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Review

Breeding of Buckwheat in Kyushu Okinawa Agricultural Research Center, NARO

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ABSTRACT

The Kyushu Okinawa Agricultural Research Center is one of the regional agricultural research and development centers of the National Agriculture and Food Research Organization (NARO) in Japan. The center aims to bring NARO's agricultural technologies to the forefront of agriculture.

BREDING BUCKWHEAT AT NARO

Buckwheat breeding is one of the important programs at the Kyushu Okinawa Agricultural Research Center, as it contributes to the stable production of high-yield and high-quality buckwheat (Fig. 1). In the Kyushu Okinawa Agricultural Research Center, NARO, buckwheat breeding have been conducted twice a year (spring and summer sowing) in test plots of approximately 2.5 hectares each and greenhouses (Fig. 2).

1) Breeding of common buckwheat

DC: Double cropping
SR: Shattering Resistance
PHS: preharvest sprouting resistance

Stable production, High Yield
① 'Kyushu 9' (DC, SR, PHS)
② 'Kyukei 50' (semidwarf, DC, SR, PHS)
High quality
③ 'low amylose'

2) Breeding of perennial buckwheat
④ Rutin and Reduction of bitterness
⑤ Perenniality and non-shattering trait
⑥ 3D plant modeling system

Figure 1. *Main breeding issue of buckwheat in Kyushu Okinawa Agricultural Research Center, NARO.*

In Japan, shattering and preharvest sprouting (Fig. 3) are significant factors that can decrease buckwheat production. Green flower had leaf like green parts in petals with stronger pedicels than normal buckwheats (Alexeeva et al. 1988). The green-flower lines had higher breaking tensile strengths. In Japan, we identified a green-flower mutant named 'W/SK86GF' (Fig. 4A) in 1999, which was from a progeny of hybridization between Kitawasesoba and Skorosperaya 86. Consequently, green-flower appears to be promising as breeding material for shatter resistant varieties. Morishita and Suzuki (2017) performed a large-scale practical test of the green-flower shattering-resistant breeding line by using a seeding machine and combine harvester. In late harvesting with the combine harvester, despite an increased 'head loss' in the green-flower line, the'threshing and sorting loss' the green-flower line decreased and the 'pre-harvest shatter

