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Internode Elongation under Different Rising Water Conditions in African Floating Rice (*Oryza glaberrima* Steud.)

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The African and Asian floating rices were grown under different rising water conditions, and internode elongation ability with increasing water depth was measured. In 5 cm/2 day-submerged lot, all varieties having LEI positions at the 8th and 9th internodes could grow until the end of the experiment along with the increase of the water depth in both species. In these varieties, differences between species in almost growth characters were not observed. Among varieties having LEI positions from the 10th to 12th internodes, one African and one Asian variety failed to grow. No varieties having LEI position at the 13th internode could grow, because its average internode length was considerably short. Among varieties with LEI positions from the 8th to 11th internodes in 10 cm/2 day-submerged lot, 4 African varieties and one Asian variety did not grow. All varieties with LEI positions from the 12th to 14th internodes could not grow. From these results, it was suggested that under slow rising water conditions, internode elongation ability of both African and Asian floating rices was almost the same. Under rapid rising water conditions, however, internode elongation in the former was slightly inferior to that in the latter.

INTRODUCTION

Recently, in West African countries, rice cultivation areas are growing rapidly with an increase in the demand for rice (Nozaki 1989). However, the cultivation of African rice (*Oryza glaberrima*) is decreasing due to the introduction of Asian rice (*O. sativa*) (Ng *et al.* 1991, Nsumbu 1991). African rice varieties are said to be adapted well to unfavourable environments such as drought at the early growth stage and sudden flooding, and they are currently cultivated mainly in the deep-water areas of West Africa (Coudhury and Will 1977, Katayama 1989, Oka *et al.* 1978).

In general, floating rice elongates with increasing water depth, while it shows a similar growth habit to ordinary paddy rice under shallow water conditions (Inouye and Hagiwara 1982, Oka 1988, Sugawara and Horikawa 1971). In Asian floating rice, the position of the lowest elongated internode (LEI) is quite stable. Floating rice internodes start to elongate upon reaching the growth stage peculiar to each variety (Inouye and Hagiwara 1981, Kiryu *et al.* 1995). Recently, on the other hand, it was revealed that the LEI position under non-submerged conditions was one to three internodes higher than that under submerged conditions in African floating rice (Watarai and Inouye 1997). This seems to show that African floating rice has a wider adaptability to various water conditions than Asian floating rice. It was reported that, among Asian varieties, the lower the LEI position, the better the elongation ability under rising water conditions (Ibi *et al.*

1995, Inouye *et al.* 1985). The present study aims to compare the internode elongation between African and Asian floating rices under rising water conditions.

MATERIALS AND METHODS

Experiment 1

We used floating rice varieties obtained from previous experiments in which the position of the lowest elongated internode (LEI) was the 10th internode under submerged conditions. The African group consisted of 7 Nigerian varieties, and the Asian group of 3 each of Indian and Thai, and 4 each of Bangladeshi, Cambodian and Vietnamese varieties.

About nine germinated seeds were sown at the end of May 1994 in a plastic pot 16 cm in diameter and 20 cm in height with a drainage hole in the bottom. Each pot contained about 3.5 kg of air-dried soil. Fertilizer was applied at the rate of 0.56 g each of N, P₂O₅, K₂O per pot. At the 4th leaf stage, seedlings were thinned to 3 plants per pot. Until the 9th leaf stage, all pots were placed in a shallow water tank (water depth: about 10 cm). In order to determine accurately the number of leaves on the main culm, small spots of enamel were applied as a marker on the leaf blades of every two leaves in each plant throughout the growing period. A few days before the rice plants of each variety reached the growth stage at which internode elongation can occur by submergence, the plants were submerged about 10 cm. When internode elongation was observed in each pot, the pot was gradually submerged at the rate of 4 cm per day by being suspended with a string in the water tank. Water depth in the tank was about 280 cm, of which about 150 cm was under the ground. Submerged treatments were terminated when about one-half of the expanded uppermost leaf blades of most culms in each pot were below water level or when the pot itself rested on the bottom of the tank. Average air temperature during the experiment ranged from 21 to 32 °C, and day length ranged from 12 hr 50 min to 14 hr 20 min.

