Upland Rice Breeding in Japan

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Position of upland rice cultivation in Japan's agriculture

In Japan upland rice is cultivated as a summer crop. It is treated separately from the paddy rice and its varieties have been bred quite independently of paddy rice varieties.

Upland rice is usually grown by direct sowing in drills in upland farms which are not irrigated as a rule except special cases of irrigated cultivation, and also not flooded by rain water.

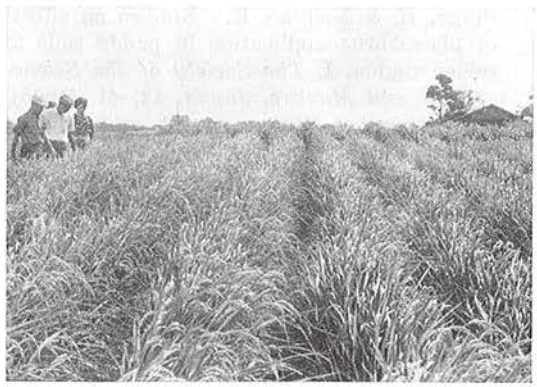

Fig. 1. Upland rice culture on farmer's fields at ripening stage

The cultivation of upland rice is incorporated into the operation of upland crops for the rotation of summer crops or summer vegetables and as a preceding or the second crop of spring and autumnal vegetables or winter crops for the purpose of avoiding damages from the continuous cropping or for the effective use of labor.

Upland rice requires ample water among various upland crops, being often damaged by drought, and it is said that an average monthly rainfall of not less than 120 mm is necessary at about the heading time when the plant is especially susceptible to drought, for obtaining a good yield of upland rice.[2] The damage from drought of upland rice is influenced by the property of soil and the atmospheric temperature.

In Japan upland rice cultivation is distributed in upland farm areas of the Tohoku, Kanto and Kyushu districts and especially concentrated in volcanic ash fields which are of large water-holding capacity, while its cultivation is scarcely seen in the Tokai district, coastal regions of the Inland Sea and islands because in these areas there is a small amount of rainfall, the soil is sandy and the crop is often damaged by drought.

Nonglutinous rice of the upland rice variety is so inferior in quality and taste to those of the paddy rice that it is only cultivated for private use in limited places where it is difficult to get paddy rice. Therefore, glutinous varieties form more than 70 per cent of the total upland rice acreage to supply materials for making rice cakes and the percentage is still increasing.

The breeding of upland rice is being carried out at the Ibaraki Agricultural Experiment Station as a link of the governmental breeding program for the improvement of varieties in Japan.

Main cultivating methods and object of breeding

As mentioned above, upland rice is cultivated in combination with other upland crops and for cultivation it has been the practice to sow seeds in drills between rows of wheat and barley, about one month before their harvest as the second crop to harvest at the beginning or middle of October.

In this method, upland rice heads toward the end of August and it is often damaged by drought. Therefore, resistance to drought as well as a good quality and a high yield under droughty conditions are the most important objects of upland rice breeding for this cultivating method.

Following a decrease in the acreage of wheat and barley, the cultivation of upland rice has increased recently to be done by seeding as early as possible in fields out of other crops.

In this method early maturing varieties are used for cultivation to complete heading before the severe droughty season appears and harvest the crop at or before the inception of September.

This method stabilizes the crop by avoiding damage from drought and has another advantage in that it makes the cultivation of autumnal and winter vegetables possible as the second crop. In this case early maturing varieties of upland rice are needed.

Since we have rather few early-maturing good varieties for cultivation in warm regions, it is desirable to breed early-maturing lodging-resistant varieties for these regions. On the other hand, early-maturing varieties with high germinability at low temperatures and high resistance to cold climates are necessary for cultivation in cold regions.

Recently, facilities for irrigating upland farms have been established in various places, and in some places cultivation of paddy rice varieties has been started by irrigating upland farms with sprinklers, obtaining results in its own way, but this method requires many points for improvement.

Therefore, breeding is now in the stage of progress to bring up varieties with blast resistance and drought resistance of upland rice in combination with a good quality, high productivity and a high lodging-resistance of paddy rices.

The importance of such rice varieties for cultivation in irrigated upland farms will become greater in the future when the establishment of facilities for irrigating upland farms progresses to stabilize upland crop productions and the water-saving cultivation of paddy rice comes to the front from a viewpoint of the utilization of water resources.

Difference between paddy and upland rice in Japan

It has been indicated by many researchers that some indigenous upland rice varieties show an affinity to varieties of the indica type sexually, being different from the Japanese paddy rice.[3),7)] But most of them belong to the same japonica type as Japanese paddy rice varieties, and there is especially no room for doubt about sexual affinity between recently improved upland rice and Japanese paddy rice varieties from the viewpoint of breeding procedure. And no difference is there on practical procedure of breeding works between upland and paddy rice in principle, except cultivating methods.

On the other hand, there are morphologically and physiologically clear distinctions between Japanese upland and paddy rice varieties (Table 1), probably owing to the adaptation of the former to severe growing conditions in upland farms concerning water supply.

Such morphological characters of upland rice varieties as a deeper distribution of the root system in the soil, longer stems and ears, a smaller number of tillers and a panicle weight type of plant are suitable for decreasing the water consumption of the plants to assure their yield and useful for maintaining their necessary growth so that their yield does not decrease under droughty conditions.

