Effects of the Dwarfing Gene from Dee-geo-woo-gen and Others on Emergence Ability under Deep Seeding Condition in Rice

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Summary

The effects of the dwarfing genes, i.e. *d-12* (yukara dwarf), *d-18^k* (kotaketamanishiki dwarf), *d-47* (dee-geo-woo-gen dwarf), and *sd-1* at the same locus as *d-47*, on emergence ability under deep seeding condition were investigated. The following lines were used: Shiokari (one recurrent parent) and its isogenic lines, i.e. *d-12* line, *d-18^k* line and *d-47* line; Taichung 65 (the other recurrent parent) and its isogenic line, i.e. *d-47*(T65) line; Calrose 76 containing *sd-1* and Calrose; and Kotaketamanishiki, the gene source of *d-18^k* and Tamanishiki. The seeding depths were 1, 4 to 7 cm. The final emergence percentages (30 days after seeding) of *d-47* line and *d-18^k* line were as low as 12.5 and 17.5 %, respectively, whereas those of Shiokari and *d-12* line were 82.8 and 42.2 %, respectively. The emergence percentages of *d-47*(T65) line, Calrose 76 and Kotaketamanishiki at the 6 or 7 cm seeding depth were lower than those of their respective parental cultivars. Coleoptile or incomplete leaf first emerged at the 1 cm seeding depth in all the 10 lines. All the lines except Calrose and Kotaketamanishiki emerged by the first, second or third leaf at the 7 cm seeding depth. The following tendency is recognized at each seeding depth: each of the dwarf lines emerged by upper leaves than its parental cultivar. At the 7 cm seeding depth, the lengths of incomplete leaf internode, mesocotyl, coleoptile and incomplete leaf of each of the dwarf lines were shorter than those of its parental cultivar. It is inferred that *d-47*, *sd-1*, *d-18^k* and *d-12* depress the elongations of these four organs under deep seeding condition, and they lower emergence ability.

Key Words: *Oryza sativa*, dwarfing gene, pleiotropy, isogenic line, deep seeding, emergence ability, mesocotyl.

Introduction

The areas of direct seeding are less than 1.0 % of the total rice area of Japan (Crop Production Division, Agricultural Production Bureau, Ministry of Agriculture, Forestry and Fisheries, Government of Japan 1992), whereas rice cultivation is almost carried out by

direct seeding in USA (Akita 1990). The water-seeded cultural system is applied in California. On the other hand, the dry-seeded cultural system is applied ordinarily in southern USA including Texas etc., because it is comparatively warm during the sowing season. Long culm varieties, most of which are offsprings of *javanica* varieties (Akita 1990), have been cultivated for long time in these regions. Recently, a short culm variety, Lemont, which was released in 1983, is cultivated for more than 40 % of the total rice area of southern USA (Akita 1990). However, Lemont has the disadvantage of low emergence percentage and poor stand establishment when seeded about 2.5 cm or deeper (Dilday *et al.* 1990). Lemont is regarded as containing the dwarfing gene from Dee-geo-woo-gen, viz. *d-47* (Bollich *et al.* 1985 and Akita 1990), like the short culm and high yielding varieties in Southeast Asia. In this study, the authors investigated whether *d-47* and a few other dwarfing genes affect the ability of emergence from soil surface or not, by using isogenic lines. Further, relationship between the emergence ability and seedling organs such as mesocotyl and coleoptile was investigated.

Materials and Methods

1. Isogenic lines of Shiokari

The names of the dwarfing genes in this study and their symbols follow the proposal by the Committee on Gene Symbolization, Nomenclature and Linkage Groups (Futsuhara *et al.* 1986).

Shiokari, and its isogenic lines of *d-47*, *d-12* (yukara dwarf) and *d-18^k* (kotaketamanishiki dwarf) were used. They were abbreviated to *d-47* line, *d-12* line and *d-18^k* line with their gene symbols, the numbers of backcrosses of which were 12, 11 and 15, respectively. The recurrent parent, Shiokari is of intermediate culm length and one of the leading varieties of Hokkaido around 1970 (Hokkaido Central Agricultural Experiment Station 1979). The morphological characteristics of the three dwarf lines were reported by Murai *et al.* (1982, 1990 and 1995) and Murai and Kinoshita (1983); the culm lengths of *d-12*, *d-18^k* and *d-47* lines and Shiokari were 42.0, 34.3 and 38.1 and 64.6 cm, respectively, under a field condition. According to Murai *et al.* (1990), *d-12* is the same or allelic to the dwarfing gene of Fukei 71 which is resistant to lodging (Futsuhara

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1868). *d-18^k* enhances not only the cool temperature tolerance at the booting and flowering stages but also the high temperature tolerance at the flowering stage (Murai *et al.* 1991 a, b and 1992 a, b).

