Variation of Elongation Ability in the Asian Floating Rice (*Oryza sativa* L.)

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Introduction

It is widely known that elongation ability of floating rice varies not only among varieties from different countries but also among varieties within a country.

Until the standard scoring system for measuring elongation ability was proposed at the 1976 Deep-Water Rice Workshop,[1] various scoring systems had been used by different researchers in different countries. As a result, it is difficult to compare each other's data obtained in different countries on the elongation ability of floating rice. The standard method evaluates total plant elongation.

Comparing the standard method with their original method for measuring elongation ability, IRRI researchers suggested that the standard method offered no problem for floating rices growing in the medium deep water area, while it may not be applicable to the evaluation of internode elongation of floating rice in the deep water area.[7]

In the present paper, the relation between the elongation ability and the position of the lowest internode exhibiting elongation under submerged condition,[2] and variation of the lowest elongated internode (LEI) in the Asian floating rice (*O. sativa* L.)[3,4,5] were discussed.

Internode elongation in the lag phase of floating rice under submerged condition

It is known in Japan that the internode elongation of rice plants usually begins to occur during the panicle initiation stage, and proceeds with the following regularity: elongation of an internode occurs synchronously at the same rate with the elongation of the leaf blade which is produced on the second node counted upwards from the upper node of that internode.[8]

In floating rice, on the other hand, elongation of an internode in the lag phase under submerged condition is generally synchronized with emergence of the leaf blade of the upper next node, e.g. elongation of the 7th

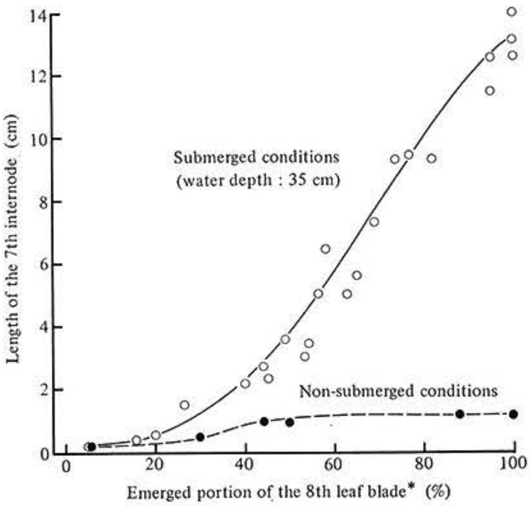

Fig. 1. Relation between emergence of the uppermost leaf blade from the leaf sheath below and internode elongation in a Bangladesh floating rice variety, DW8

* Ratio of length of the 8th leaf blade that emerged from the 7th leaf sheath to the total length of the 8th leaf blade that emerged fully.

internode (between the 7th and 6th nodes) and emergence of the 8th leaf blade from the 7th leaf sheath occurred simultaneously at about the same pace (Fig. 1).

The above result shows that in floating rice the younger the growth stage at which internode elongation can occur under submerged condition, the lower the position of LEI is.

Effect of some environmental factors on the position of LEI

Materials used were DW 8 from Bangladesh, Pin Gaew 56 from Thailand and Cu La from Vietnam. Under submerged condition, the position of LEI was usually the 7th, 9th and 10th internode in the first, second and last, respectively.

In each of the three floating rice varieties, the plants could elongate their internode even under non-submerged condition, and the position of LEI was the same under both submerged and non-submerged conditions. Length of LEI was shortest under non-submerged condition and it increased with increasing water depth in each variety (Fig. 2).

