Varietal Difference in Root Distribution of Direct Seeded Rice

Hyun Ho Kim

ABSTRACT

This study examined root growth and distribution under the direct seeding of rice cultivars developed in Korea, Japan, and the U.S. Cultivars from the U.S., especially 'M202' and 'Caloro', had a high ratio of the dry matter partitioning for root and top plant components. Caloro had high root and top growth. 'Koshihikari' from Japan showed the lowest ratio of R/T (root/total dry matter) due to the small amount of root and top plant growth. Most Japanese cultivars except transplanted 'Hatsuboshi' showed low ratio of R/T.

Patterns of root distribution for each soil block were recorded by the root box-pin board method. Roots of all cultivars were distributed in blocks A, C, and E in the middle of box, i. e., just below the plant base. Roots of 'Dongjin', M202, and Caloro were distributed deeper than the others.

Roots of transplanted Hatsuboshi developed much better than direct seeded Hatsuboshi. Total root weight density was highest in Caloro followed by Dongjin, 'Gancheok', 'Calrose', and the others.

The root density of Caloro was twice as much as those of the others except Dongjin. According to cumulative percentages of root distribution on each soil layer, roots of most cultivars were distributed below 20cm. The U.S. cultivars showed vertically well developed root systems as compared to others. A large amount of roots were distributed in the top 15cm of soil layer for Hatsuboshi and Koshinikari, and their root systems appeared to be shallow. In contrast, the rates of root distribution in the top 10cm of soil layer were low for Dongjin, Calrose, and Caloro. These cultivars had relatively deep root systems.

Key words : rice, direct seeding, root box, root distribution, soil depth.

In recent years, labor saving methods have been emphasized for rice culture in Korea since the population in the rural area has decreased. As one of the efforts to save labor in farming, rice cultivation methods have changed from machine transplanting to direct seeding. However, there are many problems in direct seeding cultivation such as poor seedlings, lodging, selection of suitable cultivars, and weed control (Kim et al., 1993; Oh & Kim, 1992; Son, 1991).

In direct seeding cultivation of rice, root lodging occurs frequently because seeds are planted on the surface or just below the top layer of the soil and plants grow with less physical support of the soil (Kim et al., 1993; Lim et al., 1990; Terashima et al., 1994). Thus root distribution has a very close relationship with lodging in direct seeded rice (Kim et al., 1993; Lee & De Datta, 1990; Morita et al., 1986; Son, 1991).

Root systems of rice have several important functions including absorption, anchorage, storage, and synthesis of various organic compounds (Kramer, 1969). In fact, most of management practices in crop production, such as fertilization and irrigation influence plants through the root-soil systems. Therefore, root system is greatly important for yield (Morita et al., 1986; Oh & Kim, 1992).

The characteristics of root systems of rice cultivars with high yield have been studied. These previous studies showed that such root systems consisted of a large number of long and well-branched roots with large diameters (Mori, 1957 and 1960). However, all high-yielding rice cultivars don't always have such large root systems. These facts suggest that the characteristics of the root system such as total root number or total root length, are not the only factors of root systems for yield (Mori, 1957 and 1960; Morita et al., 1986; Pilbert, 1995; Yamauchi et al., 1987).

The objective of this study was to compare root distribution and morphology among nine rice cultivars developed in Korea, Japan, and the U.S. for direct seeding.

MATERIALS AND METHODS

The experiment was conducted at National Agriculture Research Center (NARC), Tsukuba, Japan in 1995. Nine cultivars from three different countries were selected; Gancheok, (adaptable to reclaimed paddy soil, Korea), Nongan (suitable for direct seeding culture, Korea), Dongjin (widely adaptable in planted area, Korea) Hitomebore (susceptible to lodging, Japan), Hatsuboshi (high quality and popular cultivar in Ibarakiken, Japan), Koshihikari (most popular cultivar in Japan), M202 (semidrawf and mid-grain type cultivar, USA) Calrose (main cultivar in California, USA), and Caloro (old cultivar with long culm, USA).