2. Other isogenic lines

The other isogenic line of *d-47*, designated as *d-47* (T65) line, was developed by the backcross of Taichung 65 which is a *japonica* cultivar developed in Taiwan in 1928. The number of backcrosses was 10.

The other experimental lines were Calrose 76, Calrose, Kotaketamanishiki and Tamanishiki. Calrose 76 (abbreviated to "C76" hereafter) is a γ -ray induced mutant from Calrose which contains a dwarfing gene named *sd-1* at the same locus as *d-47* (Foster and Rutger 1978). Kotaketamanishiki (abbreviated to "KT" hereafter) is the gene source of *d-18^k*. The authors assumed that KT is a natural dwarf mutant from a native cultivar, Tamanishiki. The morphological and floral characteristics of these 6 lines were reported by Murai *et al.* (1991 a and 1995).

3. Method of experiment

The subsoil of the volcanic ash soil in Kanuma was used after the following process: air-drying, crushing and sifting through a 5-mm-mesh screen. No fertilizer was applied. A cylindrical pot was used, the inside diameter and depth of which were 10.9 and 14.0 cm, respectively, and which had a bottom hole of diameter at 1.0 cm. A sheet of cotton gauze of a 7×7 cm square was put on the hole. The soil was taken into a pot at the depth of 6.0 cm, forming a seeding bed. Sixteen seeds were sown in a 5×5 cm square (1.7 cm between seeds) on the soil surface. The thicknesses of covering soil were 1.0, 4.0, 5.0, 6.0 and 7.0 cm for each line, i.e. the 1, 4 to 7 cm seeding depths. One pot per seeding depth for each line was used for one replicate, and four replicates were carried out one after another.

The seeds of the lines for the experiment were harvested after being grown in the natural light growth cabinet which were 25/19°C of day/night temperatures in 1991, viz. the year before the year of the experiment. There was small difference among Shiokari and its isogenic lines as well as between the other three dwarf lines and their respective parental cultivars in 1000

kernel weight (Table 1). Seeds for sowing were selected by salt solutions of 1.10 and 1.13 gravities for Shiokari and its isogenic lines, and the other six lines, respectively. The seeds were sterilized by the saturated solution of Benomyl for 30 minutes, and they were rinsed. All the pots were placed in an artificial light growth room which was kept at 25°C and about 30,000 lux (9:30 a.m. to 9:30 p.m.), and 19°C and the dark (9:30 p.m. to 9:30 a.m.). The relative humidity in the room was always kept at about 70 %. The pots were watered with a sprinkling can on every third day.

Emergence from soil surface was observed every day at 6 p.m. from one to 30 days after sowing. Just after the final observation, the lengths of the seedling organs shown in Table 2 were measured for about half the seedlings of every pot. It was investigated what kind of leaf first emerged from soil surface, since the first or a upper leaf first emerged at the 4, 5, 6 and 7 cm seeding depths.

The germination percentages of all the ten lines were 97.8 % or higher. The emergence percentage in this study was calculated with the exception of the nongerminated seeds.

Results

1. Emergence percentage

Fig. 1 shows daily change of emergence percentage in Shiokari and its isogenic lines at all the seeding depths. All the lines exceeded 90 % on 7, 12 and 15 days after seeding at the 1, 4 and 5 cm seeding depths, respectively. The emergence percentages of Shiokari and *d-12* line increased more quickly at all the seeding depths than those of *d-18^k* line and *d-47* line. As shown in Table 3, the final emergence percentages of *d-18^k* line and *d-47* line at the 6 cm seeding depth were lower than those of Shiokari and *d-12* line. Those of *d-18^k* line and *d-47* line at the 7 cm seeding depth were as low as 17.5 and 12.5 %, respectively, whereas that of Shiokari was 82.8 %.

