Jpn. J. Crop Sci. 64(2) : 304—309 (1995)

Comparison of Internodal Elongation between Asian Deepwater Rice and Its Wild Relatives

Makoto MAESAKO, Yoshio SANO* and Jun INOUYE
(*Faculty of Agriculture, Kyushu University, Fukuoka 812, Japan ;
National Institute of Genetics, Mishima 411, Japan)
Received October 27, 1994

Abstract : Using 747 varieties of Asian deepwater rice (*Oryza sativa*) and 112 strains of wild rice including *O. rufipogon. O, nivara*, and their intermediates, the position of the lowest elongated internode (LEI) and the elongation ability under rising water conditions at a rate of 2 cm and 4 cm per day were examined. The wild rice strains were distinguishable as both erect and creeping strains at the 8th leaf stage and both types were equally frequent. When creeping seedlings were submerged in water, even the seedling with most creeping growth stood nearly erect at around five days after submerging treatment. The average LEI position was about one internode higher in the wild rice, while in the creeping wild rice it was one internode higher than in the erect type. The range of the LEI position among the wild rice strains was nearly the same with that among the deepwater rice varieties. These results show that the age at which plants begin to elongate their internodes seems to be nearly the same between the both rices. Under rising water conditions, on the contrary, elongation ability of most wild rice strains was inferior to that of deepwater rice. In wild rice strains with poor elongation ability, both length of leaf sheath and leaf blade and/or each internode length was shorter than in the deepwater rice.
Key words : Deepwater rice, Elongation ability, Floating rice, Lowest elongated internode (LEI), Wild rice.

アジア稲の浮稲と祖先野生種における節間伸長性の比較 : 前迫　誠・佐野芳雄*・井之上準（九州大学農学部・*国立遺伝学研究所）

要　旨 : アジア稲の浮稲と祖先野生種の浮稲性を比較する目的で，浮稲 747 品種と祖先野生種 112 系統を用いて，伸長最低節間（LEI）の位置および水位上昇条件下（2 cm/日，4 cm/日）における節間伸長性について調査した．本実験に供した野生稲系統を第 8 葉期の草型によって類別すると，立ち型と匍匐型の頻度は半々であった．匍匐型系統の稲苗を深水処理したところ，約 5 日後には主茎・分げつ共に屈起し，立ち型系統の稲苗と同じような草型を示した．LEIの位置を平均値で比較すると，匍匐型は立ち型より約 1 節間高く，野生稲は浮稲より 1 節間高かった．一方，水位上昇下における生育についてみれば，野生稲系統の多くは浮稲より節間伸長性が劣っており，その程度は匍匐型系統において著しいようであったが，その原因としては，葉鞘および葉身が短いこと，系統によっては，さらに個々の節間の伸長性が劣ることが考えられた．
キーワード : 浮稲，浮稲性，最低伸長節間，節間伸長性，野生イネ．

The wild progenitor of *Oryza sativa* is considered to be the Asian common wild rice, *O. perennis* Moench[5,7,8] (= *O. rufipogon* Griff. [8]). Generally, wild rice showed floating ability and the perennial type (*O. rufipogon*) a higher floating ability than the annual type (*O. nivara*)[4,6,8]. Therefore, the ability for floating in deepwater rice may be related to that in their wild progenitor[8].

In deepwater rice, one of the most important internal factors for floating ability may be the age at which seedlings begin to elongate internodes[2]. In the lag phase of deepwater rice plants, elongation of an internode is generally syncronized with the emergence of the leaf blade of the next upper node[1]. Therefore, the earlier the plant age at which internode elongation can occur, the lower the position of the lowest internode exhibiting elongation[3].

In the present study, using Asian deepwater rice and its putative ancestral wild species (*O. rufipogon*, *O. nivara* and intermediates), the position of the lowest internode showing elongation and the elongation ability of internodes under rising water conditions was examined.

Materials and Methods

Deepwater rice varieties and the putative ancestral wild species were from different Asian countries (Table 1).

Experiment 1. One hundred and twelve strains of wild rice were used. One seedling was grown in a plastic pot, 7.7 cm in diameter and 12 cm in height, with a hole at the bottom. Each pot contained about 480 g of air-dried paddy soil. Pots were placed in a shallow water

*Present address, Faculty of Agriculture, Hokkaido University, Sapporo 060, Japan.

