Differences in Sprouting and Respiration of Seeds between Japonica and Indica Rice under Low Oxygen Tension

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It appears to be a common practice in the tropical regions including Thailand where indica rice is cultivated exclusively that, for obtaining satisfactory sprouting, seeds are pregerminated to such an extent that the plumules and radicles elongate to several millimeters or more before sowing into the wet nursery beds. Contrarily, in Japan where cultivated rice belongs to japonica type, pregermination to the extent of 1 or 2 mm in length is usually regarded as optimum (Plate 1). In addition, nursery beds are submerged after sowing in Japan but not in Thailand, as submerging results in the considerable deterioration of sprouting seeds.

These differences in pregermination treatment and water management after sowing suggest that indica rice may require more oxygen for sprouting than japonica rice. Actually, Takahashi et al.[6,7] argued the possibility of different oxygen requirements from the result that rate of germination and especially elongation of plumules and radicles of indica rice seeds were more retarded than those of japonica under deep water experimental conditions, and also in the atmospheres of low oxygen percent.

In an attempt to ascertain the physiological basis for this difference in oxygen requirement the present author studied respiratory activity during sprouting of seeds under anaerobic conditions[5] using 10 lowland rice varieties for each of japonica and indica (Table 1).

Germination and elongation of plumules in deep water

1) *Emergence of seedlings in deeply submerged seed-bed*

In the seed-bed prepared by using plastic tubs filled with paddy soil, dry seeds were

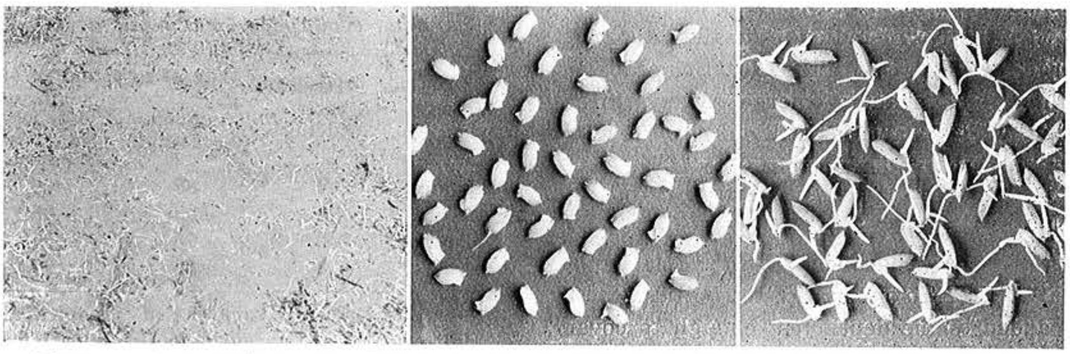

Plate 1. A farmer's nursery bed just after sowing in the Central Plain, Thailand (left), intensity of pregermination in Japan (middle) and in Thailand (right)

Table 1. Varieties tested

Variety	Origin
Japonica:	
1. Nihonbare	Japan
2. Koshihikari	Japan
3. Toyonishiki	Japan
4. Akihikari	Japan
5. Kochihibiki	Japan
6. Hatsuboshi	Japan
7. Kiyonishiki	Japan
8. Kokuryohmiyako*	Japan
9. Tamanishiki*	Japan
10. Ginbohzu*	Japan
Indica:	
1. Gam Pai 15	Thailand
2. Gaw Ruang 88	Thailand
3. Khao Pahk Maw 148	Thailand
4. Luang Tawng	Thailand
5. RD 2	Thailand
6. T-136	India
7. Boro 8	India
8. BG 34	Sri Lanka
9. BG 90	Sri Lanka
10. IR 8	IRRI

* Old type

sown and sprouted under non-submergence and submergence of 5 cm depth at about 25°C mean daily temperature. In the submergence, elongation of plumules and emergence above water surface of indica varieties were remarkably inferior to those of japonica varieties, although all varieties of both types germinated and elongated well under non-submergence (Table 2). Some seedlings of japonica varieties emerged 14 days and many seedlings did 18 days after sowing. Emergence rate varied from 22 to 45% depending on varieties. On the contrary, indica varieties did not emerge for 14 days with the exception of a few seedlings but began to emerge 18 days after sowing, while 2 varieties still did not. Varietal emergence rate ranged from 0 to 12%.