Table 2. The definitions of the seedling organs in this study

Organ	Definition or explanation
1. Coleoptile	Coleoptile or seminal root first appears at germination.
2. Incomplete leaf	This leaf appears next to coleoptile, which lacks leaf blade.
3. 1st to 3rd leaves	The first complete leaf next to incomplete leaf, and the following two leaves.
4. Mesocotyl	From the base of seminal root to the base of coleoptile.
5. Coleoptile internode	From the base of coleoptile to the base of incomplete leaf.
6. Incomplete leaf internode	From the base of incomplete leaf to the base of the first leaf sheath.
7. 1st leaf internode	From the base of the first leaf sheath to the base of the second leaf sheath.
8. 2nd leaf internode	From the base of the second leaf sheath to the base of the third leaf sheath.

Table 1. The 1000 kernel weights (g) of the 10 lines used in the experiment

(1) Shiokari and its isogenic lines

<i>d-12</i> line	<i>d-18^k</i> line	<i>d-47</i> line	Shiokari	LSD (0.05)
18.9	18.6	19.0	19.2	1.8

(2) The other three dwarf lines and their parental cultivars

<i>d-47</i> (T65) line	Taichung 65	C76	Calrose	KT	Tamanishiki	LSD (0.05)
22.7	23.7	23.8	23.2	20.8	20.8	0.7

Fig. 1. Daily change of emergence percentage of Shiokari and its isogenic lines at the 1, 4 to 7 cm seeding depths.

---□--- d-12 line.
 ---△--- d-18^k line.
 ---○--- d-47 line.
 —●— Shiokari.

As shown in Table 4, the final emergence percentages of d-47(T65) line, C76 and KT at the 6 or 7 cm seeding depths were lower than those of their respective parental cultivars. Especially, KT could not emerge at the 7 cm seeding depth.

2. Leaf of first emergence

At the 1 cm seeding depth, all the ten lines emerged by

coleoptile or incomplete leaf (the figures were abridged).

Fig. 2 shows what kind of leaf first emerged from soil surface at the 4 to 7 cm seeding depths in Shiokari and its isogenic lines. At the 4 cm seeding depth, d-12 line and Shiokari emerged by coleoptile or incomplete leaf. On the other hand, the emergence by the first leaf was more than 65 % in d-18^k line and d-47 line. At the 5 cm

Table 3. The emergence percentages of Shiokari and its isogenic lines on 30 days after seeding

Seeding depth	d-12 line	d-18 ^k line	d-47 line	Shiokari	LSD (0.05)
1 cm	100.0	100.0	100.0	100.0	—
4 cm	100.0	98.4	98.4	100.0	—
5 cm	93.5	95.3	95.2	100.0	5.5
6 cm	93.8	79.7	79.4	100.0	15.7
7 cm	42.2	17.5	12.5	82.8	29.6

seeding depth, the percentage of the first leaf was more than 90 in d-12 line, d-18^k line and d-47 line, whereas that was 56.3 % in Shiokari. At the 6 cm seeding depth, the emergence by the second leaf was observed in all the lines. There was the emergence by coleoptile only in Shiokari. At the 7 cm seeding depth, the percentage of the second leaf increased in each line. Further, the emergence by the third leaf was observed in d-47 line. It is noteworthy at the 7 cm seeding depth that the order of

Table 4. The emergence percentages of d-47 (T65) line, C76, KT and their parental cultivars on 30 days after seeding

Seeding depth	d-47 (T65) line	Taichung 65	C76	Calrose	KT	Tamanishiki	LSD (0.05)
1 cm	100.0	100.0	100.0	100.0	100.0	100.0	—
4 cm	98.4	96.8	98.4	98.4	95.3	100.0	—
5 cm	95.3	96.9	100.0	100.0	85.7	100.0	8.2
6 cm	64.7	92.2	84.1	96.8	43.8	95.3	19.8
7 cm	50.0	80.6	49.2	75.8	0.0	48.4	34.4

Fig. 2. Diagrams exhibiting what kind of leaf first emerged from soil surface at the 4 to 7 cm seeding depths in Shiokari and its isogenic lines.

Percentage of:

the four lines in the percentage of the first leaf agreed with that in emergence percentage (Table 3).