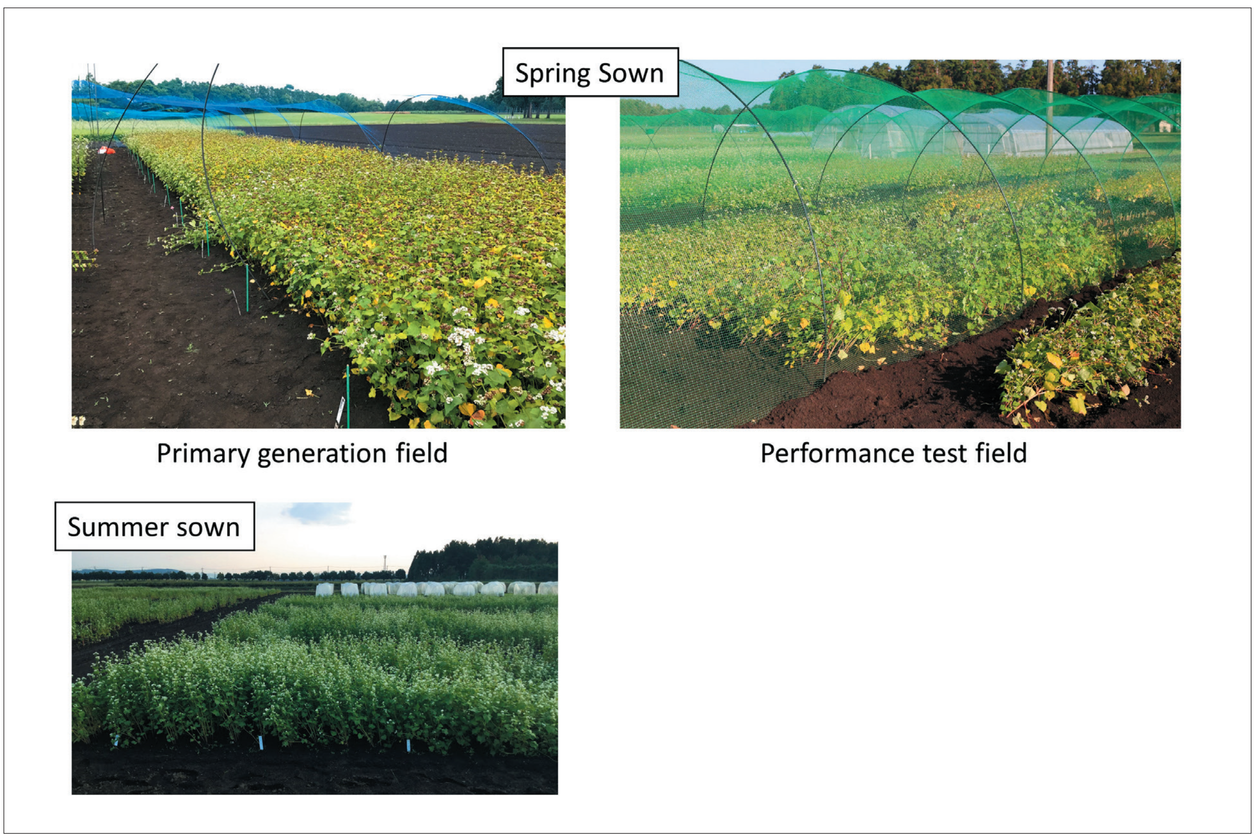

Figure 2. *Pictures of buckwheat breeding field.*
Bird netting is used for spring sowing due to the high bird damage. Summer sowing is not covered because it causes less bird damage.