2) Germination in deep water

Seeds were bedded in small plastic cylindrical bottles. To one half of the bottles, water was added to the depth just enough to cover the whole caryopsis (shallow water condition), whereas to the other half to a depth of 5 cm

Table 2. Emergence rate of seedlings above the water surface under submerged conditions, 5 cm depth, in the seed-bed

Variety	Days after sowing	Rate of emergence (%)	Rate of sprouting under non-submerged (%)
Japonica:	14	2	96
	18	33	97
Indica:	14	0.3	87
	18	5	93

Mean of each 10 varieties of japonica and indica.

(deep water condition). After being kept in a dark thermostatic incubator at 30°C for 2 to 4 days, germination rate was counted.

There was no difference in germination rate of japonica varieties between shallow and deep water conditions. On the other hand, germination of indica varieties was retarded to some extent in the deep water, as seen 2 days after bedding, but even in these varieties the difference became less 3 days after bedding (Table 3).

3) Elongation of plumules in deep water

In order to compare the influence of water depth on the elongation of plumules, seeds which germinated almost equally but not elongated in both deep and shallow water conditions prepared by the same method as described in 2) were selected 2 or 3 days after bedding and kept continuously under each water condition. After two days of incubation, ratio of elongation of plumules in the deep water to that in the shallow water was

Table 3. Germination rate under deep water conditions, 5 cm depth

Variety	Days after bedding	Rate of germination (%)	
		under deep water	under shallow water
Japonica:	2	88	88
	3	93	95
Indica:	2	75	91
	3	93	97

Mean of each 10 varieties of japonica and indica. With a few varieties, germination of which was relatively slow, determination was done at 3 and 4 days after bedding.

determined. Elongation of plumules of both japonica and indica was increased by deep water. But the ratio of elongation was remarkably higher in japonica than in indica; mean of the former and the latter varieties being 284 and 142%, respectively (Table 4).

Table 4. Ratio of plumule elongation under deep water, 5 cm depth, to that under shallow water conditions

	Ratio of elongation (%)	
	Japonica	Indica
Mean of 10 varieties	284	142
Varietal range	234~329	113~189

Plumule was allowed to develop for a period of 2 days after germination

Oxygen tension and plumule elongation

Seeds were bedded in 100 *ml* conical flasks under different oxygen tensions, 20.8 (air), 10, 5, 1 and 0% which were prepared by partially or completely substituting air with nitrogen gas, in a dark incubation at 30°C. After incubation for 2 or 3 days, seeds which had just germinated but not begun to elongate were selected and continuously kept in each oxygen tension to compare the effect of oxygen tension on the elongation of plumules. After incubation for 2 days, length of plumules was measured. Four varieties of each of japonica and indica were used.

As shown in Fig. 1, elongation of plumules of japonica varieties increased under low oxygen tensions; the longest plumules of 4 varieties being observed at 5 or 10% oxygen. Even in nitrogen gas, the plumules were longer than those in the air. Contrarily, in indica varieties plumule length decreased with decreasing oxygen tension, except for the case of Gam Pai 15 at 10%, although the deep water treatment increased their plumule length. Particularly, at the oxygen tension lower than 5%, there was a marked inhibition of elongation. Taking the mean length in air as 100, the mean length for 4 japonica varieties at 10, 5, 1 and 0% oxygen was 134, 137, 124 and 118, respectively and for indica varieties, 94, 79, 65 and 46, respectively.

Oxygen tension and respiration

Amount of CO_2 evolved (QCO_2) and O_2 absorbed (QO_2) based on dry matter was measured using Warburg manometer and respiration quotient (RQ) was calculated in the following two cases. First, respiration of Nihonbare (japonica) and T 136 (indica) under 1% oxygen was determined daily for 5 days after the seed bedding. Secondly, RQ of all varieties under 1% oxygen was determined on the 3rd day after seed-bedding. In both cases, seeds were bedded in conical flasks described above.

In the first case, seeds germinated 2 days after bedding with the rate of 76% (Nihonbare) and 55% (T 136), but afterwards the rate did not differ significantly. In each time of determination, sample materials were selected so as to represent mean developmental stage. QO_2 and QCO_2 of both varieties increased rapidly after the beginning of incubation, followed by a slow increase on the 4th and 5th days after bedding (Fig. 2). There was no significant difference in QO_2 between both varieties up to the 3rd day after bedding, but afterwards T 136 showed higher QO_2 than Nihonbare. On the other hand, Nihonbare showed considerably higher QCO_2 than T 136 throughout the 5 days of incubation period. In both varieties RQ reached the highest values within 1 day after bedding and then decreased gradually. The values were higher than unity throughout the determination (Table 5) in accordance with the results by Morinaga[3], and Taylor[12]. Nihonbare had evidently higher RQ than T 136 at any stage during germination and early growth.