Table 1. Number of materials used and classification of wild rice strains into erect and creeping strains.

Original place	Number of deepwater rice	No. of wild rice strains		
		Total	Erect	Creeping
Bangladesh	491	7	7	0
Cambodia	31	5	3	2
China	3	23	15	8
India	44	29	17	12
Malaysia	0	4	1	3
Myanmar	17	10	2	8
Sri Lanka	0	8	2	6
Thailand	97	21	9	12
Vietnam	64	5	0	5
Total	747	112	56	56

tank at a depth about 3 cm.

From results of preliminary observations, the angle of the main stem to the ground surface was measured at the 8th leaf stage in each seedling using a protractor.

Experiment 2. Three strains of W1619, W1698 and W1863 were used. Pots and cultural methods were identical with those in Exp. 1.

To examine the change in the inclination of the main stem with plant growth, the angle of the main stem to the ground surface was measured from the 3rd to the 8th leaf emerging stages.

To examine the kneeing of the main stem after submergence in water, seedlings of the 8th leaf stage which fully crept were used. After measuring an angle of the main stem to the ground surface, the seedling was submerged in water up to the highest lamina joint. From the next day until the main stem stood erect, the angle was measured and the water depth was raised up to the highest lamina joint every day.

Experiment 3. Wild rice strains used and all cultural methods were identical with those in Exp. 1.

When the seedling had reached the 8th leaf stage, each pot containing one plant was submerged in a water tank, $60 \times 180 \times 70$ cm, with 15 to 20 cm water for the erect strains and about 5 cm for the creeping strains of wild rice. The water level was raised every other day up to around the highest lamina joint in most plants in each water tank. After one to 10 weeks after submergence, the position of the lowest elongated internodes longer than 1 cm (LEI) was examined. When the LEI position varied within a strain, the most frequently encountered position was adopted. In the present study, wild rice in which the LEI position varied more than three internodes within a strain were excluded.

In the deepwater rice some results reported in the previous paper[1] were revised by the experiment in this study.

Experiment 4. Six of each of the wild rice strains and deepwater rice varieties were used.

Two seedlings, two hills with one plant, were grown in a plastic pot, 16 cm in diameter and 20 cm in height, with a lateral hole in the lower part. Each pot contained about 4.5 kg of air-dried paddy soil which had been fertilized with 6 g compound fertilizer (N-P-K : 8-8-8%). From sowing to the 10th leaf stage, plants were grown in a greenhouse and then they were grown under the natural conditions.

When plants of each strain and variety reached the growth stage at which internode elongation can occur by submergence in water, at the 10th, 11th or 13th leaf stage, each pot with two plants was gradually sunk to an increasing depth by being suspended with a string in a water tank at the different rates, 2 cm or 4 cm, per day. Water depth for the 2 cm/day-submerging lot was ca. 190 cm and for the 4 cm/day-submerging lot ca. 280 cm. The submerging treatment was finished when about one-half of the expanded uppermost leaf blade of most stems in each pot came under the water surface or the pot with plants touched the bottom of the water tank. Average

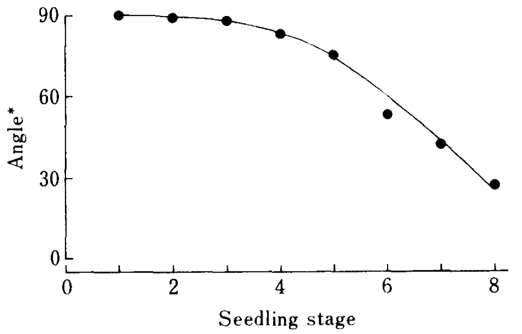

Fig. 1. Change in the inclination of the main stem of a creeping type strain (W1863) with seedling growth.
*Angle of the main stem to the ground surface.

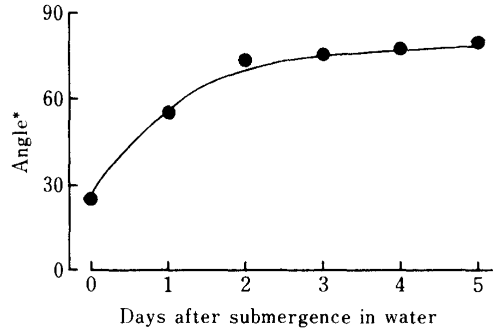

Fig. 3. Kneeing of the main stem of a creeping type strain (W1863) after submergence in water.
*Angle of the main stem to the ground surface.

