Origin and Geographical Distribution of Japanese Rice

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The *sativa* rice varieties of the world were first grouped by Kato into two types, Indian and Japanese, according to the geographical distribution and a series of morphological characters. Proving that the hybrids between the types were always highly sterile, Kato ranked those as subspecies of *O. sativa* L., under the names *subsp. indica* Kato and *subsp. japonica* Kato.[5] Therefore, Kato's subspecies well correspond to ecospecies, the term used by genecologists.[9][10][2]

Several Japanese workers, however, soon made clear by a similar method of investigation that there were many rice varieties of intermediate nature of the two subspecies of Kato. This work was started with genecological analysis and classification of *O. sativa* L.

Genecological analysis of *O. sativa* L.

Here the author used only those ecotypes presumed by him to belong to different ecospecies. They were Japan ecotype (of Japan), bulu ecotype and tjereh ecotype (of Indonesia) and aman ecotype, aus ecotype and boro ecotype (of Bengal-Assam region of India).

The cross between bulu and tjereh has been known not to bring promising progeny for breeding.[11] The hybrid between aman and aus has been reported to show partial sterility.[7] The author wanted to have three ecotypes from Indo-China which correspond agriculturally to aman, aus and boro of India, but it was impossible.

Experimental results

Taking some numbers of varieties from each ecotype, the intertype hybrids of all 15 kinds of combinations of six ecotypes were raised, and their seed fertility was carefully recorded. The results are shown in Table I and Table II (for convenience the fertility records of the hybrids between the rice of Himalaya and those six ecotypes were also included in the tables). From these tables we may say as follows:

1) Japan ecotype is distinguished from other ecotypes in that respect that it makes hybrid of intermediate degree of fertility with bulu ecotype and aus ecotype, and highly sterile hybrid with aman, boro and tjereh ecotypes.

2) The difference of bulu ecotype and aus ecotype is shown in that bulu makes highly sterile hybrid with aman and tjereh, while aus makes highly fertile hybrid with boro, tjereh and aman.

3) The difference of boro ecotype and aman ecotype was very slight, and the difference was noticed only in the point that boro makes highly sterile hybrids with Japan ecotype, and aman ecotype makes highly sterile hybrids with Japan and bulu ecotypes.

4) The difference of aman ecotype and tjereh ecotype was noticed only in the point that aman makes hybrids of intermediate fertility with boro, while tjereh makes highly fertile hybrids with boro type.

The above mentioned intersterility relations seem to suggest that all of the six great ecotypes here investigated belong to each different ecospecies. Taking clear differences only, however, the author grouped those into four ecospecies. They are ecospecies "japonica", ecospecies "bulu", ecospecies "aus" and ecospecies "aman". Ecospecies "aman" includes ecotype

"aman", ecotype "boro" and ecotype "tjereh".

It is quite an exceptional case that a Linnean species is divided into so many ecospecies. For all that, the author does not think that *O. sativa* L. is a polyphiletic species as it was thought before. If it be so, where will be the primary centre of origin of *O. sativa* L. in the meaning of Vavilov's.[12]

The following experiments were carried out referring to this problem.

Experiments concerning the primary centre of origin of *O. sativa* L.

Vavilov assumed that the primary centre of origin of *O. sativa* L. was south-west Himalaya.[7] Any experimental data serving to estimate this hypothesis will be very desirable. In this experiment, the fertility of the hybrids between the rice of Himalaya and the six ecotypes mentioned above were tested.

Eight varieties from Himalaya, one from Sikkim and seven from the Darjeeling district were used. The Sikkim variety contained two types, one of short cariopsis (length/width ratio 1.8) and the other of somewhat longer cariopsis (length/width ratio 2.4). Out of seven varieties from Darjeeling, three varieties were also mixtures of easily discriminable types. The length/width ratio of cariopsis of these varieties ranged from 1.6 to 3.3, and their colour was either white or red. The Sikkim varieties showed short awns, but all Darjeeling varieties were awnless.

Experimental results

The results were shown in Table 1. and Table 2. Unlike inter-ecospecies hybrids discussed already, the rice of Himalaya produced hybrids of intermediate degree of fertility with all of those ecospecies. How shall we understand these strange relationships?

If the Himalaya districts are the primary centre of the origin of cultivated rice as Vavilov has thought, the complex of genotypes there existed long time ago and may even now be found there without clear differentiation. On the contrary, those complex of genotypes dispersed from there to every parts of Asia gradually differentiated to have their own gene patterns harmonized themselves and harmonized to all ecological factors they met with.[8][14] Such differences of gene patterns are clearly traceable for those ecospecies mentioned above.

If the Himalaya districts are the primary centre of the origin of cultivated rice, it may not be strange that all ecospecies or ecotypes make hybrids of intermediate degree of fertility with the rice of Himalaya. When two ecospecies having quite different genic patterns are mated their hybrids will show high sterility. If the difference of the genic patterns of two ecospecies is not so large, the hybrids will show low sterility. From the results of the present experiments, the author assumes that the primary centre of the origin of cultivated rice is south-east Himalaya.