The varieties, however, are lower in adapt-

Table 1. Differences of characters between upland and paddy rice

Characters	Upland rice	Paddy rice
Plant height	High	Low
Number of tillers	Few	Many
Panicle length	Long	Short
Stem character	Thick and stiff	Slender and flexible
Grain character	Large and long	Small and roundish
Leaf character	Large and broad	Short and narrow
Root system	Deep	Shallow
Lodging resistance	Weak	Resistant
Drought resistance	Resistant	Weak
Blast resistance	Resistant	Susceptible
Grain quality	Inferior	Superior
Adaptability for heavy manuring	Low	High

ability for heavy manuring and insufficient in lodging-resistance because they have been adapted to growing conditions of upland farms where active growth of plants by the application of much fertilizer is not desirable for avoiding damage from drought.

Cultivation in upland farms promotes occurrence of the blast disease owing to the augmentation of the nitrogen content of rice plants and moreover, intermittent water supply due to the change of wether further promotes its occurrence.

Accordingly, upland rice varieties adapted to such conditions are notably stronger in blast resistance as compared with paddy rice varieties. The former is markedly inferior in quality and taste to the latter. This is said to be attributed to the unsuitable cultivating conditions in upland farms, under which the assimilation and translocation of carbon are inferior, rice grains tend to be incomplete in maturity and endosperm cells show a peculiar structure.[1)]

Resistance to drought

Many studies have been conducted on drought resistance of upland rice. But this character is very complicated and has not yet been fully explained.

As for the morphological character of drought resistance, Hasegawa et al.[2)] have reported that upland rice is smaller in the total number of roots than the paddy rice, but it is larger in the number of roots distributed in a soil layer 20 cm or more in depth and its roots are heavier in every soil layer, especially in deeper layers (Table 2).

Table 2. Comparison of root systems distributed in different depths of soil between upland and paddy rice (Hasegawa 1960)

Variety	Dry weight of plant	Number of roots			Weight of roots		
		0–10 cm	10–20 cm	20 cm<	0–10 cm	10–20 cm	20 cm<
	g				g	g	g
Paddy rice							
Obanazawa 6	14.13	250	50	4	2.16	0.35	0.03
Fujisaka 5	12.60	265	50	2	2.31	0.25	0.01
Upland rice							
Norin Mochi 1	14.76	180	49	11	2.75	0.70	0.24
Norin 12	14.49	198	38	17	2.24	0.49	0.16

Togawa and Ando[5] classified upland rice by the seedling type into two, dwarf and elongate, and found that individuals belonging to the former type are higher in physiological drought resistance. This classification has been adopted into the breeding work as a method for selecting drought resistant individuals and lines, because it can easily be applied to selection from among many materials.

But when considered collectively, the drought resistance of upland rice has intimate relation to such yield component as the number of tillers and the amount of terrestrial growth. And in the breeding of upland rice varieties a question hard to solve is how to maintain an equilibrium among drought resistance, productivity, lodging resistance and fertilizer response.

Resistance to diseases and insect pests

As mentioned above, upland rice is noticeably higher in resistance to the blast disease than paddy rice. And their selection has been continued attaching the most importance to blast resistance as well as drought resistance in the course of breeding.

Consequently, upland rice varieties are so improved at present that their resistance to the disease is practically out of question.

But as to the resistance of upland rice to such diseases and insect pests as Helminthosporium leaf spot [*Cochliobolus miyabenus* (S. ITO et KURIBAYASHI) DRECHSLER], sheath blight [*Pellicularia sakaii* (SHIRAI) S. ITO] and rice stem maggot [*Chlorops oryzae* MATSUMURA], these questions remain still unsettled because the mechanisms of resistance to them have not yet been made clear or we have no reliable method to test their resistance.

It is said that blast resistance of upland rice is not due to the genes for true resistance, which were analyzed in paddy rice but to unknown genes or so-called field resistance.

Iwatsuki[4] paid attention early to this point and bred blast-resistant paddy rice varieties, Shinju and Futaba, by making use of an upland rice variety, Senshō, as material. This blast resistance has contributed to the breeding of many resistance paddy rice varieties through Fujisaka No. 5 and other varieties thereafter.

Since the infection with the blast disease of paddy rice varieties, which were bred by introducing true resistant genes, has come into question recently, blast resistance of upland rice is attracting the breeder's attention now.

Toriyama et al.[6] found that Japanese upland rice was highly resistant to the rice stripe disease [rice stripe virus, KURIBAYASHI] and bred Chugoku Nos. 40–42 and 49 by using an upland rice line Kanto No. 72, as material. These are practically usable paddy rice strains with high resistance to the disease.

Breeding of upland rice varieties by crossing upland rice with paddy rice

The introduction of excellent characters from paddy rice into upland rice was tried from ancient days, but it was not successful for a long time. This is attributed to the fact that an increased number of tillers and short stems, which are necessary characters for a high yield and lodging resistance, are incompatible in many respects with drought resistance and a high yield under droughty conditions, which are essential characters of upland rice varieties.

In 1966, however, a new variety, Okaminori, was bred from a combination of upland rice Norin No. 24 × paddy rice Norin No. 29. Okaminori is the highest in lodging resistance and productivity among the existing upland rice varieties, but it is medium in drought resistance and rather displays its ability in cultivation in irrigated upland farms.

In 1969 Mizuhata-mochi was brought up from a combination of upland rice Hatakogane-mochi × paddy rice Koshiji-wase as a variety for cultivation in upland farms irrigated with sprinklers.

Mizusawa-mochi is intermediate in charac-

ter between the upland and the paddy rice. It is a variety comparable to paddy rice in lodging resistance, yield and quality and has a high blast resistance which is characteristic of upland rice as well as some drought resistance when cultivated in irrigated upland farms. This variety was recommended or recognized in five prefectures until now.

As mentioned above, the breeding of upland rice varieties by crossing upland rice with paddy rice is not yet completely successful, but considering the lack of excellent gene sources in upland rice varieties, it is thought to be a necessary method of breeding from now on and is continuously in use in combination with back and multiple crosses.

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