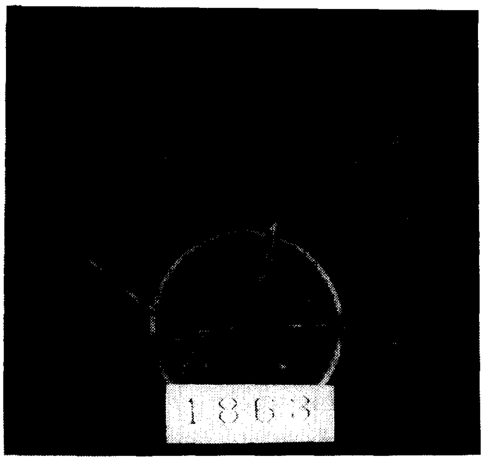

Fig. 2. A creeping type strain (W1863) at the 8th leaf stage (over view).

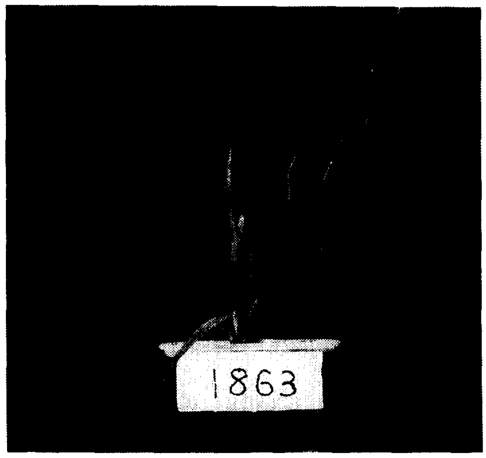

Fig. 4. A creeping type strain (W1863) after five days from the beginning of submergence in water.

air temperature during the treatment ranged from 25 to 32°C, and the day-length from 14 hr 23 min to 12 hr 20 min.

Before the submerging treatment was begun, LEI position was recorded. At the end of the treatment, total plant length, number of leaves, number of elongated internodes and the length of each internode was determined. In this experiment, the main stem was subjected to investigation and data on each plant was presented by an average value of two to four main stems.

Results

1. Plant type of wild rice strains used

When each seedling had reached the 8th leaf stage, the inclination degree (angle of the main stem to the ground surface) varied greatly according to strain. For convenience, we call in the present paper the "erect" type of which the angle is more than 44°, while calling the "creeping" type with an angle less than 45°.

In the all wild rices used, as shown in Table 1, the number of erect strains was equal to that of creeping strains. There were erect and creeping strains in most countries, while only the erect strain was found in Bangladesh and only the creeping strain in Vietnam.

2. Change in the inclination of the main stem of the creeping strain with seedling growth

In each of the three wild rice strains used, the main stem stood erect from emergence to around the 3rd leaf stage in similar appearance to that of the erect strain. From around the 4th leaf emerging stage, as given in Fig. 1, the main stem began to oblique little by little and had crept at the 8th leaf stage. In the present study, an angle of the main stem to the ground surface at the 8th leaf stage was nearly 0°, 15° and 30° in W1619, W1863 and W1698, respectively. Further, each seedling produced two to three tillers and they also crept in a similar way to that observed in the main stem (Fig. 2).

3. Kneeing of the main stem of creeping strain after submergence in water

The change in kneeing of the main stem of creeping seedling after submergence in water is given in Fig. 3. The angle of the main stem to the ground surface increased every day and the stem stood nearly erect after about 5 days from the start of the submerging treatment. At that time, morphological features were similar in the both the creeping and erect seedlings (Fig. 4).

4. Position of the lowest elongated internode (LEI) of deepwater rice and wild types

Among deepwater rice varieties, those that showed elongation of internode as early as the 8th internode were the most frequent, followed by the 9th, then 10th internode, varieties. Among wild rice strains, those that could elongate as early as the 10th internode were most frequent, followed by the strains with the 9th, then 11th internode.

As shown in Table 2, the average LEI position of deepwater rice was about one internode lower than that of wild rice, but the range of the LEI position was nearly the same in both rices. The average LEI position differed generally between deepwater rice varieties and wild rice when compared within a country, with the exception of Vietnam. In most countries, the range in deepwater rice was slightly larger than that of wild rice.

