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The *indica-japonica* classification of Asian rice ecotypes and Japanese lowland and upland rice (*Oryza sativa* L.)

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Summary

Rice cultivars (*Oryza sativa* L.) belonging to five ecotypes (*aus, aman, boro, bulu* and *tjereh*) and to two groups of Japanese rice (lowland and upland) are examined with respect to $KClO_3$ resistance, phenol reaction and apiculus hair length. These characters have been used as available criteria to classify rice into two types *indica* and *japonica*, for the last thirty years.

The findings of this study are that the *aman, boro* and *tjereh* ecotypes should be classified as typical indica; and that the Japanese lowland rice cultivars are mainly typical *japonica*. Some of the *aus, bulu* and Japanese upland rice cultivars differ from typical *indica* and typical *japonica*, so the respective terms *aus* type, *bulu* type and *J.u.r.* type, are proposed.

Aman, boro tjereh and Japanese lowland rice are cultivated in lowland. Some of the *aus, bulu* and Japanese upland rice cultivars have the characteristics of upland rice. In general, lowland rice cultivars can be clearly classified into *indica* or *japonica*, while upland cultivars cannot.

Abbreviations: Aph, dominant gene for apiculus hair length > 0.7 mm, – *aph*, recessive gene for apiculus hair length < 0.7 mm. – *J.u.r.* type, Japanese upland rice type

Introduction

Rice cultivars (*Oryza sativa* L.) have long been classified into two major groups, namely *indica* and *japonica* (Kato, 1930; Oka, 1958), which have probably arisen through adaptation to different environmental factors, such as day length, water condition and temperature.

Farmers in East Asia have traditionally classified rice into several groups. In India, *aus, aman* and *boro* have been distinguished by their cropping time (Chandraratna, 1964). In Indonesia, *bulu* and *tjereh* have been distinguished by their morphological and physiological traits (Chandraratna, 1964). Morinaga (1968) referred to these groups as ecotypes. There are several reports about the environmental conditions in which each ecotype is cultivated (Hector, 1930; Tanaka, 1958; Morinaga, 1951, 1955; Chandraratna, 1964).

So far, it is not clear how the rice ecotypes classified by Morinaga (1968) and the so-called Japanese lowland and upland rice types should relate to the *indica-japonica* classification. The classification of the various ecotypes, and Japanese lowland and upland rice, is here examined, using the modified method of Oka (1958).

Materials and methods

Twenty six *aus*, 12 *aman*, 5 *boro*, 29 *bulu* and 32 *tjereh* ecotype cultivars and 23 lowland and 12 upland Japanese rice cultivars were used. $KClO_3$ resistance, phenol reaction and apiculus hair length were examined in all cultivars.

$KClO_3$ resistance. Seeds were sterilized with 70% ethanol solution for 2 min. After washing, they were sterilized again with 2.5% sodium hypochlorite solution for 15 min. and finally rinsed with distilled water. Then these seeds were placed on moistened filter papers in Petri dishes at 30° C. Germinated seeds were sown on plastic netting set 15 mm below the top of a plastic case (185 × 115 × 55 mm). Distilled water was added up to the level of the netting and rigorously maintained at that level by manual treatment, throughout the experiment. Twenty seedlings of 2 cm height were collected from each cultivar plot and ten of them had their roots soaked in 2 ml of 0.1% $KClO_3$ solution in 18 × 180 mm tubes. The other ten (control) seedlings were soaked in 2 ml distilled water. All tubes were kept at 28° C in darkness. After 5 days, the shoot lengths of the seedlings were measured. The ratio of the mean shoot length of $KClO_3$-treated plants to that of controls provided an index of $KClO_3$ resistance.

Phenol reaction. Three seeds of each cultivar were soaked in 2 ml of 1.5% phenol solution in a 18 × 180 mm tube, and kept at 28° C for 5 days. Judgment of the phenol reaction was made by the color of the solution (Takahashi & Hamza, 1983).

Apiculus hair length. The longest two apiculus hairs of each seed were measured using a microscope at 25-fold magnification. Five seeds were measured for each cultivar and the mean was taken as apiculus hair length.

Results

The values obtained for each trait were manipulated according to the method of Oka (1958). $KClO_3$ resistance showed a bi-model distribution (Fig. 1), with a minimum frequency around 55.0. The cultivars were scored as '0', when the relative shoot length was below 55.0%, or '1' if above 55.0%. The apiculus hair length has been reported to be controlled by a major gene (Sato, 1985): the dominant allele, *Aph* is associated with apiculus hairs longer than 0.7 mm, while expression of the recessive, *aph*, yields shorter than 0.7 mm. The cultivars could therefore be divided into two groups, using Sato's criterion length of 0.7 mm, and designated as '0' (below 0.7 mm) or '1' (above 0.7 mm). For the phenol reaction, cultivars were scored as '0' when the phenol solution was stained, and '1' when it was not. Then we classified the cultivars qualitatively.

Table 1 shows the character combinations of $KClO_3$ resistance, phenol reaction and apiculus hair length. The two extreme scores, i.e., '0 0 0' ($KClO_3$ resistance weak, positive phenol reaction, short apiculus hair length) and '1 1 1' were expected to be typical *indica* and typical *japonica*, respectively (cf. Oka, 1958).