On the other hand, the position of LEI in the three varieties stayed the same irrespective

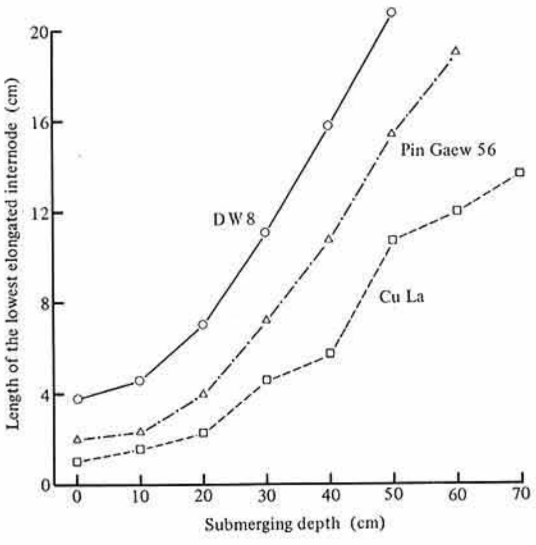

Fig. 2. Effect of submerging depth on the elongation of the lowest elongated internode in three floating rice varieties

of plant age at the beginning of submergence. According to another examination, however, the position varied in some varieties with plant age. In those varieties, variation of LEI position was mostly one internode.

The position of LEI was almost the same at the temperature from 20 to 35°C in the Bangladesh variety, while the position at 35°C in both Thai and Vietnamese varieties was higher by about two internodes than that at 20 to 30°C in each variety (Table 1).

Table 1. Effect of temperature on the position of LEI under submerged condition (water depth: ca. 35 cm)

Variety	Position of LEI*			
	20°C	24°C	30°	35°C
DW 8	7(17.3)	7(22.8)	7(23.5)	7(5.3)
Pin Gaew 56	9(7.5)	9(15.0)	9(12.6)	11(6.3)
Cu La	10(5.8)	10(11.8)	10(14.8)	12(7.3)

* Length (cm) of LEI is shown in parentheses.

Regarding the effect of photoperiod, it was possible to say that, in floating rice plants that could initiate flowers under the photoperiodic conditions shorter than 12 hours, the position of LEI went down with decreasing number of leaves on the main culm. In the lots where day-length was longer than 14 hours, however, the position was nearly the same in each of these varieties.

In shading treatment (ca. 60% of outdoor light), LEI position in both Bangladesh and Thai floating rice plants went down one internode as compared with that of untreated control plants under submerged and non-submerged conditions, while the position was the same between shaded and non-shaded under both submerged and non-submerged conditions in the Vietnamese variety.

It seems from the above results that the position of LEI in floating rice is a fairly stable morphological characteristic.

Relation between the position of LEI and the elongation ability

Using the standard method for measuring elongation ability, relations among plant length, total internode length, number of fully emerged leaves from water surface and the position of LEI were examined. Floating rices used were 60 varieties from different countries. Among these varieties, position of LEI varied from the 7th to 12th internode. Accordingly, they supposedly had the score of one to six or so in the standard scoring system of measuring the elongation ability.

A positive correlation was found between plant length and total internode length ($r = 0.615^{**}$), but there was no correlation between the plant length and number of fully emerged leaves above water surface on the main culm ($r = 0.239^{n.s.}$). On the other hand, highly negative correlations were found between the position of LEI and total internode length ($r = -0.826^{***}$), and number of fully emerged leaves ($r = -0.855^{***}$). In general, it seems that floating rice plants which had more number of fully emerged leaves from water surface could grow well in keeping pace with a rising water level.

Furthermore, according to Table 2, no significant difference was found in plant length among the plants of which the position of LEI was the 7th, 8th or 9th internode, respectively, although the length decreased by the upward shift of the LEI position from the 9th internode. Total internodes length and number of elongated internode was largest in the plants of which the position of LEI was the 7th internode, and the both decreased by the ascent of the position of LEI. Furthermore, number of fully emerged leaves from water surface on the main culm was about three in the plants of which position of LEI was the 7th or 8th internode, whereas the number of fully emerged leaves was less than one in the others.

Besides, the length of LEI was shortest in the plants of which the position of LEI was the 7th internode, and the length increased by the ascent of the LEI position. According to our investigation, among F_2 progeny of the cross between floating and non-floating rice, there were plants that had poor elongation ability but the position of LEI was as low as the 9th or 10th internode. In these plants, however, the length of LEI was shorter than about 2 cm, and also the next upper internode was not so long. On the other hand, in the true floating rice, the next upper internode was very long when the LEI was short.

