Breeding of Barley with Stiff Culms and Few Tillers

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Labor-saving mechanized cultivation of wheat and barley such as drill seeding and broadcasting with mixing-in soil layer has become popularized in Japan after the War. Varieties adapted to the mechanized cultivation require, first of all, stiffness of culms and lodging resistance.

Generally most of wheat and barley varieties produce a number of tillers, and 30–60% of them bear panicles. If varieties which do not produce any tiller or produce only few tillers are developed, they might have an advantage of stiff culms and high lodging resistance, because of the concentration of dry matter into a limited number of culms. Although grain yield per plant of these varieties is inevitably low, high yields can be obtained by increasing number of plants per unit area. In addition, it may be quite easy to regulate number of panicles in response to soil productivity and planting pattern.

Standing on this viewpoint, breeding of barley for stiff culms, extremely few tillers and high productivity was carried out.

Breeding of a cultivar, Mitake, with stiff culms and few tillers

One strain showing very few, but thick and stiff culms was selected out from F_5 progeny grown from seeds collected separately from each ear at F_4 generation of a cross, Chikurin-Ibaragi No. 2×Miho Hadaka, which had been treated with bulk method in the Central Agricultural Experiment Station (Konosu-city). This strain was named cultivar Mitake in 1963 at F_{10} generation, after subsequent selection for fixing for several generations[1].

Appearance of plants of this cultivar at the stage of initiation of internode-elongation is shown in Plate 1, in comparison with an usual variety. Number of culms including tillers is only about 3 per plant in an average. Culms are thick and extremely stiff. Tillers

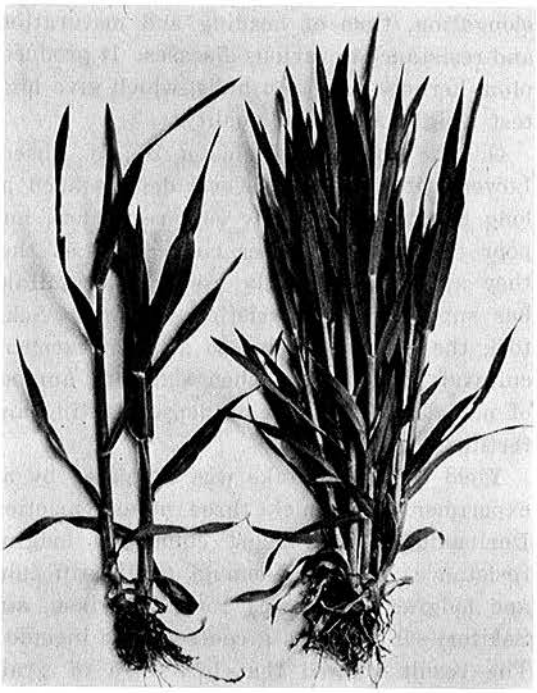

Plate 1. Plant of initial stage of internode-elongation
Left: Mitake
Right: Sekitori-sai No. 1

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Table 1. Characteristics of Mitake

Varieties	Characteristics										
	Tillers of plant	Normal or uzu	Growth habit in winter	Internode elongation	Heading and maturity	Culm length	Panicle length	Awn length	Grain shape	Cold resistance	Winter or spring habit
Mitake	0～3	uzu	medium	medium	medium	medium	short	medium	short	medium	winter
Absent lower laterals	0～3	normal	erect	extremely early	medium	long	long	long	long	extremely weak	spring
Uniculm 2	0～1	normal	erect	extremely early	late	long	long	long	long	extremely weak	spring
Sekitori-sai No. 1	many	uzu	medium	medium	medium	medium	short	medium	short	medium	winter
Haganemugi	many	normal	pro-cumbent	late	late	long	medium	long	medium	resistant	spring

are all primary ones, and nearly 100% of them bear panicles. Plants show rough feature with deep leaf color, but chromosome number is normal without sterility. Characteristics of this variety are given in Table 1, in comparison with Uniculm 2 and Absent Lower Laterals which were known at that time as few- or non-tillering strains.

Mitake is of "Uzu-type", and similar to Sekitori, a leading variety of barley, in culm length, panicle type, winter habit, internode elongation, time of heading and maturation, and resistance to various diseases. It produces plum kernels with thin hulls, which give high test weight and good quality.

On the contrary, Uniculm 2 and Absent Lower Laterals have several defects such as long culm, sterility, low cold resistance, and poor performance under cultivation, so that they are not practically used. Since Mitake has superior charatceristics similar to Sekitori, the variety is able to give an excellent cultural performance when sufficient number of panicles is obtained by dense planting and fertilizer application.

Yield level of Mitake was examined by an experiment, in which three other varieties, Dorirumugi (with short culm and lodging resistance) and Haganemugi (with stiff culm and lodging resistance) for comparison, and Sekitori-sai No. 1 as a control were included. The result showed that 57.8 Kg/a of grain yield, higher than that of Sekitori-sai No. 1, was obtained at panicle number of about 700/m² attained by increased seeding density and fertilizer application.