To analyze root distribution, the root box-pin board method was used. Rice plants were grown in specially designed polyethylene plastic boxes in which loamy sand was filled. The sun light was shielded.

Root boxes were kept under submerged conditions in a bathtub pot with standing water just below the top of root boxes. The dimension of root box was 45×3×50cm. There were nails at 1cm intervals on pin board to fix roots. Sprouted seeds were sown in the middle of root boxes with two seeds per each box and 22-day-old seedlings of Hatsuboshi were transplanted as a check.

Roots were observed 20 days after heading. Root samples were taken at 5cm-interval in soil depth and

Chungnam Provincial Rural Development Administration, Taejon 305-313, Korea.
Received 20 Dec. 1997.

dried in the oven at 80℃. The top of the plant, as well as root samples were dried and weighed.

RESULTS AND DISCUSSION

The root system anchors the plant body and absorbs water and nutrients (Kramer, 1969; Mori, 1957, 1960; Tanaka, 1995). Studies on the root system are quite tedious and time consuming.

Differences in morphologies of root systems among rice cultivars have not been fully investigated. Previous studies showed that root and shoot systems might have been changed morphologically during the development heavy fertilization (Anma & Oda, 1982; Mori, 1960; Oynagi & Namoto, 1993). Varietal differences in the dry matter partitioning ratios of root and top plant were observed, as shown in Table 1. It has been reported that the root growth is very close to the growth of top plant (Kang & Morita, 1994; Lee & De Datta, 1990; Oynagi & Namoto, 1993). The amount of roots tended to increase positively with shoot weight.

The cultivars from the U.S., especially M202 and Caloro showed high ratio of R/T. Caloro had the great at amount of the root and top growth. On the other hand, Koshihikari showed the lowest ratio of R/T due to the small amount of root and top plant. Most Japanese cultivars except transplanted Hatsuboshi showed a low ratio of R/T.

As shown in Fig. 1, roots were obtained from the root box-pin board method to evaluate their distribution. The provisional block was divided into 13 parts. The dimension of each block (A~H) was 15×5×3cm (225cm³) except block I (4,050cm³). The total volume of roots was 6, 750cm³ and their root weight density was computed in each soil block (Table 2). Most of roots in all cultivars were distributed in blocks A, C, and E in the middle of the box, just below the plant base. Root weight density

Table 1. Varietal differences in dry matter partitioning ratios of root and top plant at the beginning of ripening stage under the direct seeding rice.

Cultivar	Heading date	Dry weight (g /root box) Root(R)	Total†	R/T (%)
Gancheok	Aug. 21	5.06	39.24	13.2
Nongan	Aug. 18	4.64	31.13	14.9
Dongjin	Aug. 24	6.17	43.85	14.1
Hitomebore	Aug. 9	3.56	31.00	11.5
Hatsuboshi	Aug. 9	2.59	23.24	11.4
Hatsuboshi (T)‡	Aug. 2	4.54	36.94	14.6
Koshihikari	Aug. 16	2.42	25.71	9.4
M202	Aug. 9	4.50	27.94	16.1
Calrose	Aug. 2	5.05	36.76	13.7
Caloro	Aug. 16	9.44	58.04	16.3
LSD (0.05)	–	0.45	3.02	0.89

† Total dry weight of upper ground part and root.
‡ Hatsuboshi was transplanted with 22-day-old seedlings.

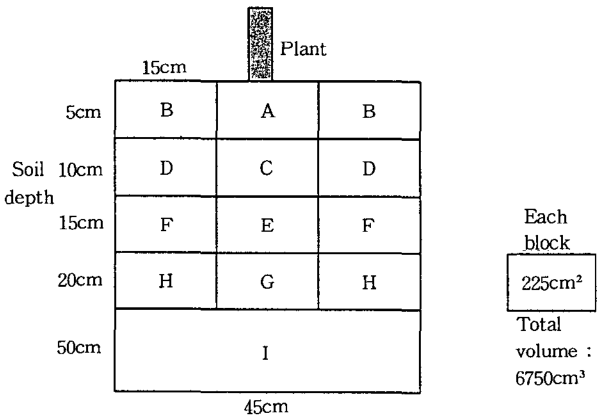

Fig. 1. Provisional names of individual soil blocks in root box-pin board methods.

