Breeding of a Rice Line with Extraordinarily Large Grains as a Genetic Source for High Yielding Varieties

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Grain size which determines weight of individual grains plays an important role in getting high yield in rice (*Oryza sativa* L.), because the yield is the product of weight of individual grains and number of grains. Therefore, it is interesting if grain size can be changed to a large one. But, there are not so many cultivars which have very large grains weighing more than 35 mg/grain in brown rice in the world, and the brown rice of standard Japanese cultivars weighs about 20 mg/grain. In addition, most cultivars with very large grains have disadvantages such as long culm length and long growth duration. In this paper, the breeding of a new line which has extraordinarily large grains, as heavy as 71.2 mg/grain of brown rice, and some other lines with very large grains will be presented. In this paper, size (length and width) and weight of grains indicate those of brown rice, unless otherwise stated.

Breeding of a new line with extraordinarily large grains[8,11]

The author and his co-workers[8] developed 4 lines with very large grains at the Agricultural Research Center (Table 1). Of them, BG1 obtained from the cross Taiho×Cho-ko-to had the largest grains, weighing 52.0 mg/grain and its grain length and width were 7.5 and 3.5 mm respectively. In contrast, the brown rice of Japanese standard cultivar, Nipponbare, weighed 22.4 mg/grain and its grain length and width were 5.2 and 3.0 mm respectively. BG4 from the cross Taiho×Sesia also had large grains weighing 44.3 mg/grain, and its grain length and width were close to those of BG1. Of their parents, Taiho is a Japanese cultivar with wide grains, 3.4 mm in width, while Cho-ko-to is a Chinese cultivar with long grains, 9.2 mm in length, and Sesia is an Italian cultivar which also has long grains, 8.4 mm in length. The fact that BG1 and BG4 have larger grains than their parents is considered to be attributed to the width and the length which certainly originate respectively from Taiho, and Cho-ko-to and Sesia. These results show that great length and width of grains can be combined in a line, and hence it seems that grain length and width inherit independently.

On the other hand, Okada[6] released a line, Giant, with very large grains, showing 58 mg/grain, from the cross [mutant of Higeyori×(Omachi×Fusayoshi)]. Of these parents, Omachi is a native Japanese cultivar with large grains. Mutants of Higeyori and Fusayoshi both are Japanese cultivars and have large grains and lax panicles. Giant also had lax panicles. Takeda and Saito[7] released 813042, showing 60 mg/grain, from the cross Aokei 79×F_1 (Fusayoshi×Nok-Khao-Ngo). Of these parents, Aokei 79 is a Japanese cultivar with large grains, while Nak-Khao-Ngo is a cultivar from Laos or Thailand and has very large grains like BG1.

Recently, the author developed SLG1 (Super Large Grain 1) from the cross BG1×813042

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Table 1. Four breeding lines with very large grains (BG1~BG4), and their characteristics

Cultivars and lines	Heading time*	Culm length (cm)	Ear length (cm)	Panicles /plant	Grain size of brown rice		
					1-grain weight (mg)	Length (mm)	Width (mm)
Toyonishiki	Aug. 11	84	21.0	14.4	21.1	5.1	2.9
Nipponbare	Aug. 25	84	22.1	16.2	22.4	5.2	3.0
Taiho (P_1)	Sept. 4	94	21.8	14.0	32.4	5.7	3.4
Sesia (P_2)	Aug. 14	83	21.6	13.2	33.3	8.4	3.1
Cseljaji	Aug. 13	122	30.0	10.2	37.8	7.3	3.2
Cho-ko-to (P_3)	Aug. 21	127	32.0	10.6	35.6	9.2	2.4
BG1 ($P_1 \times P_3$)	Aug. 17	95	26.2	10.6	52.0	8.5	3.3
BG2 ($P_1 \times P_3$)	Aug. 18	111	26.7	9.6	49.4	9.0	3.3
BG3 ($P_1 \times P_2$)	Aug. 30	111	21.5	7.8	39.3	7.0	3.4
BG4 ($P_1 \times P_2$)	Aug. 21	94	24.0	12.6	44.3	7.7	3.5

*: Seeding time was May 11 in 1978.

Table 2. A line with extraordinarily large grains (SLG1) and its characteristics

Cultivars and lines	Heading time*	Culm length (cm)	Ear length (cm)	Panicles /plant	Grains/ panicle	Grain size of brown rice		
						1-grain weight (mg)	Length (mm)	Width (mm)
BG1 (P_1)	Aug. 19	88	21.8	5.1	63	44.3	7.9	3.3
813042 (P_2)	Aug. 16	105	24.7	4.6	64	52.7	8.4	3.4
SLG1 ($P_1 \times P_2$)	Aug. 25	90	25.9	5.4	52	71.2	10.2	3.3
Koshihikari	Aug. 16	80	18.2	6.1	112	19.8	4.9	2.9

*: Seeding time was May 6 in 1982.