Fig. 3 shows what kind of leaf first emerged from soil surface at the 4 to 7 cm seeding depths in d-47(T65) line, C76, KT and their parental cultivars. It is apparent in each of the lines that the deeper the seeding depth, the upper the leaf of emergence. The following tendency is recognized at each seeding depth: each of the dwarf lines emerged by upper leaves than its parental cultivar. At the 6 cm seeding depth, the order of the six lines in the total of the percentages of the first and incomplete leaves agreed with that in emergence percentage (Table 4). Similar relationship was recognized at the 7 cm seeding depth (Table 4).

The results in this section indicate that the emergences by the first and incomplete leaves at the 6 and 7 cm seeding depths were more advantageous to enhance emergence percentage than those by the second and third leaves. There was a tendency that each of all the dwarf lines emerged by upper leaves than its parental

cultivar.

3. Morphology of seedling

Fig. 4 exhibits the lengths of coleoptile, incomplete leaf, mesocotyl, coleoptile internode and incomplete leaf internode of the emerged seedlings of Shiokari and its isogenic lines at all the seeding depths. In addition, those of the non-emerged seedlings at the 7 cm seeding depth are exhibited. The coleoptile and incomplete leaf of each line elongated more, as seeding depth became deeper. The incomplete leaf internode and mesocotyl of each line showed similar elongations. The coleoptile internode of each line elongated from the 1 to 4 cm seeding depths, but it showed small change from the 4 to 7 cm seeding depths. At the 7 cm seeding depth, the order of the lines was Shiokari > d-12 line > d-18^k line > d-47 line in the lengths of coleoptile and incomplete leaf (Fig. 4-(5) and Table 5-(1)). The mesocotyl lengths of the lines at the 7 cm seeding depth were in the order of d-12 line > Shiokari > d-18^k line > d-47 line, but that of d-

Fig. 3. Diagrams exhibiting what kind of leaf first emerged from soil surface at the 4 to 7 cm seeding depths in d-47 (T65) line, C76, KT and their parental cultivars.

KT could not emerge at the 7 cm seeding depth. T65: Taichung 65.

Percentage of:

12 line was shorter than that of Shiokari at the 4, 5 and 6 cm seeding depths. The incomplete leaf internode lengths of the lines at the 7 cm seeding depth were in the order of Shiokari > d-12 line > d-47 line > d-18^k line. As the result, the order of the lines at the 7 cm seeding depth was Shiokari > d-12 line > d-18^k line > d-47 line in the length from seed to the tip of incomplete leaf internode, which is the same as the order in emergence percentage (Table 3). At the 7 cm seeding depth, the lengths of the four organs except coleoptile internode of the non-emerged seedling of each line were shorter than those of the emerged seedling (Fig. 4-(5) and (6)).

Fig. 5 exhibits the lengths of coleoptile, incomplete leaf, mesocotyl, coleoptile internode and incomplete leaf internode of the emerged seedlings of d-47(T65) line, C76, KT and their parental cultivars at the 1, 6 and 7 cm seeding depths; and those of the non-emerged seedlings at the 7 cm seeding depth. At the 6 cm seeding depth as well as at the 7 cm seeding depth, the four organs except the coleoptile internode of each of the

dwarf lines were shorter than those of its parental cultivar, with the exception of the incomplete leaf of d-47 (T65) line at the 6 cm seeding depth. At the 7 cm seeding depth, the four organs except the coleoptile internode of the non-emerged seedling were shorter than those of the emerged seedling in each of all the lines except KT.

Table 5 shows the morphologies of the emerged seedlings of Shiokari and its isogenic lines, d-47(T65) line, Taichung 65, C76 and Calrose at the 1 and 7 cm seeding depths. As mentioned above, the coleoptile and incomplete leaf of each line elongated at the 7 cm seeding depth. On the other hand, the lengths of the first to third leaf sheaths and the second and third leaf blades at the 7 cm seeding depth were shorter than those at the 1 cm seeding depth in all the eight lines, with a few exceptions. The first leaf blade length of each line showed small change between the two seeding depths. The incomplete leaf internode and mesocotyl of each line elongated at the 7 cm seeding depth, as mentioned

Fig. 4. The lengths of coleoptile, incomplete leaf, mesocotyl, coleoptile internode and incomplete leaf internode of the emerged seedlings of Shiokari and its isogenic lines at the 1, 4 to 7 cm seeding depths, and those of the nonemerged seedlings at the 7 cm seeding depth.