It was also shown that lodging resistance decreased markedly (characters related to lodging moved in favor of lodging) when number of panicles was increased by heavy manuring, whereas decrease in the resistance was relatively less when panicle number was increased by dense seeding.

Significance of few-tillering habit in breeding varieties with stiff culms and high productivity

By examining tillering process of Mitake, it was revealed that not only tiller bud formation was quite less, but also tiller buds often failed to grow further. Characteristic is that only primary tillers are produced without bud formation for secondary tillers, and that no coleoptile tiller was formed at all.

At an extremely high seeding density, only main stems bear productive panicles even with varieties of panicle number type like Dorirumugi. With any varieties, number of tillers and productive panicles decreases and percentage of productive tillers increase with an increase of seeding density. However, at any level of seeding density, Mitake gave the highest percentage of productive tillers. Such a high percentage of productive tillers makes panicle number regulation more easy than the case of usual type barley.

Relations among panicle number per unit area, dry matter yield, and grain yield were examined under different seeding time, seeding density and rate of fertilizer application, using

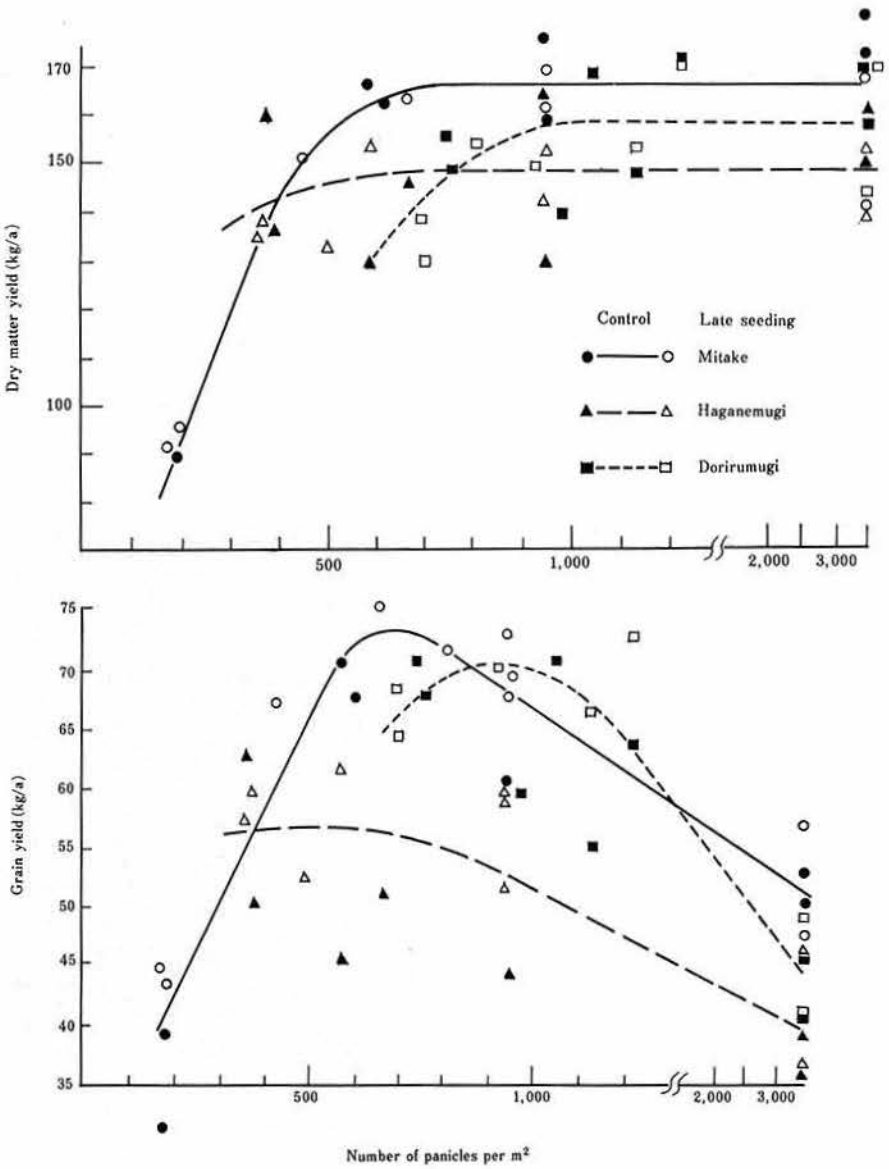

Fig. 1. Relationship between number of panicles per unit area and dry matter yields or grain yields

Mitake, Haganemugi and Dorirumugi. As shown in Fig. 1, with any varieties dry matter production became constant beyond a certain panicle number, and grain yield was highest at the panicle number at which dry matter production reached a constant level. That panicle number seems to vary depending on soil and climatic condition as well as rate of fertilizer application. In this experiment, it was about 1000/m² for Dorirumugi, 700/m² for Mitake and 500/m² for Haganemugi.

