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Studies on New Breeding Methodologies and Variety Developments of Two Buckwheat Species (*Fagopyrum esculentum* Moench and *F. tataricum* Gaertn.)

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Summary

New breeding methodologies for common buckwheat (*Fagopyrum esculentum* Moench) and Tartary buckwheat (*F. tataricum* Gaertn.) according to their reproduction systems were studied, and development of varieties was conducted using various genetic resources with heredity analyses of their traits.

1. Breeding of common buckwheat using self-compatibility derived from an autogamous wild relative species (*F. homotropicum* Ohnishi)

At first, selection for non-shattering plants was carried out among the backcrossed populations of the interspecific hybrid between common buckwheat and *F. homotropicum*. A non-shattering self-compatible plant that was estimated to have a non-shattering gene, *sht1*, was successfully obtained through progeny tests. This plant was used as a parent in the following cross breeding for self-compatible buckwheat, and shattering has not been observed since then.

Outcrossing rate of self-compatible buckwheat in an open field was estimated using determinate growth habit as a morphological marker. The percentages of determinate plants were around 90 % in the progeny of self-compatible determinate plants even when they were grown among indeterminate pollen sources. Outcrossing rate of self-compatible buckwheat seemed to be higher than that of other allogamous crops; therefore, we have to pay attention not to select outcrossed progeny.

A method for emasculation of self-compatible buckwheat using hot water was developed to eliminate laborious work for crossing. Apical clusters of flower buds were soaked in hot water and the flowers that had opened the next morning were used for the following artificial pollination. Self-fertilization was completely inhibited by hot water treatment at 42℃ for 5 min, and a relatively high rate of pollinated flower set seeds was obtained by subsequent hand pollination. We concluded that hot water treatment at 42℃ for 5 min was optimum, and we have since routinely used this method for emasculation of self-compatible buckwheat.

The yield of self-compatible lines in middle to late generation was inferior to that of an open-pollinated standard variety. Plant growth was generally weak and total top dry weight was considerably small. We supeculated that inbreeding depression occurred due to repeated selfings. The disadvantage of inbreeding depression was much bigger than the advantage of self-compatibility in pure line breeding.

We then developed an alternative breeding methodology based on the use of self-compatibility. This methodology involves inbred development of homostyle (S^hS^h) and pin (ss) lines by using the self-compatibility gene. Furthermore, single-cross hybrid seeds are produced using these inbred homostyle and pin lines as pollen and seed parents, respectively. This strategy successfully produced self-compatible homostyle hybrids (S^hs)

NARO Hokkaido Agricultural Research Center

; the percentage of hybrid plants among the progeny was more than 90 % . The seed yield of the progeny obtained in single-cross experiments was superior to that of an open-pollinated standard variety by 10% on average. These results suggest that heterosis breeding can be used to increase seed yield in common buckwheat.

The inheritance of a green flower trait and the relationship between the green flower trait and shedding resistance was investigated using self-compatibility. The segregation patterns suggested that the green flower trait was controlled by a single recessive gene and that the green flower locus was independent of the *S* locus. The breaking tensile strength of pedicels in green flower segregates was generally larger than that in white-flower segregates, suggesting that pleiotropy or strong linkage between green flower and strong pedicel existed. The green flower would be a simple morphological marker for seed shedding resistance.

2. Crossbreeding of Tartary buckwheat

At first, a simple emasculation method using hot water was developed to establish the cross-breeding system of Tartary buckwheat. Apical clusters of flower buds were soaked in a constant-temperature water bath in the afternoon, and the flowers that had opened the next morning were used for artificial pollination. The best performance was obtained with treatment at 44℃ for 3 min, in which the seed set of the hand-pollinated flowers was at an acceptable level. The hot water treatment at 44 ℃ for 3 min was available to other varieties and must be practically useful in crossbreeding of Tartary buckwheat. We have been routinely using this method in the crossing of Tartary buckwheat and carrying out the variety development as described below.

Rice-Tartary is a particular Tartary buckwheat variety cultivated and used as a rice replacement in limited areas of Nepal, Bhutan and southern China. It has a non-adhering hull having three lengthwise splits, though other Tartary buckwheat varieties have adhering hulls that are difficult to remove. Hybridizations between Tartary buckwheat and Rice-Tartary buckwheat were not difficult when using hot water emasculation. The segregation patterns suggested that the non-adhering hull trait was controlled by a single recessive gene and was independent of the trait of hull color. Almost no relation was observed between the non-adhering hull trait and extreme lateness, and we were able to develop early maturing Rice-Tartary buckwheat. Rice-Tartary buckwheat is a useful material for crossbreeding, and the non-adhering hull trait may promote grain use of Tartary buckwheat.

Rutin degradation in dehulled whole seeds, grits, and flour of rice-Tartary buckwheat was investigated. Rutin concentration in dehulled whole seeds remained stably high even when immersed in water, while 87.5% of the rutin in flour had degraded 10 min after the addition of water and approximately one-fourth of the rutin in grits degraded when immersed in water for 1 h. Crude infusion of dehulled whole seeds showed a high level of rutin-degrading activity, but degradation of rutin in intact embryos was not observed even when immersed in the infusion, suggesting that the act of crushing embryos is the trigger of rutin degradation. Rutin concentration in dehulled whole seeds decreased by 20% when boiled for 2 h in distilled water, indicating that rutin in dehulled whole seeds has a tolerance to heat. Consumption of dehulled whole seeds may contribute to effective intake of rutin.

Lodging resistance is an important target in Tartary buckwheat breeding. Inheritance of 7 semidwarf strains derived from the mutants by irradiating gamma rays or various ion beams was investigated. The populations of F_2 from crosses between IRBFT-6,20,45 (semidwarf-mutant lines) and their original varieties fitted a 3:1 ratio of wild type to semidwarf type, suggesting that the trait of semidwarf in IRBFT-6,20,45 was controlled by a nuclear single recessive gene. Judging from the plant type (wild versus semidwarf) in F_1 and F_2 of half diallel cross, it was estimated that IRBFT-6,20,45 had a common semidwarf gene (*sdA*) and IRBFT-38,63,67,77 had another semidwarf gene (*sdB*) .

Inheritance of dark red cotyledonal trait was investigated using a mutant variety of Tartary buckwheat. The segregation patterns suggested that the dark red cotyledonal trait in the mutant variety was controlled by a single recessive gene. The segregates having dark red cotyledons contained a much larger amount of keracyanin, a major anthocyanin found in the sprouts of Tartary buckwheat, than did those having green cotyledons. Progeny analysis of the cross between Rice-Tartary type and dark red cotyledonal variety suggested no linkages between the loci of non-adhering hulls and dark red cotyledons.

The results described above indicate that the positive use of heterosis and steady pyramiding of characters through cross-breeding will be important in future breeding of common and Tartary buckwheat, respectively.