at the National Institute of Agricultural Sciences. SLG1 had extraordinarily large grains, showing 71.2 mg/grain, and the grain length and width were 10.2 and 3.3 mm respectively (Table 2, Plate 1). The reason why SLG1 has larger grains than its parents is considered to be its longer grain length, though the grain width is same as its parents. Fig. 1 shows that the development of SLG1 is a result of gathering many different genes

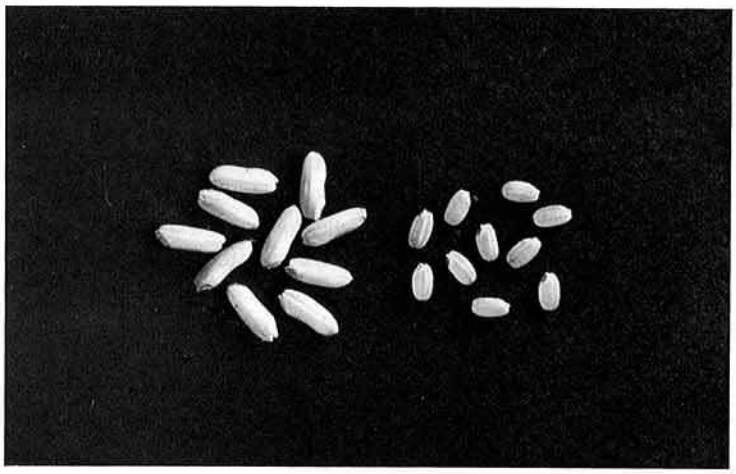

Plate 1. Brown rice of SLG1 (left) and standard cultivar Koshihikari (right)

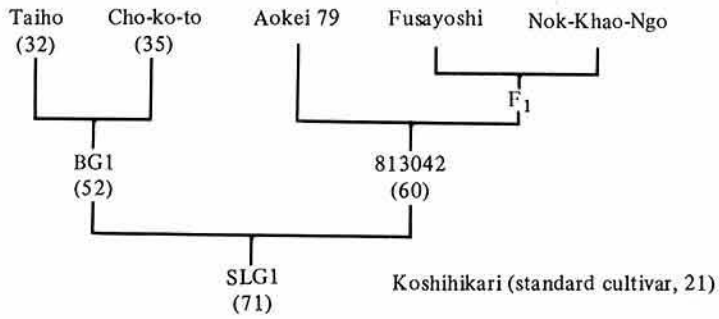

Fig. 1. Genealogy of SLG1
Numerals in parentheses indicate 1-grain weight (mg) of brown rice.

determining grain size from many cultivars with large grains. The yielding ability of SLG1, however, seems to be poor because SLG1 has fewer panicles and a bad plant type such as long drooping leaves.

According to the catalog of IRRI[1] which lists 9,926 cultivars or lines, a cultivar with the largest grains is Cseljaj from Hungary, and its performance in Japan is shown in Table 1. IRRI[2] also reported that the unhulled grain weight of 14,128 accesions of the IRRI world collection varies from 6 to 52 mg/grain, which is converted to 5 to 42 mg/grain in brown rice if the ratio of brown rice grain to unhulled rice grain is defined as 0.8. Based on the rice variety catalog of Malaysian Agricultural Research and Development Institute (MARDI)[5] listing 1969 cultivars or lines, Cho-ko-to, which is shown in Table 1, has the longest and largest grains. It may not be wrong to say that SLG1 has the largest grains in the world so far.

Large grain lines as a high yielding cultivar[9,11]

The author and Sato[9] released promising large grain lines, BG25 and BG26, developed from the cross Taiho×Sesia. Their yielding ability was shown to be similar to that of Nipponbare which is a standard leading cultivar with the same growth duration as them (Table 3). BG25 and BG26 have the grain weight of 35.5 and 32.7 mg/grain, respectively, but they have long culm which causes lodging and undesirable plant type with drooping leaves. It is considered that more promising, high yielding lines with very large grains can be bred if these adverse characteristics are improved.

The cultivar Shinho 38 may be a good example with large grains and high yielding ability. It was released by Nagano Prefectural Agricultural Experiment Station as a mutant of Toyonishiki, a standard leading cultivar with early maturing. It shows 25.0 mg/grain, slightly larger than 21.2 mg/grain of the original cultivar and 5% higher yield (Table 3).

The author[11] also developed 10 large grain lines with short culms and good plant type like modern promising cultivars (Table 4). These lines were bred from the crossings between the very large grain lines, BG1, BG25, and the leading Japanese cultivars. The yielding abilities of these lines are to be tested. These lines showed fewer panicles per plant (PN) but larger ear size (ES) which is calculated from 1-grain weight×number of grains per panicle. This negative correlation between grain size and PN may become a problem in developing high yielding large grain lines, if the capacity of the sink (PN×ES) does not increase in large grain lines due to decreasing PN. A further study on this point is now in progress using some near isogenic lines regarding grain size.