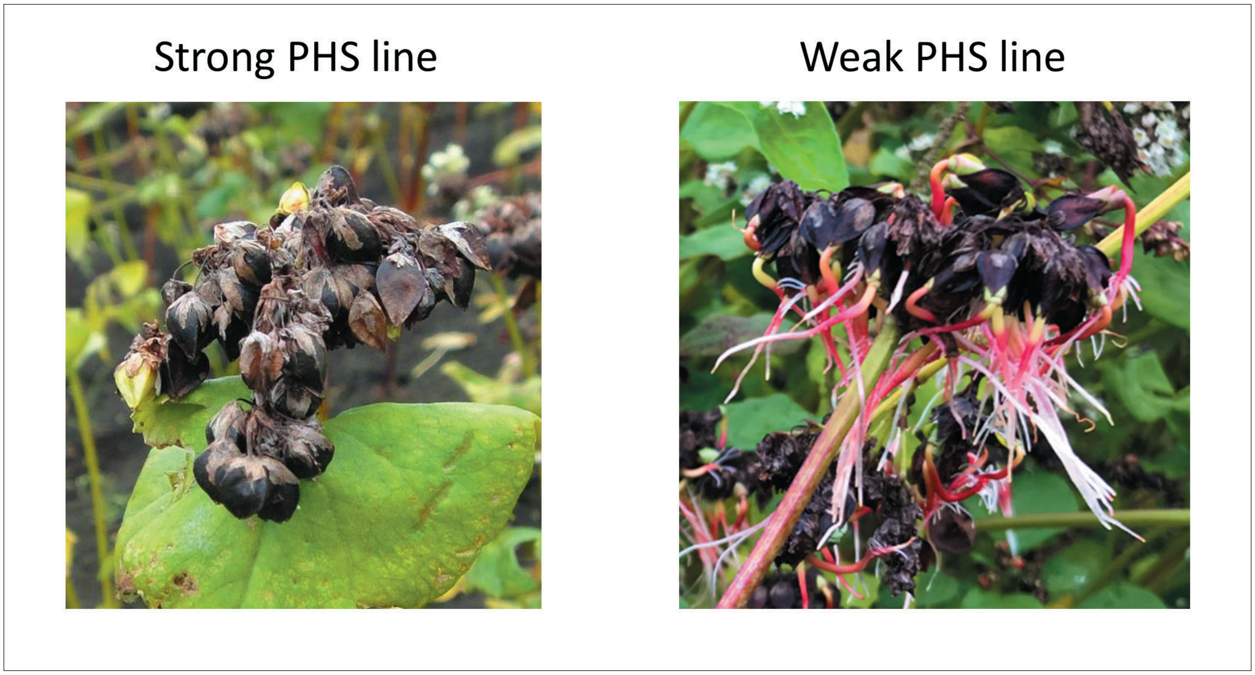

Figure 3. *Pictures of PHS in buckwheat.*
Pictures were taken in maturing time in spring sown field.

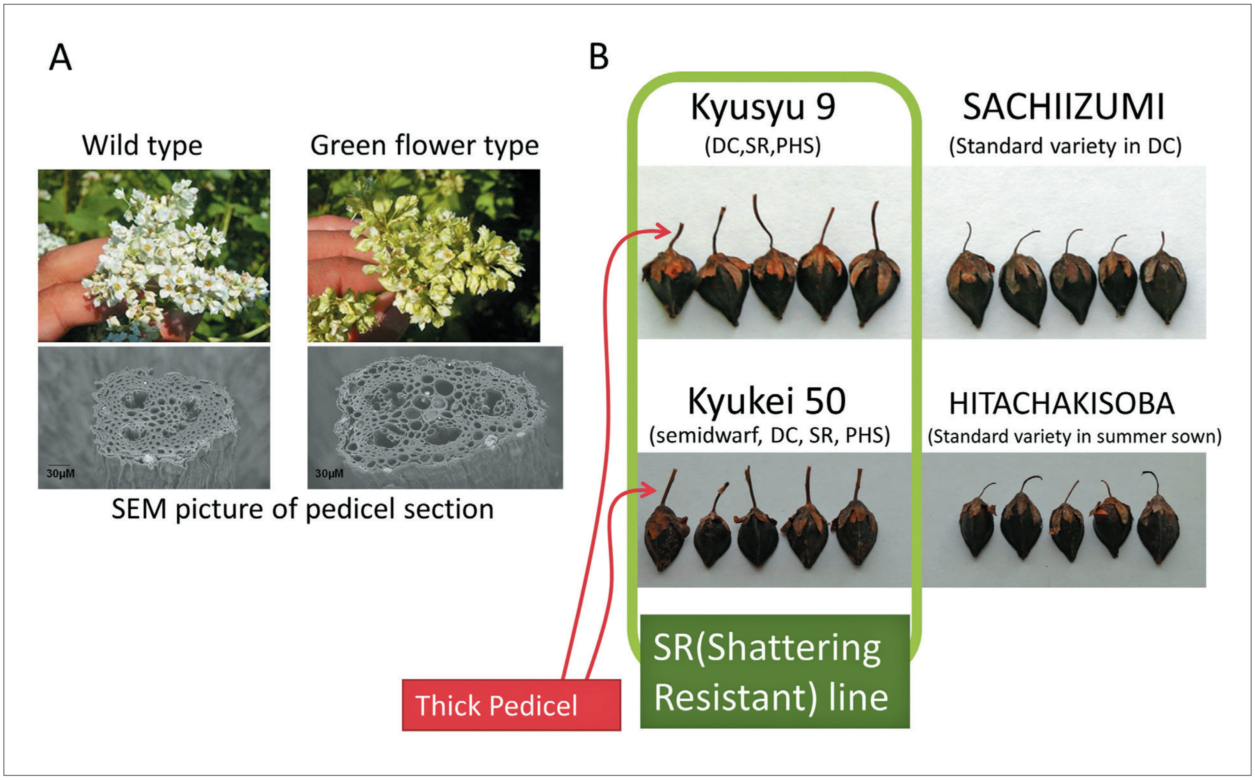

Figure 4. *Shattering resistant trait in buckwhaet.*
A: Pictures of flower and pedicel in greenflower type mutant and wild type. B: Pictures of pedicles in promissing breeding line and standard variety.