For our observations, the internodes whose length exceeded 0.5 cm were defined as the elongated internodes (Suetsugu 1968). The main culm was only subjected to investigation in which the datum of each variety was represented by the average value of two to three main culms. Before the onset of the submerging treatment, the LEI position and seedling height of each variety were recorded. At the end of the treatment, total plant length, number of leaves, number of elongated internodes, and the length of each internode were examined.

Experiment 2

Floating rice varieties from prior experiments were used. Their LEI position ranged from the 8th to the 14th internodes under submerged conditions. We used 13 African rice and 14 Asian rice varieties. The former consisted of 9 Nigerian and 4 Guinean varieties, and the latter of 3 each of Bangladeshi, Cambodian, Indian and Thai, and one each of the Myanmar and Vietnamese varieties.

Seeds were sown in a greenhouse at the end of May 1996 in same manner as in the experiment 1. At the 6th leaf stage, pots containing three plants were placed outdoor in a shallow water tank (water depth: about 5 cm). The plants were submerged about 20 cm

upon reaching the particular leaf stage at which internode elongation would occur for each variety. Each pot in which elongation was observed was gradually submerged at different rates of 5 cm and 10 cm every other day. The measuring procedure at the beginning and end of treatment were the same as in experiment 1. Average air temperature during the experimental period ranged from 20 to 31 °C, and day length from 11 hr 40 min to 14 hr 20 min.

RESULTS

Experiment 1

In the preliminary experiment, the LEI position of all varieties used was the 10th internode under shallow water conditions. In 4 cm/day-submerged lots, however, the LEI position was the 9th internode in 2 Bangladeshi varieties and one Nigerian variety. The LEI position was the 10th internode in all the others (Table 1). In this experiment, all the varieties were allowed to grow until the pot reached the bottom of the water tank, and the difference in growth between varieties with LEI positions at the 9th and 10th internodes in each rice species was not observed.

At the end of the experiment, in varieties with LEI position at the 10th internode, the number of leaves on the main culm ranged from 21 to 23 in the Asian and from 20 to 22 in the African floating rice, an average 21.8 ± 1.2 and 20.8 ± 0.8 leaves, respectively. The plant length varied from 280 cm to 321 cm in the Asian and 243 cm to 301 cm in the African floating rices. The average length of the latter was shorter than that of the former by 27 cm. The total internode length, which seems to have a close relation to the plant length, was from 194 cm to 255 cm in the Asian floating rice and from 179 cm to 224 cm in the African floating rice. The average length of the latter was shorter than that of the former by 19 cm. The average internode length was almost the same in both groups. In 3 out of 7 African varieties used, the plant length was shorter by 20–40 cm than an Asian variety (Boyra) having poor elongation ability. The other 4 were almost similar to the Indian variety in plant length, the length of total elongated internodes, and the number of

Table 1. Comparison of some characteristics between *O. sativa* and *O. glaberrima* in 4 cm/day-submerged lots.

LEI Positions	Species	Country of origin	No. of var.	Plant length	No. of leaves	No. of elongated internode	Total internode length	LEI length	Average internode length*
9	<i>O. sativa</i>	Bangladesh	2	292±16	19.5±0.7	10.5±0.7	218±9	4.6±3.0	21.2±3.8
	<i>O. glaberrima</i>	Nigeria	1	285	19	10.0	198	2.4	21.6
10	<i>O. sativa</i>	Bangladesh	2	291±16	22.5±0.7	12.5±0.7	225±43	4.4±2.7	18.9±3.9
		Cambodia	4	311±11	21.0±0.0	11.0±0.0	231±11	6.5±2.7	22.3±1.5
		India	3	288±8	21.7±0.6	11.7±0.6	220±5	9.2±2.1	20.3±0.4
		Thailand	3	316±1	22.0±0.0	12.0±0.0	231±7	3.0±1.9	20.3±1.3
		Vietnam	4	307±7	22.0±1.2	12.0±1.2	213±7	5.3±3.3	19.2±1.8
		Total	16	304±14	21.8±1.2	11.8±0.8	223±15	5.8±3.1	20.2±1.2
	<i>O. glaberrima</i>	Nigeria	6	275±22	20.8±0.8	10.8±0.8	204±18	4.9±2.3	19.9±1.2

* Average length of all elongated internodes excepting the youngest internode.

elongated internodes.