IRRI[3] reported, based on detailed studies, that yield potential, which is calculated from 1-grain weight×spikelet number, is maximum

Table 3. Promising large grain lines (BG25, BG26) with high yielding ability

Cultivars and lines	Heading time*	Culm length (cm)	Ear length (cm)	Panicles /m²	Yields (kg/a)	(%)	1000-grain weight of brown rice (g)
Toyonishiki	Aug. 20	94	20.9	298	58	(100)	21.2
Shinho 38	Aug. 20	92	21.8	259	61	(105)	25.0
Nipponbare	Aug. 31	79	21.9	292	56	(100)	21.8
BG25	Aug. 30	105	24.6	146	55	(98)	35.5
BG26	Aug. 30	105	23.3	148	55	(98)	32.7

*: Seeding time was May 14 in 1980. BG25, BG26=Taiho × Sesia.

Table 4. Large grain lines with short culms (SLG2~SLG11) and their characteristics

Cultivation method*	Cultivars and lines	Heading time**	Culm length (cm)	Ear length (cm)	Panicles /m²	Grains/ panicle	1-grain weight of brown rice (mg)
A	Toyonishiki	Aug. 15	85	20.0	325	84	21.1
	Kochihibiki	Aug. 19	71	18.8	371	74	21.6
	Nipponbare	Aug. 26	83	19.6	387	84	21.0
	SLG2	Aug. 13	79	19.3	269	84	32.0
	SLG3	Aug. 19	79	19.3	256	77	32.0
	SLG4	Aug. 19	86	18.3	285	56	35.2
	SLG5	Aug. 25	79	19.1	251	58	37.4
	SLG6	Aug. 24	89	19.2	261	65	37.9
	SLG7	Aug. 16	84	19.0	224	56	42.5
B	Kochihibiki	Aug. 20	70	20.1	320	90	21.1
	Kanto 124	Aug. 24	69	21.9	275	116	22.2
	BG25	Aug. 25	88	22.5	173	87	38.1
	SLG8	Aug. 24	65	21.0	218	85	34.8
	SLG9	Aug. 25	66	21.6	189	103	27.8
	SLG10	Aug. 26	71	22.0	192	107	30.6
	SLG11	Aug. 27	73	21.7	208	108	35.2

*: amount of fertilizer, A=9.0 kgN/10a, B=5.6 kgN/10a.
**: Seeding time was May 6 in 1982.
SLG2~7=BG1 × Koshihikari, SLG8~11=Kochihibiki × F_1 (Kanto 124 × BG25).

when the unhulled grain weight is 39 mg/grain, and that it becomes larger if large grain size is combined with short stature. Jones et al.[4] reported that grain filling speed is positively and highly significantly correlated with 100-grain weight. These reports seem to indicate that large grain size might increase grain yield by increasing the yield potential and grain filling speed. However, these studies were conducted by using large grain cultivars with long culms, so that there still remains a problem of lodging. In this sense, the large grain lines with short culms developed by the author here will be used as good materials to analyze the relationship between grain size and grain yield.

Grain quality and other aspect of large grain lines[10]

The author[10] examined the grain quality of large grain lines. The grain size showed a highly positive correlation with white belly rice ratio (Fig. 2, r=0.884**). Furthermore, in the very large grain lines, BG1, BG3 and BG4, high ratios of broken rice, 59–92%,

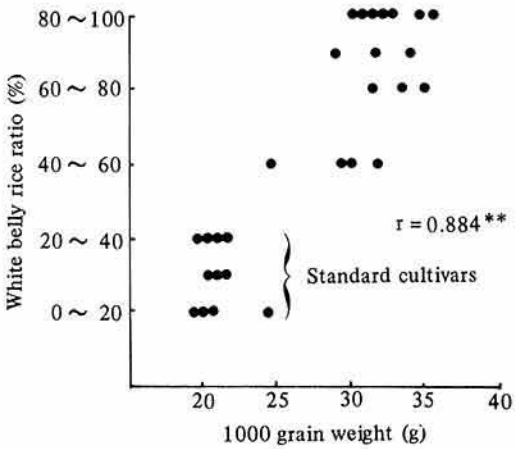

Fig. 2. Relationship between 1000-grain weight and white belly rice ratio

were observed after milling as compared to 1% of the standard cultivar Nihonmasari (Table 5). The occurrence of broken rice at such high ratios is considered to be caused by a wider presence of powdery portions such as the breakable white belly in a large grain.

Although the large grain rice shows a possibility of being used as a genetic source for developing high-yielding varieties, it has serious defects in grain quality at present. However, if the time comes in future to consider the utilization of rice for feeding purpose, which is being discussed by some people including the author,[12] the very large grain lines may be suitable for that purpose, because they can be distinguished easily from the rice for human consumption by their grain size and their high yielding ability can reduce the production cost of feed rice.

Table 5. Broken rice ratio of large grain lines

Cultivars and lines	1-grain weight of brown rice (mg)	Broken rice ratio* (%)
Nihonmasari	24.6	1
BG1	47.2	92
BG3	43.3	59
BG4	45.4	85

*: broken rice/total weight after milling, BG1=Taiho × Cho-ko-to, BG3, BG4= Taiho × Sesia.

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(Received for publication, February 10, 1983)