Table 2. Varietal difference in root distribution to each soil block obtained from the root box.

Cultivar	Root weight density ($\times 10^{-1}$mg /cm³) A	B	C	D	E	F	G	H	I	Total
Gancheok	56.4	2.9	29.8	7.3	21.7	6.2	12.4	3.3	3.7	7.53
Nongan	68.0	1.8	21.8	6.2	20.9	6.0	4.9	7.3	2.7	7.17
Dongjin	69.7	9.6	29.2	10.4	17.7	4.9	10.7	6.0	3.1	9.14
Hitomebore	46.7	3.1	23.5	4.4	12.4	4.4	6.2	4.0	2.0	5.27
Hatsuboshi	41.7	4.7	25.8	2.7	12.9	2.0	4.0	0.9	0.4	3.84
Hatsuboshi (T)†	33.7	5.8	25.7	7.1	16.9	6.4	9.1	5.7	3.3	6.73
Koshihikari	36.0	4.2	15.7	3.1	8.4	2.2	5.3	1.1	1.2	3.59
M202	57.3	4.2	33.7	7.3	10.2	5.5	5.3	3.3	1.8	6.67
Calrose	40.0	2.0	33.3	5.1	15.5	6.4	8.4	6.9	4.8	7.48
Caloro	51.5	2.7	41.3	9.7	28.4	3.1	28.0	14.2	10.4	13.21
LSD (0.05)	11.2	2.4	5.4	1.9	3.9	1.3	2.5	1.2	0.8	1.9

† Hatsuboshi was transplanted with 22-day-old seedlings

was relatively high in the three Korean cultivars, and two U.S. cultivars (M202 and Caloro) as compared to others. Dongjn had the highest root weight density in block A, and was followed by Nongan, M202, Gancheok, and Calrose. In block C, cultivars from the U.S. were higher than others. Roots of Gancheok, Dongjin, and Caloro were distributed deeper in the soil in block G. In Caloro from the U.S., roots were distributed even deeper in soil in block I, indicating that cultivars from Korea and the U.S. were distributed to deeper soil vertically rather than horizontally as compared to others.

The root system of transplanted rice was developed much better than direct seeded rice. Dongjin had well developed roots not only in vertical but also in horizontal soil blocks. Root distribution to both vertical and horizontal soil layers seemed to be related with root lodging in direct seeding cultivation. Thus, Dongjin and Nongan could be adaptable to direct seeding cultivation in terms of root lodging under the direct seeded rice.

Total root weight density was highest in Caloro followed by Dongjin, Gancheok, and Calrose. Root density in Caloro was twice as much as those in the others except Dongjin.

Table 3 illustrates the varietal differences in ratios ofroot distribution in each soil layer. According to the cumulative percentages of root distribution on each soil layer, about 50% of roots were distributed below 10cm in soil depth for cultivars from Korea and Japan. However, the U.S. cultivars had 30~40% of roots below 10cm in soil depth. About 60% of roots were distributed up to 20cm in soil depth for Gancheok and M202. For Hatsuboshi and Koshihikari, most roots (92% and 83%, respectively) were observed at this depth. Roots of direct seeded rice under flooded condition were largely distributed on the soil surface so that plants were easily lodged.

The U.S. cultivars along with Gancheok showed about 60% of cumulative root distribution was below 20cm in soil depth, suggesting that the root systems of these cultivars developed well and were deeper than others. Photo 1 and Fig. 2 show the various vertical distributions among nine cultivars. In these figures, most of roots of Hatsuboshi and Koshihikari were distributed in the top 15cm of soil layer, and their root systems appeared to be shallow. On the other hand, the amount of roots of Dongjin, Calorose and Caloro distributed in the top 10cm of soil layer was small. The root systems of Calrose and Caloro from the U.S. could be deeper below 25cm from the soil surface.