Experiment 2

In 5 cm/2 day-submerged lots, all the varieties in which the LEI position was at the 8th and the 9th internodes we allowed to grow until the pot reached the bottom of the tank (Table 2(a)). The variation in most growth characters in the African was smaller than that in the Asian floating rice, whereas the average value was nearly the same in both.

Each one variety of African and Asian floating rice with LEI positions at the 10th and the 11th internodes did not grow until the end of the treatment. In varieties which did grow, the average value of most growth characters was the same in both groups. In the Asian group, the variation in plant length among varieties paralleled that in total internode length, whereas, in the African group, the internode length variation among varieties was larger than that of plant length. In varieties which failed to grow among

Table 2. Comparison of some characteristics between *O. sativa* and *O. glaberrima* in submerged lots.

(a): 5 cm/2 days

LEI position	Species	No. of var.	Plant length	No. of leaves	No. of elongated internodes	Total internode length	LEI length	Average internode length**
8-9	<i>O. sativa</i>	7 7	294±11	21.3±1.4	12.4±1.5	214±10	9.4±5.0	18.5±1.6
	<i>O. glaberrima</i>	4 4	282±12	21.0±0.0	12.0±0.0	214±4	6.0±2.4	17.5±0.4
10-11	<i>O. sativa</i>	4 3	292±13	22.7±1.5	12.3±1.2	203±4	7.2±0.4	17.4±2.0
		1*	237	20	10	154	5.6	15.1
	<i>O. glaberrima</i>	5 4	279±15	22.0±0.8	11.7±0.6	198±36	9.3±3.7	17.6±2.4
		1*	223	20	9	169	4.2	18.5
12	<i>O. sativa</i>	1 1	290	23	11	211	7.6	19
13	<i>O. sativa</i>	2 2*	139±9	19.0±0.0	6.0±0.0	58±2	3.0±1.5	9.1±1.0
	<i>O. glaberrima</i>	4 4*	156±25	20.3±3.0	7.5±3.1	95±45	3.8±2.3	12.6±2.7

(b): 10 cm/2 days

LEI position	Species	No. of var.	Plant length	No. of leaves	No. of elongated internodes	Total internode length	LEI length	Average internode length**
8-9	<i>O. sativa</i>	7 7	278±9	18.0±1.4	9.1±1.6	212±13	12.9±7.2	23.5±2.8
	<i>O. glaberrima</i>	4 2	271±2	17.5±0.7	8.5±0.7	200±8	21.6±4.3	24.3±0.9
		2*	203±1	15.0±0.0	6.5±0.7	133±8	11.6±3.6	21.7±1.6
10-11	<i>O. sativa</i>	4 3	277±25	16.3±0.6	6.7±1.2	185±28	9.3±4.4	27.4±4.5
		1*	134	13	3	47	8	14.2
	<i>O. glaberrima</i>	4 2	262±16	17.5±0.7	8.0±0.0	197±17	19.5±5.9	27.5±1.9
		2*	144±27	15.5±0.7	4.5±0.7	65±37	8.0±2.4	15.5±5.1
12-14	<i>O. sativa</i>	3 3*	122±67	15.5±0.6	3.7±1.2	48±59	5.9±7.4	11.3±10.5
	<i>O. glaberrima</i>	5 5*	123±18	16.4±2.3	3.8±2.2	43±24	4.8±1.3	10.9±3.4

* Number of the varieties which could not grow until the end of the submerging treatment.

** Average length of all elongated internodes excepting the youngest internode.

Asian floating rices, the average internode length was shorter than in the other varieties. However, in the African floating rice, the leaf emergence rate was slightly late, and the length of the leaf blade and leaf sheath were short, although there was no difference in average internode length. The characters of an Asian variety with LEI position at the 12th internode were quite similar to the floating rice varieties with LEI positions at the 8th and the 9th internodes. The floating rice varieties with LEI positions at the 13th internode failed to grow, and the average internode length was short. Further, the average value of almost all characters in the African group was superior to that in the Asian, but the variation among varieties in the former was larger than that in the latter.