loss' of 'Kitawasesoba' increased dramatically, so the total loss ratio of the green-flower line was lower than that of 'Kitawasesoba'. Furthermore, the use of green-flower traits was effective for reducing yield loss under conditions when shattering occurs heavily, such as in rain, strong wind, and late to extremely late harvesting. These experiments indicated that it is necessary to reduce 'threshing and sorting loss' by adjustment of the operating conditions of the combine harvester and choosing a suitable harvest time with the combine harvester for practical use with shattering-resistant varieties.

Recently, we developed a promising breeding line named 'Kyushu 9', which exhibits resistance to both shattering and preharvest sprouting. The 'Kyushu 9' possesses the 'green flower type' shattering resistance trait, and as a result, it had a thick pedicel (Fig. 4B) with breaking tensile strength approximately two-fold stronger than that of 'HITACHIAKISOBA', a leading variety of summer-sown buckwheat in Japan (Table 1). The yield of 'Kyushu 9' was also higher than that of 'HITACHIAKISOBA'. Additionally, 'Kyushu 9' has a pre-harvest sprouting resistance class similar to that of 'KANOYAZAIRAI', which has the strongest resistance against pre-harvest sprouting. In addition, double cropping (Fig. 5) is essential to increase buckwheat production. However, in buckwheat production areas, contamination caused by shattered fallen seeds during harvesting is a serious problem. To address this issue, the use of the same variety in both spring and summer is necessary. To achieve this, the use of a variety with an appropriate ecotype, such as an intermediate-autumn type, is required. 'Kyushu 9' has a suitable ecotype for double cropping. Lodging is also an important factor that can reduce buckwheat production. Recently, we also developed 'Kyukei 50' which has a semi-dwarf trait with shattering resistance and practical pre-harvest sprouting resistance (Suzuki et al., 2023a).

Starch is the chief constituent of buckwheat groats, making up to 75% of their dry weight (D.W.). In general, the amylose content of buckwheat starch is 20–30%. The Key enzyme for amylose synthesis, GBSS-I, has partly characterized by Chrungoo et al., 2012. The varietal difference in amylose content of buckwheat starch is limited compared to that of major cereal starch, such as rice and wheat. In addition, there has been little research into developing buckwheat varieties with waxy-type starch (amylose-free) that would have sticky mechanical characteristics. Gregori and Kreft (2012) reported a low-amylose (3.8–16%) buckwheat mutant. However, the causative genes, starch properties, and physical properties of this food have not yet been characterized. To produce high-quality buckwheat, we identified a promising mutant that lacks the accumulation of granule-bound starch