82.6% of Japanese lowland rice showed '1 1 1' (typical *japonica*) and most of the *aman boro* and *tjereh* cultivars were '0 0 0' (typical *indica*). Some of the *tjereh* showed the '1 1 0' or '0 1 0' combination. The latter was also found to characterize almost half of the *aus* cultivars, while the other half of *aus* were typical *indica*. High frequencies of other combinations were found in the *bulu* (69.0% '1 1 0') and in the Japanese upland rice (58.3% '1 0 0'). It is therefore concluded that the *aus, bulu* and Japanese upland rice cannot be included as either typical *indica* or typical *japonica*.

The occurrence of the combinations '1 1 0', '1 0 0' and '0 1 0' lead us, then, to designated these as *bulu* type, *J.u.r.* type and *aus* type, respectively. There were scarcely any cultivars with combinations opposite to these types ('0 0 1', '0 1 1' and '1 0 1').

Discussion

Hector (1930) reported that rice in Bengal can be subdivided into five groups, namely Highland *aus*, Lowland *aus*, Transplanted *aman*, Lowland *aman*

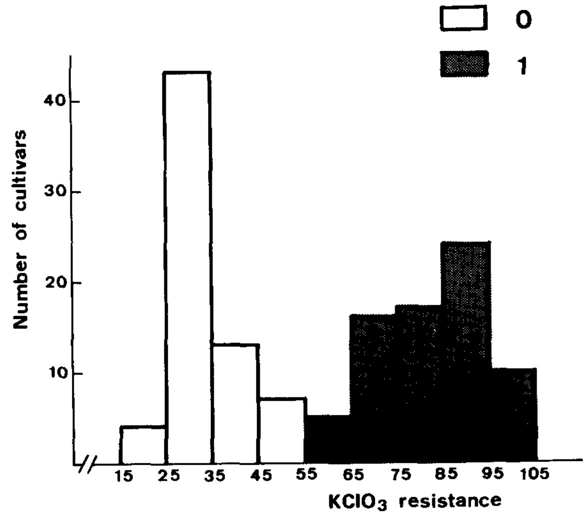

Fig. 1 Frequency distribution of $KClO_3$ resistance.

and *boro*. Highland *aus* is sown on high land in April or May and does not grow in standing water. Lowland *aus* is sown in February or March with the first showers of rain, and the cultivated area becomes inundated. These groups are harvested between July and September and are called 'summer rice'. Transplanted *aman* is sown in June or July, transplanted in July or August, and harvested between October and January. Lowland *aman* is sown in February or March, and harvested between November and January. *Aman* is cultivated under plenty of water in the rainy season, and because it is harvested in winter it is called 'winter rice'. *Boro* is sown around October, transplanted around January and harvested between March and April, and is therefore referred to as 'spring rice'. It is generally cultivated where irrigation facilities are available, as there is no rain at this time of the year.

The *bulu* and *tjereh* of Indonesia are very different from each other in physiological and morphological traits (Morinaga, 1951). Generally, the cultivars which have awn are *bulu*, while those without are *tjereh*. *Tjereh* was recently introduced to Indonesia from India and China, and was generally cultivated in lowland places. *Bulu* has been cultivated in Indonesia for a long time and has many of the characteristics of an upland rice, such as long culms and a small number of long panicles (Tsunoda, 1987).

In Japan, rice is sown in March or April and harvested between September and October. Japanese lowland rice is cultivated in paddies, in contrast to Japanese upland rice which is cultivated in relatively dry, upland fields.

In essence, Lowland *aus*, Transplanted *aman*, Lowland *aman, boro, tjereh* and Japanese lowland rice are cultivated in lowland areas, while Highland

Table 1. Frequencies of various character combinations found in the cultivars of this study

Assigned types	Character combinations			Cultivars						
	$KClO_3$ resistance	Phenol reaction	Apiculus hair length	*aus*	*aman*	*boro*	*bulu*	*tjereh*	*J.l.r.**	*J.u.r.***
typical *japonica*	1	1	1	7.7	–	–	24.1	3.1	82.6	16.7
bulu type	1	1	0	–	8.3	–	69.0	18.8	13.0	16.7
	1	0	1	–	–	–	3.4	–	–	8.3
	0	1	1	–	–	–	–	–	4.3	–
*J.u.r.*** type	1	0	0	–	–	–	–	–	–	58.3
aus type	0	1	0	46.2	–	–	–	12.5	–	–
	0	0	1	–	–	–	–	–	–	–
typical *indica*	0	0	0	46.2	91.7	100	3.4	65.6	–	–
Total (%)				100	100	100	100	100	100	100
No. of cultivars				26	12	5	29	32	23	12

* Japanese lowland rice.
** Japanese upland rice.

aus, bulu and Japanese upland rice have the characteristics of upland rice.

Most of *aman, boro, tjereh* and half of *aus* belonged to typical *indica*. The Japanese lowland rice were mainly typical *japonica. Bulu,* Japanese upland rice and half of *aus* differed from typical *indica* and typical *japonica*.

It is considered that the lowland rice are clearly classified into typical *indica* or typical *japonica*. On the other hand, the upland rice may be divided into *aus* type, *bulu* type and *J.u.r.* type.

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