Table 3. Varietal difference in ratio of root distribution on shallow layer of soil.

Cultivar	Cumulative percent of root weight on each soil layer			
	0~5	5~10	10~15	15~20cm
Gancheok	25.7	44.1	59.3	60.4
Nongan	34.7	51.3	67.2	76.7
Dongjin	27.6	53.5	66.6	74.9
Hitomebore	33.4	53.9	69.4	78.4
Hatsuboshi	45.2	72.2	86.5	91.5
Hatsuboshi (T)†	22.4	42.3	57.1	70.3
Koshihikari	41.4	61.4	75.4	82.5
M202	32.4	40.6	52.5	59.2
Calrose	19.6	39.1	52.9	62.4
Caloro	13.6	28.2	47.1	63.4

† Hatsuboshi was transplanted with 22-day-old seedlings.

REFERENCES

Anma, M. and K. Oda. 1982. Improved monolith method. In Togari, Y. et al. Crop experiment method. Association for advancement of agricultural science, Tokyo. p. 145-153.

Kang, S. Y. and S. Morita. 1994. Root growth and distribution in some japonica-indica hybrid and japonica type rice cultivars under field condition. Japan J. Crop Sci. 63(1):118-124.

Kim, J. K., M. H. Lee, and Y. J. Oh. 1993. Lodging pattern of rice plant in broadcast-seeded and hand-transplanted cultivation. Korean J. Crop Sci. 38(3):219-227.

Kramer, P. J. 1969. Plant and soil water relationship, Macgrew-Hill, Newyork. p. 104-109.

Lee, S. C. and S. K. De Datta. 1990. Effect of plant growth regulator Hoe 78784 on lodging in rice. Korean J. Crop Sci. 35(3):184-194.

Lim, M. S., C. W. Lee, and S. K. Lee. 1990. Research status and prospects of direct seeded rice in Korea, Focus on irrigated rice. 1st Asian Crop Sci.

Mori, T. 1957. Studies on ecological characters of rice roots. Part 3. Development of root systems with reference to the top growth. Bulletin of the Institute for Agricultural Research Tohoku University 8:265-282.

______. 1960. The relative growth of the root and shoot in rice plants. Proceedings of the Crop Science Society of Japan 29:69-70.

Morita, S., A. Iwabuchi, and K. Yamazaki. 1986. Relationships between the growth direction of primary roots and yield in rice plants. Japan. J. Crop Sci. 55:520-525.

Oh, Y. J. and C. K. Kim. 1992. Improvement of seedling stand and lodging prevention in direct seed rice. Kor. J. Weed Sci. 12(3):200-222.

Oynagi A. and T. Namoto. 1993. Relationship between root growth angle of seedlings and vertical distribution of roots in the field in wheat cultivars. Japan J. Crop Sci. 62(4):565-570.

Pilbert, B. 1995. Physiological response to salinity in rice plant. Japan J. Crop Sci. 64(2):266-272.

Son, Y. 1991. Effect of light intensity on photosynthesis on direct seeding rice cultivar. Kor. J. Crop Sci. 33(3):56-65.

Tanaka, S. 1995. Easily accessible method for root length measurement using an image analysis system. Japan J. Crop Sci. 64(1):144-147.

