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REVIEW
Rice Breeding Lines with High Seedling Emergence from Direct Sowing into Submerged Soil

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Abstract
We investigated the seedling emergence of rice seeds direct-sown in submerged soil. Germinated seeds with 0.4 to 1.4mm coleoptiles were placed at 1, 2, or 3 cm beneath the submerged soil surface in a growth chamber kept at 15 or 25°C. In the field, seeds held on seeder-tape were placed at 2 cm beneath the soil surface with a tape seeder. Cultivar Ta Hung Ku, from China, proved to be a new genetic resource, with the highest percentage of seedling emergence. We screened rice lines with a high seedling emergence rate by testing in the growth chamber and in the field. To breed a practical cultivar with good agronomic characters and a high seedling emergence rate, we crossed cv. Dontokoi with Ta Hung Ku. From the hybrid progeny, we selected the lines with a high seedling emergence rate by repeated backcross selection. However, these lines had inferior grain yield and quality, so further attempts at selecting lines with high yield and good grain appearance are necessary.

Discipline: Plant breeding
Additional key words: *Oryza sativa* L, Tape Seeder

Introduction

Direct sowing of rice, which does not require nurseries or transplanting machines, is regarded as the most effective method for reducing costs and labor. However, submerged, direct-sown rice has lower yields, due mainly to poor seedling establishment and frequent plant lodging. In contrast, when seeds are directly sown about 1 to 2 cm below the surface of the submerged soil, plants are less susceptible to lodging than surface sown rice[5]. For the further extension of direct sowing rice cultivation in Japan, breeding of cultivars with a high seedling emergence is a high priority.

To develop cultivars suitable for direct sowing cultivation, the character of high seedling emergence from beneath submerged soil must be introduced from foreign cultivars into Japanese elite cultivars. However, undesirable traits, such as low yield and poor grain appearance, must be omitted. To investigate seedling emergence from beneath submerged soil, we developed new screening methods using a growth chamber and seeder tape.

Here we discuss the introduction of high seedling emergence under direct sowing from beneath submerged soil from a Chinese cultivar, Ta Hung Ku, into a Japanese elite cultivar, Dontokoi.

Preliminary exploration of genetic resources in a growth chamber

Initially we tested eight rice cultivars of various origins: Akihikari, Koshihikari, Kinuhikari, Akage, Akamai, Arborio, Lemont, and Habataki. Germinated seeds with 0.4 to 1.4 mm coleoptiles were placed at 1, 2, or 3cm depth under the submerged soil surface in a growth chamber kept at 15 or 25°C. Seedling emergence varied widely among cultivars when seeds were sown at 2 or 3cm at 25°C and at 1 cm at 15°C[2].

Next we compared the seedling emergence of 360 cultivars sown at 2 cm depth at 25°C (45 improved and 102 indigenous cultivars from Japan, 61 from China and Korea, 64 from India, Nepal, Sri Lanka and Bangladesh, 65 from Italy, Portugal and Russia and 23 from other countries). Genetic variations in seedling emergence were obvious (Fig.1). Several cultivars with different rates of seedling emergence were selected for further experiments.

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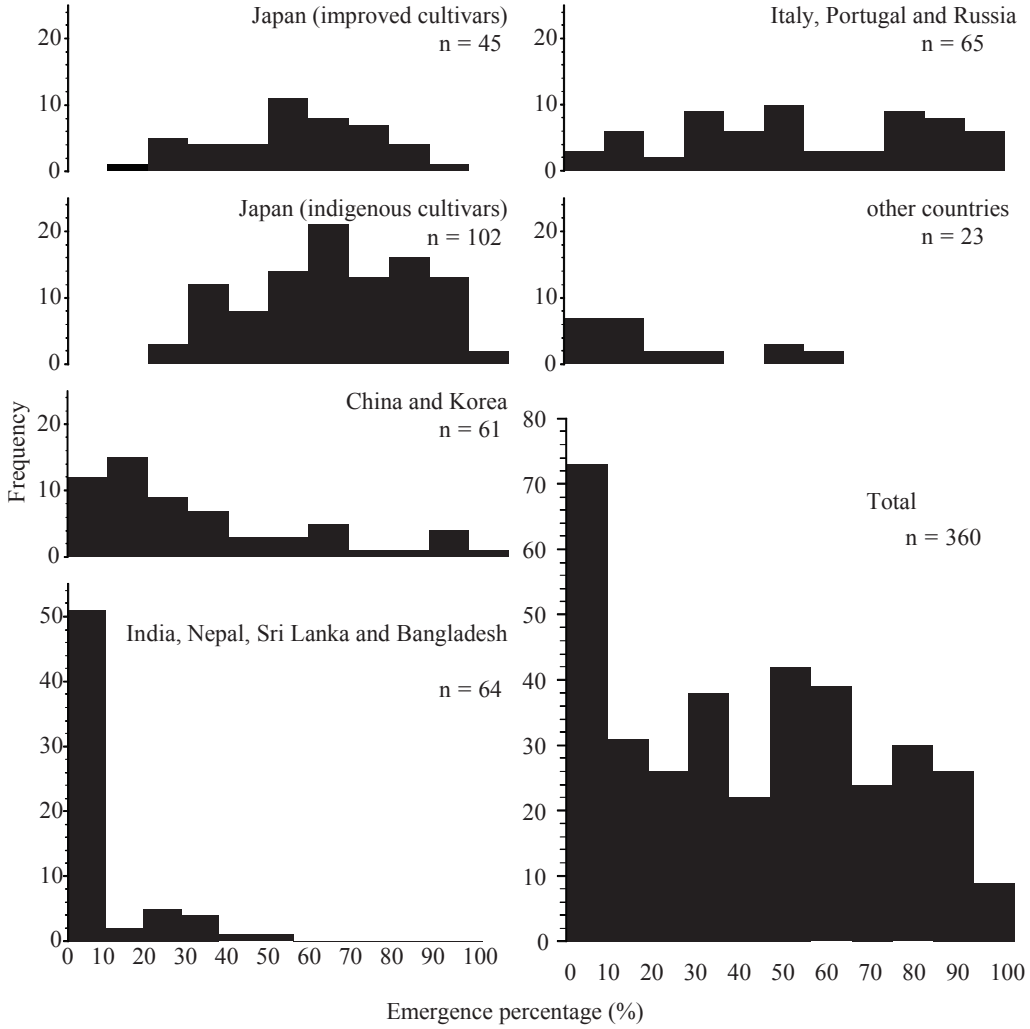