In the second case, since all varieties germinated well and began to develop plumules at the time of determination, seedlings with plumule in length 2~3 to 5~6 mm were used for the determination. All japonica showed higher RQ than indica varieties (Table 6),

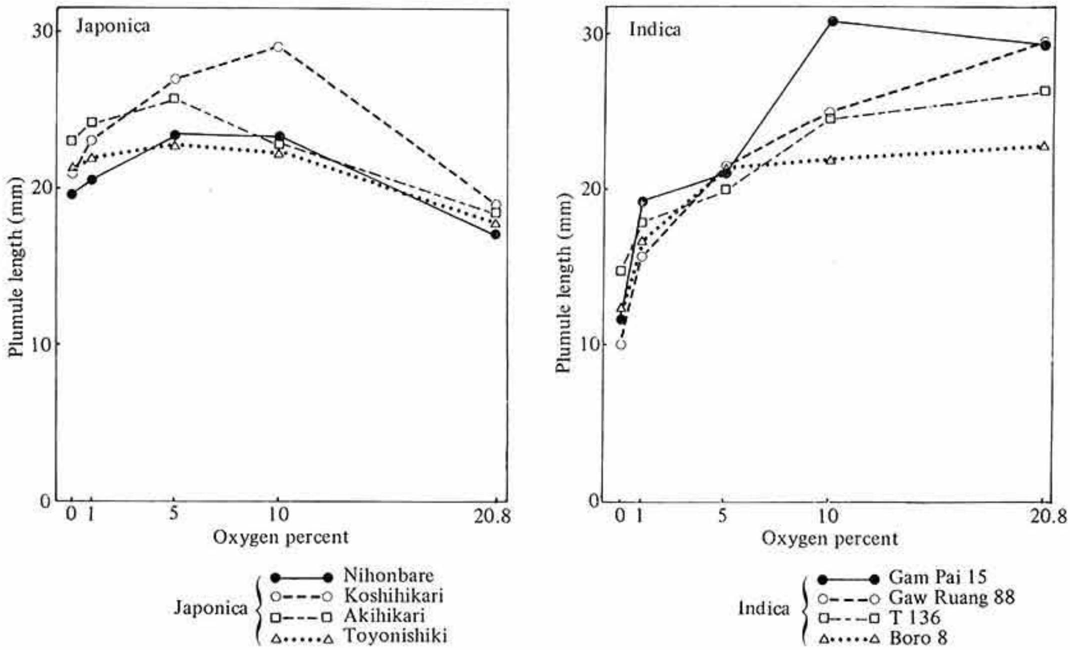

Fig. 1. Elongation of plumules during a period of 2 days after germination under different oxygen tensions

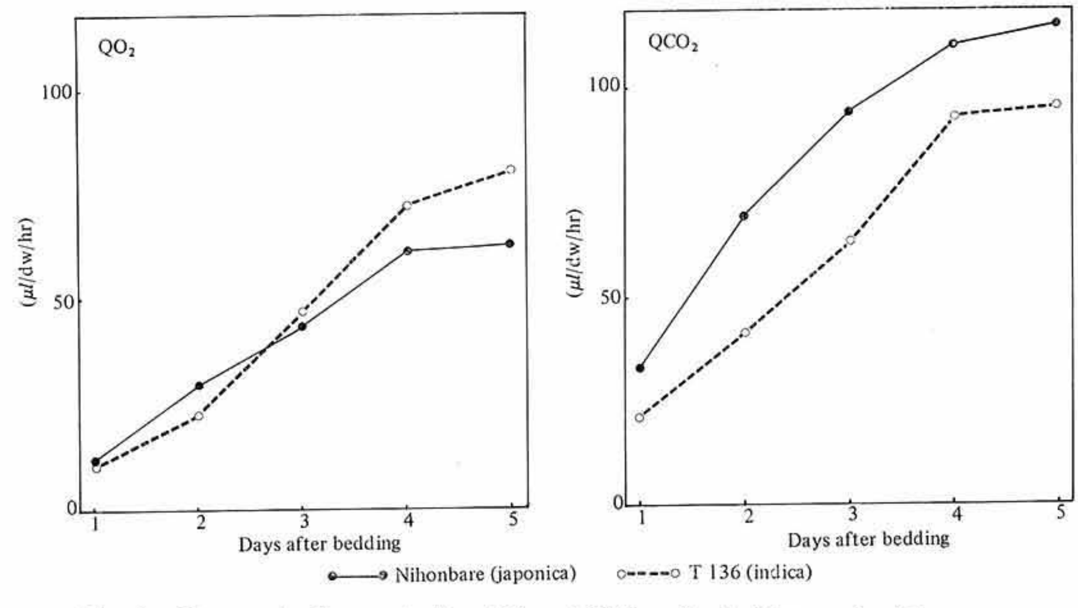

Fig. 2. Changes in the respiration, QO_2 and QCO_2, after bedding under 1% oxygen