Dry matter production and grain yield of Mitake were highest among these varieties. These facts indicate that there is no intrinsic relation between tillering ability and yield potential, and that it would be effective to carry out preliminary selection on dry matter yield under a very high planting density

which gives more than 1000 panicles per m^2 in breeding varieties for stiff culm and high productivity.

To make clear the relation between tillering ability and culm stiffness, number of tillers of usual varieties was limited experimentally and compared to Mitake. With Sekitori-sai No. 1 and Musashinomugi, tillers were removed successively so that number of panicles per plant became equal to that of Mitake. Breaking strengths was increased by this treatment, but far lower than that of Mitake. Low seeding density also resulted in more or less increased culm stiffness. Breaking strength of main culm was 550 g for Musashinomugi, 600 g for Sekitori-sai No. 1, and 800–850 g for Mitake, each value being without variation. Breaking strength of tillers was lower than that of main culm, and it decreased with increasing number of panicles per plant. Therefore, even when the number of panicles per m^2 is same, population with main culms comprising a greater portion of total number of culms is more resistant to lodging. This indicates an advantage of varieties with few tillers.

Using Mitake and seven few-tiller varieties derived from Mitake as a parent, as well as five usual varieties, relations among dry matter yield, grain yield, ratio of grain weight to total dry matter weight, and culm stiffness were examined. Mitake and Dorirumugi showed a marked increase of dry matter by increasing rate of fertilizer application, giving largest dry matter production among varieties tested. However, a negative correlation between ratio of grain weight to dry matter weight and culm stiffness was clearly observed. Since there is a positive correlation between the ratio and grain yield, the selection for higher grain yield under normal cultural condition resulted in the selection for higher ratio of grain weight to dry matter weight, and hence there is a possibility of eliminating high lodging resistance.

Therefore in breeding for high productivity and stiff culm, it is desirable to select, at first, for high dry matter yield, and then select for lower ratio of grain weight. One of the key point in this case is to decide what degree of the ratio should be adopted.

Breeding of other strains with stiff culms and high productivity

During thirteen years from 1959 to 1971, 36 crosses were carried out using Mitake as a parent with an aim of developing varieties with stiff culm, high productivity and good quality at the Central Agricultural Experiment Station. Two improved strains, Kanto-kawa No. 43 (medium tillers) and 45 (few tillers) were released (Plate 2).

Plate 2. A. Mitake (few tillers)
B. Kanto-kawa No. 43 (medium tillers)
C. Kanto-kawa No. 45 (few tillers)
D. Sekitori-sai No. 1 (normal)

The former, developed from Mitake × Musashinomugi by pedigree method at F_6 generation, is characterized by very early maturity, medium tillering ability and culm stiffness. Although the strain is of normal type without major gene for few tillers, it produces considerably few tillers, with high percentage of productive tillers (63% with

Kanto-kawa No. 43 whereas 40% with Sekitori-sai No. 1). It has good grain quality and high resistance to lodging. In 1968, this strain yielded 73.3 kg/a with drill-seeding culture.

The latter was developed from a cross, Mitake × Tosan-kawa No. 7, by derived line method at F_7, and it has few tillers and stiff culms. Major characteristics are similar to Mitake, but more resistant to diseases than Mitake. In 1967, it yielded 67.3 kg/a with drill seeding by heavy application of fertilizer and dense seeding.

All these results indicate the significance of breeding for few tillers and stiff culms, as a type of varieties with stiff culms and high productivity. Under the circumstance of more labor-saving, however, there is a fear that sufficient number of panicles might not be obtained with extremely few tillers due to lack of seeding uniformity. Therefore varieties with moderate number of tillers seem to be more adaptable practically. Anyway, high tillering ability is not required for high yielding. Selection for high tillering may not be needed in the breeding of normal type varieties.

Heredity of tillering habit

Examination of F_2 individuals from a cross between normal cultivar and Mitake revealed that the tillering habit of Mitake is governed by a single recessive gene. This gene is named *rnt*, which implies reduced number of tillers[1]. It is considered to be originated from spontaneous mutation occurred during the course of growing hybrid population. It was proved that *rnt* is located between *uz* and *als* on chromosome 3 based on the three point experiment.

As tiller-controlling genes, *als* and *uc2* (on chromosome 6) are also known in addition to *rnt*. Number of panicles is presumably determined by these major genes and several other minor genes.

References

1) Nonaka, S.: Studies on the breeding of barley with stiff culms and few tillers. *J. Centr. Agr. Exp. Sta.*, 21, 1–77 (1974).
2) Nonaka, S.: Further information of the *rnt* locus on chromosome. 3. *Barley Genetics Newsletter*, 4, 56–58 (1974).