From the above results, the position of LEI seems to be useful for checking the elongation ability at an early stage of growth.

Table 2. Relation between the elongation ability and the position of LEI (water depth: ca. 155 cm)

Position of LEI*	Number of varieties	Plant age**	Number of leaves above water surface		Plant length (cm)	Total internode length (cm)	Number of elongated internode	Length of LEI (cm)
			Emerged	Fully emerged				
7	13	14.9	4.5	3.2	213	142	7.8	8.9
8	10	14.8	4.4	2.9	212	136	6.6	12.7
9	12	13.7	3.7	0.5	212	110	4.7	19.3
10	14	13.4	3.2	0	207	89	3.8	22.7
11	8	13.8	3.3	0	198	82	2.6	31.6
12 or higher	3	11.4	0	0	144	0	0	0

Procedure for regulating water conditions was the same as proposed by Ahmed et al.[1]

* e.g. the 7th internode indicates the internode between the 7th and 6th nodes.

** Total number of leaves on the main culm at the end of the experiment.

Lowering of the position of LEI by exogenous gibberellic acid

Plant materials used were DW 8 from Bangladesh, and Nakawn Gan and Wad Jan from Thailand. The first has a very good elongation ability, the second has the score of "1" in the standard scoring system of measuring the elongation ability, and the last has the score of "5".

As shown in Table 3, internode elongation was induced by foliar application of gibberellic acid (GA_3) in DW 8 and Nakawn Gan, but did not in Wad Jan. In the GA_3-treated plants of DW 8 and Nakawn Gan, their position of LEI went down by one to three internodes as compared with control plants under submerged condition. The position of LEI in the treated plants was usually lower in DW 8 than in Nakawn Gan, irrespective of concentrations of GA_3.

Table 3. Effect of GA_3 foliar application on the position of LEI in different varieties

Variety	Position of LEI*			
	Concentrations of GA_3 in ppm			Control**
	1,000	100	10	
DW 8	4(3.7)	4(1.3)	6(2.0)	7(15.2)
Nakawn Gan	6(4.8)	6(3.1)	8(2.0)	9(10.1)
Wad Jan	—	—	—	12(4.1)

GA_3 was applied at the 3rd leaf emerging stage and internode elongation was investigated at the 10th leaf stage.
* Length (cm) of LEI is shown in parentheses.
** Under submerged condition (water depth: ca. 55 cm).
— No internode elongation was observed at the 10th leaf stage.

On the other hand, elongation of both leaf blade and leaf sheath was also promoted by the foliar application of GA_3. Until a certain leaf blade emerges, elongation of the leaf blade and the next below leaf sheath occurs synchronously in rice plants. When GA_3 solution was applied at the 3rd leaf emerging stage in this experiment, elongation of the 4th leaf blade and the 3rd leaf sheath was extremely stimulated. However, unlike the effect of GA_3 on the position of LEI, no difference among the three varieties was observed in the elongation of leaf blade and leaf sheath.

The above results suggest that the response of leaf elongation to GA_3 does not differ among floating rice varieties, but the response of internode elongation is larger in the variety having good elongation ability than in the variety having inferior elongation ability.

Variation of the LEI position of floating rice from different countries

A total of 376 floating rice varieties from different countries were used. When each seedling had reached the 8th leaf emerging stage, they were submerged in water. Table 4 shows the mean value for the LEI position of all varieties derived from each country.

Table 4. Position of LEI under submergence of floating rice originated in different countries (water depth: ca. 55 cm)

Origin	Number of varieties*	Position of LEI	
		Average	Variation
Bangladesh	189	8.3	6–14
India	17	10.6	7–14
Thailand	79	10.8	8–14
Vietnam	36	11.4	8–13
Cambodia	26	11.6	9–14
China	2	12.0	11–13
Indonesia	3	12.7	12–13
Burma	5	13.0	12–14

* Number of varieties which failed to elongate internode even at the 15th leaf stage were excluded.