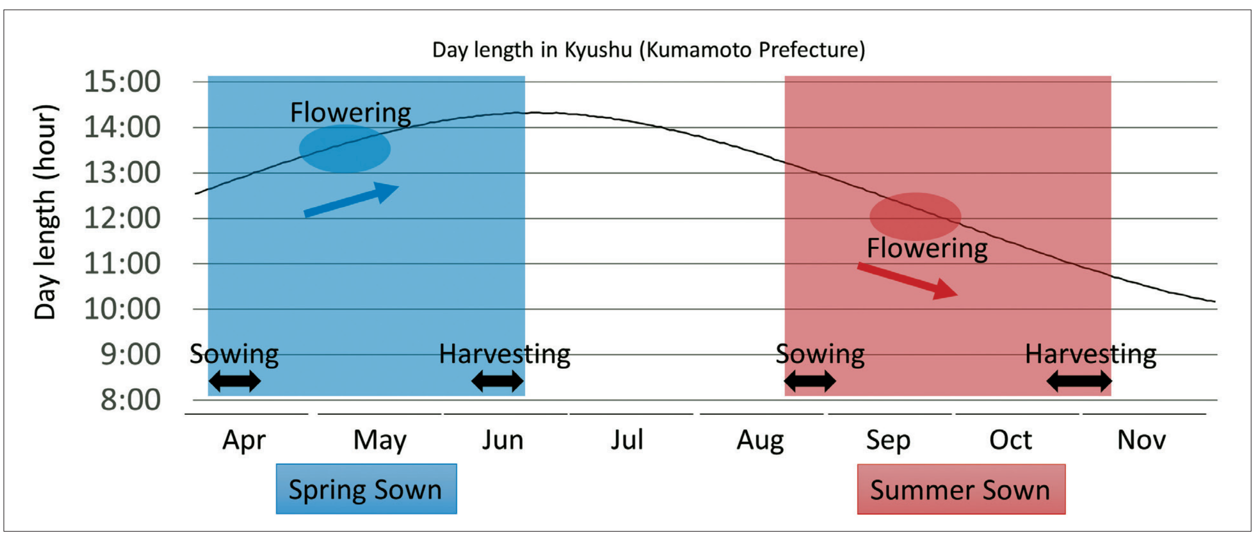

Figure 5. *Typical double cropping in buckwheat in Kyushu island.*
Spring and summer sowings have significant differences in day length. Therefore, it is important to use varieties suitable for each sowing time (different varieties) in order to achieve the maximum annual yield.
However, due to limited field area in Japan, using different varieties would pose a contamination problem of seed shattering and pollen cross-pollination. As a result, it is necessary to use the same variety for both spring and summer sowings.

Figure 6. *Picture of a breeding Field for Perennial Buckwheat.*
A: Picture of a breeding Field for Perennial Buckwheat in 2022 summer.
B: Picture of inter-specific hybrids sprouting and growing from last year's plant roots after soil freezing.

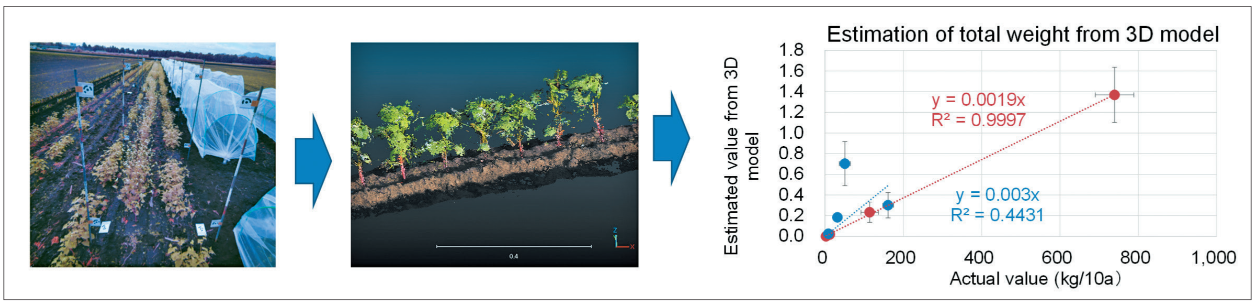

Figure 7. *3D plant modeling system. Breaf scheme to make 3D plant modeling and estimation of total weight.*

synthase a GBSSa mutant (Suzuki et al., 2021, 2023b). This mutant line has a low amylose concentration compared to the wild type line. The noodles made from the GBSSa mutant were soft and sticky compared to those made from the wild type. Furthermore, the soft texture of the noodle was retained even when stored in chilled conditions.

To develop a practical breeding line of perennial buckwheat, we crossed Tartary buckwheat (*F. tataricum*) and perennial buckwheat (*F. cymosum*) and performed selection suitable for the climate of Japan. We identified the key enzyme that generate strong bitterness in its food (Suzuki et al., 2023c). We have identified some promising breeding lines that exhibit a non-shattering trait with pereniallity (Fig. 6). Additionally, we have developed an 3D plant modeling system (Kochi et al., 2021) for buckwheat that operates using images and can measure plants non-destructively without physical contact (Fig. 7). This system is particularly useful for estimating parameters such as total weight during plant growth for individual plants or colonies of plants, especially for perennial buckwheat. It allows for continuous tracking of the same individual plant or plant colony throughout its growth period without the need for any destructive measures.