In the wild rice, average LEI position of the creeping type strains was about one internode higher than that of the erect type, while the range of LEI position was nearly the same between both types. For respective countries, there were two groups in which average LEI position of the creeping strains was higher than in the erect strains and the average value of the former was lower than that of the latter. In most countries, however, the range of the LEI position within a country was almost the same in both types.

5. Internodal elongation under rising water conditions

As shown in Table 3, in the 2 cm/day-submerging lot, all deepwater rice varieties used could grow until the end of the submerging treatment. In wild rice, on the other hand, all strains of which LEI position was the 9th or 10th internode could grow until the end of the treatment, but two strains where the LEI position was the 12th internode could not. In the two strains which failed in continue to grow, the number of elongated internode and total internode length was smaller than in the other strains.

In the 4 cm/day-submerging lot, all deepwater rice varieties for which the LEI position was the 9th and 10th internode could grow until the end of the treatment, but one out of two varieties for which the LEI position was the 12th internode could not grow unitil the end of the treatment. In a variety which failed in continue to grow, each internode length (divide "total elongated internode length" by "number of elongated internodes") was shor-

Table 2. Average values and variations of the position of the lowest elongated internode (LEI) in each country.

Original place	Deepwater rice*	Wild rice		
		Total	Erect type	Creeping type
Bangladesh	9.2 (6-16)	8.0 (7- 9)	8.0 (7- 9)	—
Cambodia	11.1 (9-16)	12.8 (10-15)	14.0 (13-15)	11.5 (10-13)
China	11.3 (11-12)	10.0 (8-12)	9.8 (9-11)	10.3 (8-12)
India	9.9 (7-14)	10.8 (8-14)	11.4 (8-13)	10.6 (8-14)
Myanmar	12.8 (9-17)	11.1 (9-13)	12.5 (11-13)	10.9 (9-13)
Thailand	10.9 (8-16)	11.6 (8-17)	9.1 (8-11)	13.4 (9-17)
Vietnam	11.0 (8-16)	11.2 (10-13)	—	11.2 (10-13)
Others**	—	10.8 (7-15)	11.7 (10-14)	10.4 (9-12)
Total	9.8 (6-17)	10.7 (7-17)	10.2 (7-15)	11.2 (8-17)

*Some results in the previous paper[1)] were revised by this additional experiment.

**Malaysis and Sri Lanka.

Table 3. Growth of deepwater rice and wild rice plants under conditions of increasing water depth.

Strains or varieties	Original place and type*	LEI**	2 cm/day-submerging lot***				4 cm/day-submerging lot***			
			Plant length	No. of leaves	No. of E. I.	Total E. I	Plant length	No. of leaves	No. of E. I.	Total E. I
Deepwater rice			cm		cm	cm	cm		cm	cm
Rajphal	B	9	273	19	10	164	303	21	11	224
Schulpan	B	9	259	19	10	153	281	20	10	213
Chaw Ma-gawk	T	10	268	22	12	161	317	22	12	238
Khao Hawn	T	10	263	23	12	162	316	22	12	225
Potka	B	12	235	22	10	138	295	24	12	210
Jed Jib	T	12	244	24	11	140	228	23	10	135
Wild rice										
W621	M, c	9	206	20	11	134	120	14	5	65
W625	M, c	9	229	21	12	151	125	14	5	78
W145	T, c	10	239	24	14	148	272	21	11	189
W0234	T, e	10	274	24	14	161	292	22	12	195
W1690	T, c	12	139	21	8	58	120	17	5	42
W1802	B, e	12	178	22	8	92	122	17	5	45

*Type means plant type at the 8 th leaf stage ; e shows erect type and c creeping type. B, M and T show Bangladesh, Myanmar and Thailand, respectively.

**Position of the lowest elongated internode.

***Main stem was subjected to investigation. E I. shows elongated internode.

ter than that of the others. In the wild rice, on the other hand, two strains for which LEI position was the 10th internode could grow until the end of the treatment but four strains with LEI position of the 9th and 12th internodes could not. Among the wild rices which failed in continue to grow, two strains for which the LEI position was the 9th internode belonged to the creeping type and could not grow after 20 days from the beginning of treatment. In the two strains, both the length of leaf sheath and leaf blade were rather shorter than for the strains where LEI position was the 10th internode. While, in the two strains for which the LEI positon was the 12th internode, both lengths where nearly identical to the others but each internode length was shorter than that of the others.