Table 5. Changes in RQ after bedding under 1% oxygen

	Days after bedding				
	1	2	3	4	5
Nihonbare (japonica)	2.77	2.31	2.12	1.78	1.83
T 136 (indica)	2.02	1.81	1.33	1.28	1.17

i.e., RQ of japonica varieties ranged from 1.84 to 2.60 with the mean for all varieties, 2.13, while that of indica ranged from 1.03 to 1.55 with the mean, 1.34.

Table 6. Varietal difference in RQ of germinated seeds on the 3rd day after bedding under 1% oxygen

Japonica		Indica	
Nihonbare*	2.12	Gam Pai 15	1.38
Koshihikari	2.15	Gaw Ruang 88	1.42
Toyonishiki	1.84	Khao Pahk Maw 148	1.38
Akihikari	2.01	Luang Tawng	1.26
Kochihibiki	2.60	RD 2	1.40
Hatsuboshi	2.03	T 136*	1.33
Kiyonishiki	2.21	Boro 8	1.34
Kokuryomiyako	2.24	BG 34	1.03
Tamanishiki	1.98	BG 90	1.35
Ginbohzu	2.08	IR 8	1.55

* From Table 5.

Discussion and conclusion

Varietal difference in oxygen requirement among rice varieties has not so far been paid much attention, although there are a few comparative studies between lowland and upland rice[1,4,11]. Hayamichi et al.[2] observed that the growth of coleoptile or leaf under deep water differs depending on varieties. Recently, varietal difference between japonica and indica rice in the ability of germination and early growth in deep water conditions was reported by Takahashi et al.[6,7], as cited already and also by Takahashi[9,10].

Results obtained in the present study accord with those cited above, except the plumule elongation of indica varieties was larger in the deep water than in the shallow water conditions, contrary to the result of Takahashi et al.. As they measured plumule length under both conditions on the same days after bedding, the length of plumules of indica varieties in the deep water may be shorter than it might be, being effected by retarded germination of indica caused by deep water. In the present experiment, however, the plumule elongation was compared using the seeds germinated almost equally but not elongated in each conditions in order to eliminate the effect of retarded germination in the deep water. Similarly, determination of plumule elongation in the different oxygen tensions was also done using the selected seeds by the same way.

In the deep water or low oxygen tensions, elongation of radicles was extremely poor, but the changes in it were not investigated in the present study. In shallow water and in the air, the leaf often emerges from the coleoptile, but when oxygen is limited only the coleoptile elongates. However, in this study, this difference was not taken into consideration and the length of the coleoptile or the length to the tip of the emerged leaf was regarded as the plumule length.

Japonica rice always showed higher RQ than indica under 1% oxygen. Considering that RQ of rice seeds, starchy ones, should be near unity during germination under aerobic conditions, this difference between both types can be taken as showing an important implication. According to Erygin[1], the RQ of upland rice was less than that of the lowland variety during germination in water. Takahashi[8] reported that the seeds of rice cultivars, particularly of japonica rice do not require so much oxygen as the wild rice seeds do, and inferred that the latter seeds do not germinate in water possibly because alcohol fermentation is limited. With regard to the difference in crop plants, rice has higher germination rate and QCO_2 than barley at low oxygen tension[13]. Taylor[12] concluded that the superiority of rice over wheat in an ability to germinate and grow under very low oxygen concentrations is dependent upon the possession by rice of a highly functional fermentation system.

From these facts, it may be concluded that the higher ability of japonica as compared with indica rice to germinate and grow in deep water or under oxygen deficient conditions can be attributed to that the former has a more functional fermentation mechanism than the latter as an anaerobic respiration system.

One may think that the pregermination treatment commonly seen in Japan is preferable to that in the tropics because the latter aims at longer plumules and radicles which are prone to physical damages. But such a treatment in the tropics is a practice adapted to the characteristics of indica rice. It must be emphasized in agricultural technology transfer that knowledges developed in the temperate zone are often not suitable for direct application to the tropics, but have to be modified according to differences in environmental conditions, cultivars, and even socioeconomic factors, etc.. The different behavior of rice seeds observed between japonica and indica varieties offers a typical example of it.

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(Received for publication, July 29, 1982)