Fig.1. Variations in percentage of seedling emergence among 360 rice cultivars from around the world

Development of seeder tape method and finding of Ta Hung Ku

To test large numbers of cultivars in the field, we developed a new, efficient method using seeder-tape. Seeds held on seeder-tape were placed at 2 cm beneath the soil surface (Fig.2).

In a preliminary experiment, we grew 23 cultivars of various origins in both the growth chamber and the field. We screened those with a high seedling emergence rate by sowing the seeds at 3 cm beneath the soil surface at 20°C in the growth chamber and by placing the seeder-tape at 2 cm beneath the soil surface in the field. Rates of seedling emergence showed a positive correlation between the growth chamber and the field[3].

Cultivar Ta Hung Ku, from China, proved to be a new genetic resource, with the highest percentage of seedling emergence (Table 1, Fig. 3). However, it had many unfavorable agronomic characters.

Breeding of Hokuriku PL3 and Kanto PL13

To breed a practical cultivar with good agronomic characters and a high seedling emergence rate, we crossed Dontokoi with Ta Hung Ku. Dontokoi has superior eating quality, tolerance to lodging (short culm), and high yielding ability[1,6]. From the progeny, we selected the lines with a high seedling emergence rate by repeated backcross selection of plants sown by seeder-tape[4] (Tables 2, 3).

1. Agronomic characters of Hokuriku PL3

Hokuriku PL3 was derived from the cross between Dontokoi and Ta Hung Ku. The seedling establishment rate under surface sown cultivation of Hokuriku PL3 was similar to that of Dontokoi. Heading and maturation dates of Hokuriku PL3 were 5 and 3 days earlier than those of Dontokoi. The culm was 1 cm longer than that of Dontokoi. Its panicle was longer, but panicle number per

unit area was less than that of Dontokoi. Its lodging resistance was similar or superior to that of Dontokoi (Table 4). Resistance to grain shattering was strong. Like Ta Hung Ku, it had many long awns. Its aboveground weight and yield of brown rice were less than those of Dontokoi (Table 5). The appearance grade of brown rice of Hokuriku PL3 was very bad, similar to that of Ta Hung Ku.

2. Agronomic characters of Kanto PL13

Kanto PL13 was derived from the cross combination of Dontokoi//Dontokoi/Ta Hung Ku. Differences in seedling establishment rate under surface sown cultivation were not significant between Kanto PL13 and Dontokoi ($P = 0.17$). Heading and maturation dates were 15 and 20 days later than those of Dontokoi. The culm of Kanto PL13 was 24 cm longer than that of Dontokoi. Its panicle was longer, and panicle number per unit area was similar to that of Dontokoi. Lodging resistance was greatly inferior (Table 6). Resistance to grain shattering was strong. There were few awns. Its aboveground weight was greater than that of Dontokoi, and its yield of brown rice was similar to that of Dontokoi. The appearance grade of brown rice of Kanto PL13 was slightly inferior to that of Dontokoi (Table 7).