Discussion

In the wild rice used, the morphological characteristics of the seedling varied among the strains. The main stem stood erect from emergence to the 3rd leaf stage and then began to incline toward the ground surface. The degree of inclination of the main stem increased with time and reached a maximum at the 8th leaf stage (Fig. 1). At the time, if we divide the wild rice strains roughly into erect and creeping strains by the degree of main stem inclination, the erect strains and the creeping strains were the same in number (Table 1). In the present study, the frequency of creeping and erect types varied in most countries. Perhaps, this result may be due to the small number of the wild rice strains used or reflect on differences in habitat.

When creeping seedlings at the 8th leaf stage were submerged in water, both main stem and tillers started to bend upward and they stood nearly erect after about 5 days from the beginning of submergence (Fig. 2). At this time, the morphological features of the seedlings was nearly the same as those in the erect strains. These results seem to show that the creeping strain had wider adaptability for water conditions than the erect strains.

According to Jackson*[1)], the floating ability of wild rice exceeded that of deepwater rice when the highest ones were compared. As for the LEI position, it is reported that, in Asian deepwater rice, the lower the LEI position, the better the elongation ability of internodes[3)].

In the present study, the LEI position of wild rice varied largely according to strain, and the variation was nearly the same in range

*[1)]Private communication to Dr. Oka[8)].

as that of deepwater rice. But the average value of the LEI position was about one internode higher in wild rice than in the deepwater rice (Table 2). From the results, it is possible to say that the age at which seedlings begin to elongate at internode is nearly the same between deepwater rice and wild rice. Comparing the creeping and the erect strains, the elongation ability of the former may be somewhat inferior to that of the latter.

Under rising water conditions, on the other hand, elongation ability of wild rice strains was inferior to that of deepwater rice varieties, especially in the plants for which the LEI position is the 9th and the 12th internodes. In the wild rice strains with poor elongation ability, length of the leaf sheath and leaf blade ("plant length" minus "total elongated internode length" form Table 2) and/or each internode length (divide "total elongated internode length" by "number of elongated internodes" from Table 2) was shorter than the strains having good elongation ability and deepwater rice varieties. Among the wild rice strains, the elongation of the creeping strain seems to be inferior to that of the erect strain since both length of leaf sheath and leaf blade was generally shorter in the former than in the latter.

It was suggested that the discrepancy between our results and those of Jackson*[1] may attributable to the difference of materials used, especially in the wild rice strain. This suggests that a common wild rice has a wide variation in deepwater tolerance as found in Asian deepwater rice.

References

1. Inouye, J. 1985. Variation of elongation ability in the Asian floating rice (*Oryza sativa* L.). JARQ: 82—91.
2. Inouye, J. 1987. On floating rice and its ecological traits in southeast Asia. Tonan Ajia Kenkyu (Southeast Asian Studies) 25 : 51—61*.
3. Inouye, J., D. HiLeRisLambers and C. Songkran 1985. Some morphological and ecological differences between floating rice and nonfloating rice varieties in Thai paddy rice, *Oryza sativa* L. Bull. Inst. Trop. Agric., Kyushu Univ. 8 : 55—89.
4. Morishima, H. 1985. Habitat, genetic structure and dynamics of perennial and annual populations of the Asian wild rice *Oryza perennis*. In Jacquard P. et al. eds., Genetic Differentiation and Dispersal in Plants. NATO ASI Ser., Vol. 5. Springer-Verlag, Berlin Heidelberg. 179—190.
5. Morishima, H., H.I. Oka and W.T. Chang 1960. Directions of differentiation in populations of wild rice. *Oryza perennis* and *O. sativa f. spontanea*. Evolution 15 : 326—339.
6. Morishima, H., K. Hinata and H.I. Oka 1962. Floating ability and drought resistance in wild and cultivated species of rice. Ind. J. Genet. Plant Breed. 22 : 1—11.
7. Oka, H.I. 1964. Pattern of interspecific relationships and evolutionary dynamics in *Oryza*. In Rice Genetics and Cytogenetics, Elsevier, Amsterdam. 71—90.
8. Oka, H.I. 1988. Origin of cultivated rice. Japan Scientific Societies Press and Elsevier. 216.

* In Japanese with English abstract.