Mean value for the LEI position was the lowest in Bangladesh rice, followed in ascending order by Indian rice, Thai rice, Vietnamese rice, Cambodian rice, Chinese rice, Indonesian rice, and Burmese rice. On the other hand, the ratio of varieties which could not elongate internode even when they reached the 15th leaf stage to the total number of varieties used was 50% in Burmese rice, about 13% in Cambodian rice and less than 6% in other rices. Varieties with the mean LEI position higher than 11 showed fairly large variations of the position.

With the varieties which showed internode elongation by the 15th leaf stage, it was considered that the plant age at which the internode starts to elongate due to submergence in water may be the 7th to 15th leaf stage in Bangladesh rice, 8th to 15th in Indian rice, 9th to 15th in Thai rice, 9th to 14th in Vietnamese rice, 10th to 15th in Cambodian rice, 12th to 14th in Chinese rice, 13th to 14th in Indonesian rice, and 13th to 15th in Burmese rice. Except Bangladesh and Thai rice, however, these results may be changed to some extent if many more varieties are used for each country.

Making a general classification, varietal difference of the LEI position within a country was larger in Bangladesh and Indian rices, medium in Thai, Vietnamese and Cambodian rices, and small in Chinese, Indonesian and Burmese rices. Degree of the varietal difference within a country seems to reflect the difference in the topography of rice growing areas in each country.

Character association between the LEI position and isozyme genotype

According to genic analysis of acid phosphatase isozyme, most varieties of Indica type had Acp_1^{-4}, while those of Japonica type had Acp_1^{9}.[6] As to peroxidase isozyme, most Indica varieties had Px_2^{4c}, while most Japonica varieties had Px_2^{0}.[9] Furthermore, it was revealed that the Acp_1 locus specifying acid phosphatase zymograms was linked with Px_2 specifying peroxidase 4C band.[6] Therefore, from the combinations of four alleles at two loci, four kinds of genotypes are expected.

As shown in Table 5, two genotypes, Acp_1^{-4} Px_2^{4c} and Acp_1^{-4} Px_2^{0}, were found in Burmese, Cambodian, Thai and Vietnamese floating rices. The former genotype may be able to be regarded as the Indica type and the latter a recombinant type. In addition to the two genotypes, the other genotype, Acp_1^{9} Px_2^{0}, which may be regarded as Japonica type was found in Indian rice. In Bangladesh rice, all the four genotypes expected by both loci were found, and about two-thirds of varieties which had the Japonica type zymograms belonged to the floating rice adapted to the high flood level.

As described before, varietal variation of the LEI position was the largest in Bangladesh floating rice, which was followed by Indian floating rice. The fact that the acid phosphatase and peroxidase genotypes are more complicated in Bangladesh and Indian floating rices than varieties of other countries may be related to the greater varietal variations in the elongation ability of Bangladesh and Indian floating rices.

Table 5. Classification of floating rice varieties originated in different countries based on acid phosphatase and peroxidase zymogram genotypes

Origin	Number of varieties				
	$Acp_1^{-4}Px_2^{4c}$	$Acp_1^{-4}Px_2^{0}$	$Acp_1^{9}Px_2^{4c}$	$Acp_1^{9}Px_2^{0}$	Total
China	2	0	0	0	2
Indonesia	3	0	0	0	3
Burma	3	2	0	0	5
Cambodia	16	10	0	0	26
Thailand	66	13	0	0	79
Vietnam	28	8	0	0	36
India	10	5	0	2	17
Bangladesh	77	78	4	30	189

Conclusion

In both Bangladesh and India, a good many floating rice varieties could elongate their internode at the early stage of growth. While, in other countries, particularly in Burma, most varieties did so at the rather late stage of growth. This difference may be derived from the difference in the duration from sowing time to the time of field submergence.

Furthermore, when the growing period of rice plants is nearly the same among varieties, grain yield may be low in those varieties having very good elongation ability. Perhaps, floating rice varieties having very good elongation ability may be close to the wild type rice. To test the above assertion, further experiments are needed.

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