Conclusion

For selecting lines with a high seedling emergence rate, repeated backcross selection is necessary. As Hokuriku PL3 and Kanto PL13 had inferior grain yield and quality, further attempts at selecting lines with high brown rice yield and good grain appearance are necessary. Kanto PL13 had inferior lodging resistance, so further attempts at selecting lines with tolerance to lodging

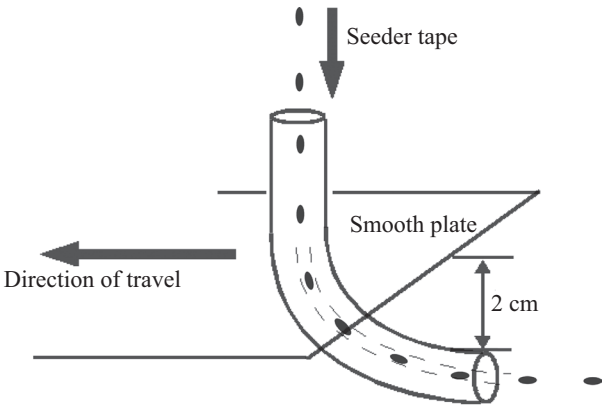

Fig.2. An outline of tape seeder

Fig.3. Seedling emergence about 60 days after sowing in the field in 1997
1:Ta Hung Ku, 2:GNOM, 3:Arroz da Terra, 4:Kinuhikari, 5:KAEN N 635, 6:KAEU N 16.

Table 1. Selected cultivars with good seedling emergence

	Cultivar	Origin	Percentage of seedling emergence (%)		
			1996	1997	1998
	Ta Hung Ku	China	33	48	24
	Arroz da Terra	Portugal	17	38	
	Italica Livorno	Italy	23	21	
	KAEU N 16	Russia		42	
Reference	M401	USA	0		
	FR13A	India	0		
	Akamai	Japan	6		
Control	Dontokoi	Japan	2		8
	Kinuhikari	Japan	2	28	
	Koshihikari	Japan	2		

Table 2. Percetage of seedling emergence of Hokuriku PL3

Cultivar		Generation of Hokuriku PL3			
		F3	F4		F5
		Field test (%)	Field test (%)	Growth chamber (%)	Field test (%)
	Hokuriku PL3	26	18	60	72
Control	Ta Hung Ku	27	13	63	74
	Dontokoi	6	0	13	57

Table 3. Percentage of seedling emergence of Kanto PL13

Cultivar		Generation of Kanto PL13					
		BC1F2	BC1F3	BC1F4		BC1F5	BC1F6
		Field test (%)	Field test (%)	Field test (%)	Growth chamber (%)	Growth chamber (%)	Growth chamber (%)
	Kanto PL13	17	81	59	57	85	60
Control	Ta Hung Ku	10	72	65	67	40	60
	Dontokoi	1	51	30	3	10	13

Table 4. Agronomic characters of Hokuriku PL3 under surface seeded cultivation

Cultivar	Seedling establishment percentage (%)	Heading date	Maturing date	Culm length (cm)	Panicle length (cm)	Number of paniclesper unit area (No./m^2)	Degree of lodging (0-5)
Hokuriku PL3	69	7.30	9.07	69	19.6	330	1.0
Haenuki	69	7.29	9.05	63	16.9	608	0.0
Dontokoi	68	8.04	9.10	68	17.0	552	2.0

These characters were investigated at National Agricultural Research Center Hokuriku Research Center in 2000. The surface direct-seeded date was April 27 in 2000. Degree of lodging was classified into 6 degree (0:standing-5:complete lodging).

Table 5. Yields and grain quality of Hokuriku PL3 under surface seeded cultivation

Cultivar	Weight of terrestrial (kg/ha)	Yields of brown rice (kg/ha)	Yield percentage (%)	Appearance of grains (1-9)	1000-kernel weight (g)
Hokuriku PL3	1,113	423	75	8.0	26.8
Haenuki	1,315	562	100	4.5	23.0
Dontokoi	1,357	608	108	4.5	22.6

Appearance of grains was estimated in comparison with ordinary rice varieties and classified into 9 grade (1:excellent good-9:especially bad).

Table 6. Agronomic characters of Kanto PL13 under surface seeded cultivation

Cultivar	Seedling establishment percentage(%)	Heading date	Maturing date	Culm length (cm)	Panicle length (cm)	Number of panicles per unit area (No./m^2)	Degree of lodging (0-9)
Kanto PL13	71	8.27	10.14	92	20.1	428	6.3
Nipponbare	71	8.22	10.11	77	18.4	505	5.3
Dontokoi	63	8.12	9.24	68	16.8	412	0.0

These characters were investigated at National Institute of Crop Science in 2003 and 2004. The surface direct-seeded date was May 7 in 2003, May 12 in 2004. Degree of lodging was classified into 10 degree (0:standing-9:complete lodging).

Table 7. Yields and grain quality of Kanto PL13 under surface seeded cultivation

Cultivar	Weight of terrestrial (kg/ha)	Yields of brown rice (kg/ha)	Yield percentage (%)	Appearance of grains (1-9)	1000-kernel weight (g)
Kanto PL13	1,793	501	84	6.9	25.0
Nipponbare	1,889	595	100	4.8	22.7
Dontokoi	1,378	495	83	4.2	21.7

Appearance of grains was estimated in comparison with ordinary rice varieties and classified into 9 grade (1:excellent good-9:especially bad).

are also necessary.

We expect to use the two lines to breed practical rice cultivars with good seedling emergence in direct sowing under submerged condition.

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