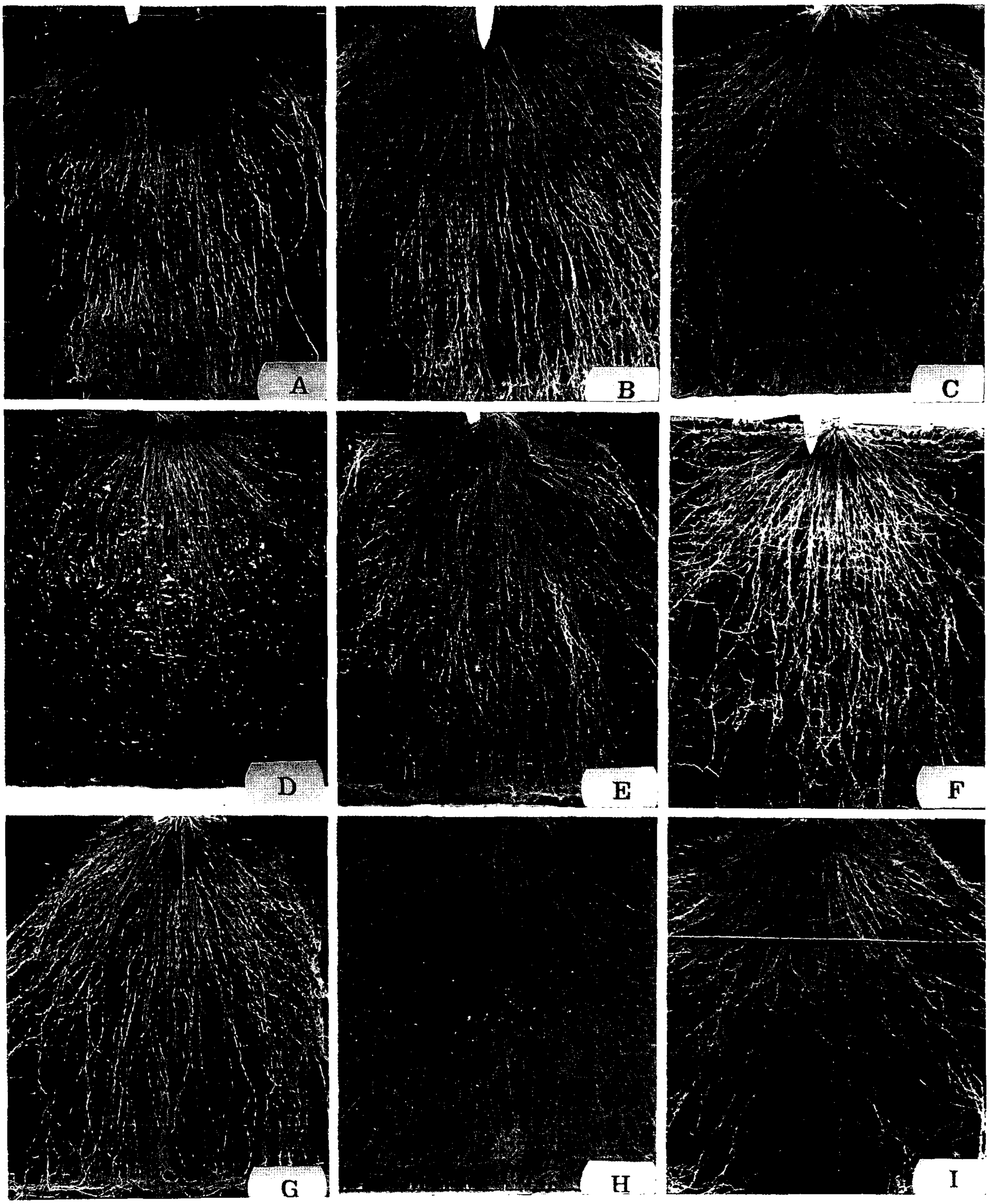

Photo. 1. Morphology of root distribution of 9 cultivars under direct seeded rice.
A : Gancheok B : Dongjin C : Nongan D : Hatsuboshi E : Hitomebore F : Koshihikari G : M202 H : Calrose I : Caloro