Fig. 5. The lengths of coleoptile, incomplete leaf, mesocotyl, coleoptile internode and incomplete leaf internode of the emerged seedlings of d-47 (T65) line, C76, KT and their parental cultivars at the 1, 6 and 7 cm seeding depths, and those of the nonemerged seedlings at the 7 cm seeding depth. KT could not emerge at the 7 cm seeding depth. T65: Taichung 65. Explanation of diagram: see Fig. 4.

above. Further, the first leaf internode of all the eight lines elongated at the 7 cm seeding depth, and the lengths of the dwarf lines were longer than those of their parental cultivars, in contrast with the incomplete leaf internodes of the lines. The numbers of fully developed leaves of the eight lines at the 1 cm seeding depth were 3.0 or 3.1, whereas those at the 7 cm seeding depth were between 3.3 and 4.0. It seems that the fourth leaf compensatingly developed when the first leaf could not emerge and died.

Discussion

Under deep seeding condition, mesocotyl, coleoptile and incomplete leaf have high ability of penetration; on the other hand, the first leaf blade has low ability of penetration, and the first leaf sheath often obliquely elongates (Kawatei *et al.* 1963, Ueyama *et al.* 1965, Ueyama and Sato 1968, and Ito and Inoue 1973), which are supported by the authors' observation. Mesocotyls of *indica* varieties and tall southern USA (probably *javanica*) cultivars could elongate easily resulting in high ability of emergence from soil surface (Ito and Inoue 1973, Turner *et al.* 1982, and Dilday *et al.* 1990), whereas those of *japonica* cultivars could not elongate more than 10 mm (Kawatei *et al.* 1963, Ueyama and Sato 1968, Ito and Inoue 1973, and Tsunematsu and Washio 1973). The four parental cultivars in this study belong to the *japonica* rice. The longest mesocotyl in this study was 12.2 mm (Calrose at the 7 cm seeding depth). According to Ueyama and Sato (1968), and Tsunematsu and Washio (1973), on the other hand, the incomplete

leaf internodes of the *japonica* cultivars used by them apparently elongated under deep seeding conditions. In this study, the incomplete leaf internodes of the lines markedly elongated at the 7 cm seeding depth (the longest was 38.5 mm), and the lengths of the dwarf lines were shorter than those of their respective parental cultivars. The emergence percentages of Shiohari, Taichung 65 and Calrose were higher than 75 % at the 7 cm seeding depth, and the emergence by the first leaf was more than 80 % in these lines. Therefore, it is inferred that their first leaves were pushed up with their elongated incomplete leaf internodes resulting in emergence, and their emergences were supported by their elongated coleoptiles and incomplete leaves. In d-18^k line, d-47 line and d-47(T65) line, on the other hand, the total of the emergences by the second and third leaves was higher than 50 % at the 7 cm seeding depth accompanied by the elongation of the first leaf internode, indicating that the second or third leaf barely emerged, supported by the elongation of the first leaf internode. To sum up, it is inferred in the *japonica* rice that d-47, *sd-1* at the same locus as d-47, d-18^k and d-12 depress the elongations of incomplete leaf internode, mesocotyl, coleoptile and incomplete leaf under deep seeding condition, and they lower emergence ability; and the effects of d-47 and d-18^k are stronger than that of d-12.

Didlay *et al.* (1990) reported that three to eight plants of dwarf and elongation of mesocotyl and coleoptile were found out of about 600 dwarf plants in each of the five F₃ progenies from the respective five cross combinations between dwarf (d-47 or *sd-1*) lines and tall American cultivars. They judged that this phenomenon

Table 5. Morphologies of the emerged seedlings at the 7 cm seeding depth, and those at the 1 cm seeding depth in parentheses