Classification of ecospecies "japonica" and its distribution.

The rice group recognised by Kato as *subsp. japoica* was ordinary Japanese rice (ecotype "japonica"). It will be distinguished from *subsp. indica* by the following characters: leaves of narrow and deep green color, wide angle formed by the uppermost leaf and the stem, thick and broad grains, various gradation of awns or awnless, thick and comparatively long hairs on the glumes, spikelet or cariopsis not stained with phenol and cariopsis falls to pieces with alkali. Among these characters, the shape of grains (length/width ratio) and phenol reaction are easily applicable with good success.

According to Nagamatsu[6] rice varieties which produce round grains, the length/width ratio less than 2, distributed throughout Asia. The frequency of occurrence, however increases as the latitude becomes higher. Thus, all ordinary rice varieties of Japan and Korea belong to this type. This is the type of *subsp. japonica* Kato.

So far as the author's experiment is concerned, the ratio for North China varieties ranged from 1.7 to 2.5, and those below 2 were usually phenol reaction −, while those above 2 were usually phenol reaction +. By the hybrid fertility test, the phenol reaction−varieties were proved to belong to ecotype "japonica". Many Japanese workers proved already that ecotype

Table 1. Average fertility of the 15 inter-type combination hybrids of 6 main Asian ecotypes, and the average fertility of the hybrids of those ecotypes and the rice of Himalaya.

	Ordinary Japanese rice	Aus	Boro	Aman	Tjereh	Bulu	Rice of Himalaya
Ordinary Japanese rice		56 (50)	27 (39)	28 (56)	16 (81)	66 (62)	63 (15)
Aus	+		90 (17)	79 (29)	87 (18)	62 (18)	65 (14)
Boro	−	++		64 (18)	80 (17)	41 (26)	63 (13)
Aman	−	++	+		83 (29)	22 (41)	62 (16)
Tjereh	−	++	++	++		25 (28)	65 (11)
Bulu	+	+	+	−	−		59 (1)
Rice of Himalaya	+	+	+	+	+	+	

Note: 1. Figures without parentheses show average fertility of corresponding hybrid
2. Figures in parentheses show the number of hybrids of different varietal combinations, from those the average fertility was calculated.
3. ++ shows average fertility over 70%.
+ shows average fertility 70% — 30%.
− shows average fertility less than 30%.

Table 2. Relative affinity of the 6 main ecotypes shown by the hybrid fertility and the affinity of the rice of Himalaya and the 6 main ecotypes.

	++	+	−
Ordinary Japanese rice	(Ordinary Japanese rice)	Bulu Aus	Aman Boro Tjereh
Aus	(Aus) Boro Tjereh Aman	Bulu Ordinary Japanese rice	
Boro	(Boro) Aus Tjereh	Aman Bulu	Ordinary Japanese rice
Aman	(Aman) Tjereh Aus	Boro	Ordinary Japanese rice Bulu

Tjereh	(Tjereh) Aus Aman Boro		Bulu Ordinary Japanese rice
Bulu	(Bulu)	Ordinary Japanese rice Aus Boro	Tjeren Aman
Rice of Himalaya		Ordinary Japanese rice Aus Bulu Boro Aman Tjereh	

Note: ++ Average fertility over 70%.
+ Average fertility 70% — 30%.
− Average fertility less than 30%.

"japonica" also distribute in Central China.

Studying the rice of Indo-China peninsula, Cho[1] proved the tendency that shorter grain varieties are found in the district of higher altitude. He finally discovered in the northern part of Laos 12 japonica varieties of which length/width ratio of grains was less than 2. He also collected in Laos, several glabrous varieties. The length/width ratio of grains of those varieties ranged from 1.9 to 2.9, but their phenol reaction was always −. These varieties were proved by the author to produce highly fertile hybrid with ordinary Japanese varieties. This type may be called ecotype "nuda".[6] Thus we can trace in Laos ecotype "japonica" and ecotype "nuda", both belong to ecospecies "japonica". The round grain rice and the semi-round grain rice grown in North Vietnam are very likely to belong also to ecospecies "japonica".

Conclusion

1) Genecologically cultivated rice was classified as follows:

Cultivated rice *O. sativa* L.

1. ecospecies "aman" (*subsp. indica* Kato)
   1. ecotype "aman"
   2. ecotype "boro"
   3. ecotype "tjereh"
2. ecospecies "aus"
3. ecospecies "bulu"
4. ecospecies "japonica"
   1. ecotype "japonica" (*subsp. japonica* Kato)
   2. ecotype "nuda"

2) The primary centre of the origin of cultivated rice was asumed to be south-east Himaraya.

3) Special gene pattern of ecospecies "japoneca" will probably be established around south-east Himaraya.

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