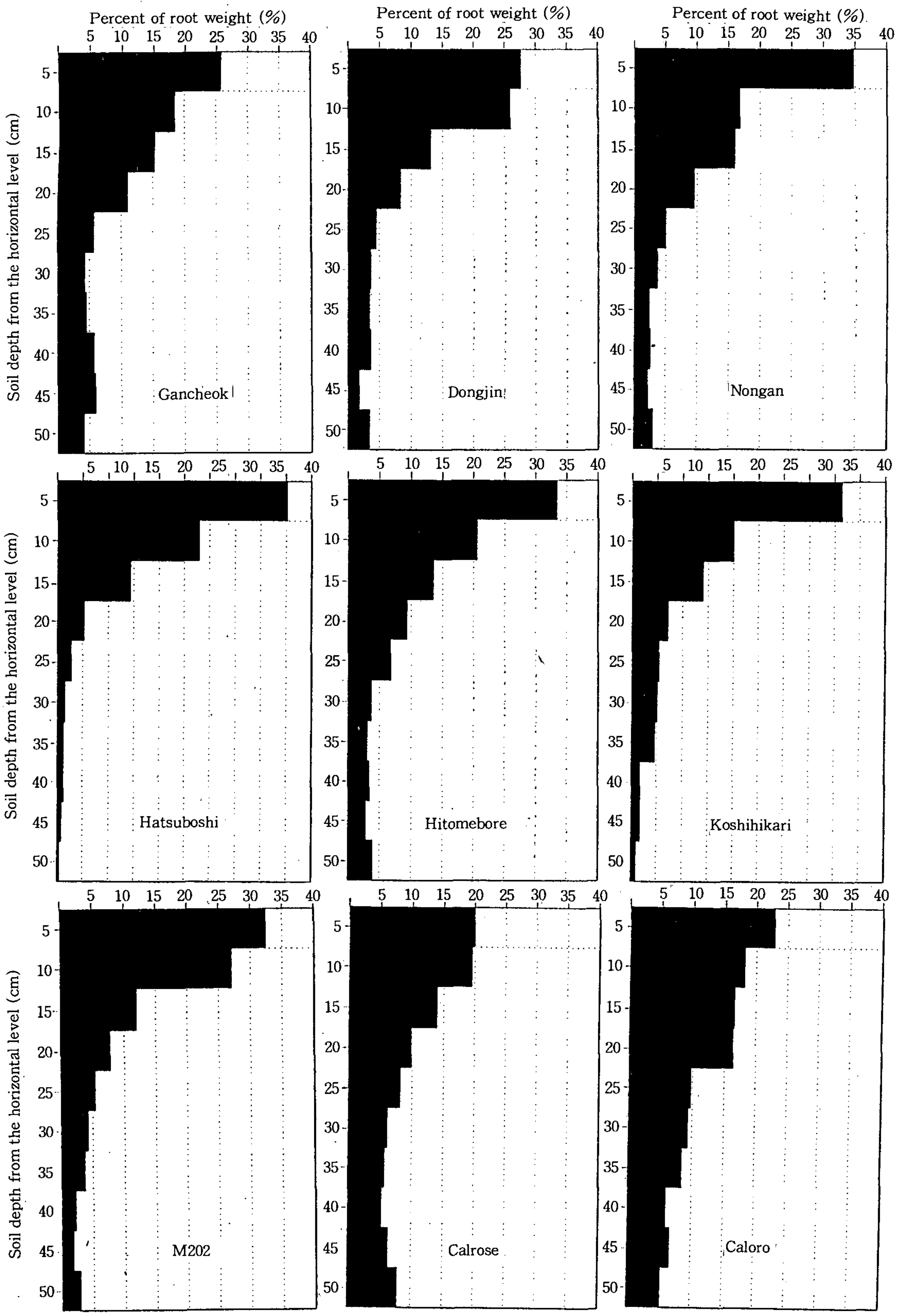

Fig. 2. Varietal difference in root distribution under the direct seeded rice.

Terashima K., T. Ogata, and S. Akita. 1994. Eco-physiological characteristics related with lodging tolerance of rice in direct sowing cultivation. Japan J. Crop Sci. 63 (1):34-41.

Yamauchi A., Y. Kono, and J. Tatsumi. 1987. Comparison of roots system structure of 13 species of cereals. Japan J. Crop Sci. 56:618-631.