(1) Shiokari and its isogenic lines

Length (mm)	d-12 line	d-18 ^k line	d-47 line	Shiokari	LSD (0.05) ¹⁾
Coleoptile	55.4 (8.2)	53.8 (7.7)	46.1 (7.3)	55.5 (8.7)	2.7
Incomplete leaf	44.3 (22.0)	39.8 (17.1)	34.9 (19.8)	47.3 (22.0)	2.1
1st leaf sheath	35.4 (48.5)	33.6 (31.5)	32.4 (39.6)	35.0 (48.9)	3.9
2nd "	51.4 (80.5)	27.8 (51.2)	26.4 (56.7)	54.6 (80.8)	19.4
3rd "	63.0 (59.4)	33.7 (35.7)	30.5 (36.3)	60.9 (62.0)	25.5
1st leaf blade	24.4 (26.9)	19.7 (19.7)	19.3 (23.1)	29.0 (27.4)	1.8
2nd "	67.1 (106.3)	48.7 (72.1)	38.4 (84.5)	73.7 (109.6)	9.9
3rd "	94.0 (121.0)	60.6 (103.1)	46.0 (77.4)	92.5 (127.3)	51.0
Mesocotyl	6.6 (1.8)	4.9 (1.2)	3.9 (1.5)	6.2 (1.7)	0.8
Coleoptile internode	2.6 (n)	2.1 (n)	2.1 (n)	2.9 (n)	—
Incomplete leaf internode	32.5 (n)	23.6 (n)	24.1 (n)	36.5 (n)	—
1st leaf internode	5.3 (n)	10.9 (n)	15.2 (n)	3.4 (n)	—
2nd leaf internode	n (n)	0.5 (n)	2.7 (n)	n (n)	—
No. of leaves ²⁾	3.3 (3.0)	3.6 (3.0)	4.0 (3.0)	3.3 (3.1)	0.1

(2) d-47 (T 65) line, C76 and their parental cultivars

Length (mm)	d-47 (T 65) line	Taichung 65	C76	Calrose	LSD (0.05) ¹⁾
Coleoptile	45.4 (9.6)	52.6 (9.6)	39.1 (7.5)	46.9 (9.2)	2.0
Incomplete leaf	44.4 (19.8)	47.5 (21.8)	42.3 (19.7)	46.0 (23.6)	1.8
1st leaf sheath	40.8 (45.1)	42.1 (52.3)	33.1 (44.7)	33.2 (57.0)	4.6
2nd "	37.7 (81.2)	62.2 (85.0)	26.7 (85.9)	51.4 (95.2)	10.7
3rd "	45.5 (74.0)	76.3 (80.9)	47.9 (75.9)	81.1 (72.8)	17.2
1st leaf blade	24.9 (25.2)	28.6 (25.1)	21.6 (20.3)	21.9 (25.5)	2.6
2nd "	63.6 (97.3)	92.1 (111.1)	47.5 (97.8)	68.4 (127.1)	14.2
3rd "	68.4 (140.6)	121.8 (135.2)	55.4 (144.8)	98.4 (146.3)	30.4
Mesocotyl	5.1 (1.7)	8.7 (1.7)	4.9 (1.8)	12.2 (3.6)	0.8
Coleoptile internode	1.3 (n)	1.4 (n)	2.4 (n)	3.2 (n)	—
Incomplete leaf internode	23.4 (n)	32.1 (n)	26.1 (n)	38.5 (n)	—
1st leaf internode	14.0 (n)	3.6 (n)	24.2 (n)	4.0 (n)	—
2nd leaf internode	0.7 (n)	n (n)	3.0 (n)	n (n)	—
No. of leaves ²⁾	3.3 (3.0)	3.7 (3.0)	3.8 (3.0)	3.6 (3.0)	0.1

n : Elongation could not observed.

¹⁾ Calculated at the 1 cm seeding depth. The LSDs at the 7 cm seeding depth could not be calculated, because there were some pots which had no emerged seedling.²⁾ The number of fully developed leaves except incomplete leaf.

was due to the linkage between the loci of *d-47* and the gene which depresses elongation of mesocotyl and coleoptile under deep seeding condition; on the other hand, the authors consider that these dwarf plants accumulated most of the genes from their parents which elongate mesocotyl and coleoptile. The mesocotyl and coleoptile of C76, a dwarf mutant containing *sd-1*, at the 7 cm seeding depth were shorter than those of its parental cultivar, Calrose. There was very small possibility that the mutation events of *sd-1* and the gene which depresses elongation of mesocotyl and coleoptile occurred at the same time. Further, the other dwarfing genes, *d-18^k* and *d-12* depress elongation of these two organs. An *indica* cultivar, IR24 containing *d-47* could elongate its mesocotyl (about 50 mm at maximum) under deep seeding conditions (Turner *et al.* 1982). It is concluded that *d-47* or *sd-1* itself has the pleiotropic effect to lower emergence ability through the mechanism mentioned above, but this disadvantage may be sufficiently compen-

sated by genes in *indica* or other varieties except *japonica* ones which elongate mesocotyl.

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