Sci.*, **65(3)**: 502–508

Seko, H. 1954 Lodging in rice plant and its testing method. A separate volume of the Japanese Journal of Breeding. Vol. 4. *Studies on rice breeding.* pp. 185–198

Terashima, K., S. Akita and N. Sakai 1992 Eco–physiological characteristics related with lodging tolerance of rice in direct sowing cultivation. I. Comparison of the root lodging tolerance among cultivars by the measurement of pushing resistance. *Jpn. J. Crop Sci.*, **61(3)**: 380–387

Terashima, K., S. Akita and N. Sakai 1995 Eco–physiological characteristics related with lodging tolerance of rice in direct sowing cultivation. III. Relationship between the characteristics of root distribution in the soil and lodging tolerance. *Jpn. J. Crop Sci.*, **64(2)**: 243–250