In 10 cm/2 day-submerged lots, all Asian floating rice varieties with LEI positions at the 8th and the 9th internodes grew until the end of the treatments, while 2 out of 4 African varieties did not (Table 2(b)). In varieties which grew, the average internode length was almost the same in both groups, although the total internode length in the African group was slightly shorter than that in the Asian. In 2 African floating rice varieties which did not grow, the average internode length was shorter than that in the others by 2.6 cm. In floating rice varieties with LEI positions at the 10th and the 11th internodes, 2 out of 4 African varieties and one out of 4 Asian varieties failed to grow. Among varieties which did grow, the total internode length of the African rice was longer than that of the Asian rice. The average internode length was nearly the same in both groups, although the plant length in the former was shorter than that in the latter. In varieties which did not grow, however, the average internode length was a half that of varieties that did. No varieties with LEI positions at the 12th to the 14th internodes grew. In both groups, the average internode length was short. In addition, in the average value of all characters, the difference between species was not observed, however, the variation among varieties in plant length and total internode length was much greater among the Asian than among the African varieties.

DISCUSSION

In African floating rice, internodes elongates with increasing water depth when they reach the lag phase. This phenomenon is the same as in the Asian floating rice. In the latter, the start of internode elongation, i.e., the position of the lowest elongated internode (LEI), is thought to be almost constant regardless of water conditions and to be quite stable in its morphological characteristics (Inouye and Hagiwara 1981, Kiryu *et al.* 1995). However, in African floating rice, the LEI position under non-submerged conditions was higher than that under submerged conditions. This suggests that the African varieties can start internode elongation to coincide with the arrival of flooding (Watarai and Inouye 1997). In floating rice, internode elongation ability with increasing water depth and the size of total internode length were essential characteristics of floating ability, and were as important as start of internode elongation. In this experiment, the African and Asian varieties were grown under different rising-water conditions.

When varieties with LEI position of the 10th internode were grown under 4 cm/day-submerged conditions, plant length and total internode length in the African varieties were shorter than those in the Asian. This was because the leaf emergence rate under the rising water conditions in the African group was slower. Therefore, number of leaves

in the African group were fewer as well as number of elongated internode. Considering that the leaf emergence rate is influenced by climate (Sato 1972, Takamura *et al.* 1961), the temperature during the experiment may be slightly low for African floating rice. However, the effect of submergence on the leaf emergence rate was not obvious. Further, the average internode length was almost the same in both groups.

In 5 cm/2 day-submerged lots, among 21 varieties having LEI positions from the 8th to the 12th internodes, one African and one Asian variety failed to grow until the end of the experiment. In floating rice varieties which grew, differences between species in plant length, total internode length and average internode length were not observed. No varieties with LEI positions at the 13th internode could grow. This seems the reason why the average internode length was considerably short. Generally, in the Asian varieties, the lower the LEI position, better the internode elongation ability. In this experiment, the African group seemed to be the same as the Asian in so far as varieties with a low LEI position could grow until the end of the experiment.

Among varieties with LEI positions from the 8th to 11th internodes in 10 cm/2 day-submerged lots, one Asian variety with LEI position at the 10th internode and each of 2 African varieties with LEI positions at the 9th and the 11th internodes did not grow. Among plants which did grow, although the plant length in the African varieties was slightly shorter than that in the Asian, the difference between species in total internode length was not obvious, and the average internode length was almost the same in the both groups. All floating rice varieties with LEI positions from the 12th to 14th internodes did not grow. This was because the average internode length was rather short. According to Ibi *et al.* (1995), Asian floating rice was grown in 4 cm/day-submerged lots; consequently, in varieties with LEI positions at the 12th and 13th internodes, the increase in water depth by 4 cm per day seemed to be the limitation for their elongation ability. In this experiment, no varieties with LEI positions from the 12th to 14th internodes could grow in 10 cm/2 day-submerged lots, and no difference between the African and Asian varieties was observed.

From the above, we conclude that under slow rising water conditions as in 5 cm/2 day-submerged lots, the internode elongation ability of both African and Asian floating rices was almost the same in that the leaf age of the start of internode elongation was the same in both. Under rapid water rising conditions such as 4 cm/day- and 10 cm/2 day-submerged lots, however, it was suggested that internode elongation in the former was slightly inferior to that in the latter.

However, it was reported that the variation in water depth in African flooding areas was more serious than in Asia, with fluctuations of more than 10 cm (Katayama 1989). In addition, there were some reports that African floating rice was more tolerant to unfavourable conditions such as flooding than Asian floating rice (Coudhury and Will 1977, Oka *et al.* 1978). Therefore, information about the internode elongation of African floating rice in such a challenging environment is always important and deserving of further study.

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