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REFERENCES

Alekseeva, E.S., Malikov, V. G., & Falendysh, L.G. (1988). Green flower form of buckwheat. Fagopyrum 8, 79-82.

Chrungoo, N.K., Devadasan, N., Kreft I., & Gregori, M. (2012). Identification and characterization of granule bound starch synthase (GBSS-I) from common buckwheat (*Fagopyrum esculentum* Moench). Journal of Plant Biochemistry and Biotechnology, 22, 269-276.

Table 1. *Result of performance test in 2022.*

	Variety name↓		sowing time	growth period	Plant height	lodeging degree	PHS *1	Green flower trait	breaking tensile Strength	Total weight	Yield	Yield rel.	DC Yiled sprintg +August	DC Yiled rel.	1000 seeds weight
				day	cm	0 : none ~ 4 :	%		g	kg/ 10a	kg/ 10a	%	kg/ 10a	%	g
Spring sown	NARO-FE-1	Spring sown standard var.	4/6	60	89	0	26	–	39. 4	494	206	100			33. 1
	HITACHAKISOBA	Summer sown standard var.	4/6	71	129	0	26	–	44. 4	696	120	58			39. 2
	Kyushu No. 9		4/6	65	104	0	1	○	103. 5	806	196	95			35. 8
Summer sown	NARO-FE-1	Spring sown standard var.	8/23	59	54	2. 3	68	–	41. 7	279	123	100	329	100	27. 6
	HITACHAKISOBA	Summer sown standard var.	8/23	68	82	4. 0	79	–	66. 0	643	212	172	332	101	36. 1
	Kyushu No. 9		8/23	68	61	2. 3	21	○	109. 6	406	217	176	413	125	31. 6

Strong PHS
(The smaller the number, the more PHS.)

Strong SR
(The higher the number, the more SR.)

High DC yield

These results are based on conditions where there was no crop lodging or encounters with typhoons during the harvest season. Therefore, it is belived that the effects of PHS and SR would be more pronounced in the presence of these adverse conditions.

Gregori, M., & Kreft, I. (2012). Breakable starch granules in a low amylose buckwheat (*Fagopyrum esculentum* Moench) mutant. Journal of Food, Agriculture and Environment, 10, 258–262.

Kochi, N., Hayashi, H., Shinohara, Y., Tanabata, T., Kodama, K. & Isobe, S. (2021). All-around 3D plant modeling system using multiple images and its composition. Breeding Science, 72(1): 75-84. DOI 10.1270/jsbbs.21068

Morishita, T. & Suzuki, T. (2017). The Evaluation of Harvest Loss Occurring in the Ripening Period Using a Combine Harvester in a Shattering-Resistant Line of Common Buckwheat. Jpn. J. Crop Sci. 86. 62-69.

Suzuki, T., Ishiguro, K., Noda, T., Otsuka, S., Hara, T., Morishita, T., Matsui, K., Takeshima. R., Hara, T, Aoki, N., Satoh, R., Aii, J, Nakano, A. & Ohsawa, R. (2021). Patent application number, 2021-143245, Japan.

Suzuki, T., Tsujimoto, K., Maruo, G., Hara, T., Katsu, K., Matsuura, A., Morishita, T., Hara, T., Ishiguro, K., & Shiori Otsuka (2023a). Development of semidwarf breeding line with shattering resistance and preharvest-sprouting resistant in buckwheat (*Fagopyrum esculentum*). Plant Breeding. https://doi.org/10.1111/pbr.13101

Suzuki, T., Noda, T., Morishita, T., Ishiguro, K., Otsuka, S., Aii, J, Nakano, A., Katsu, K., Matsui, K., Takeshima. R., Aoki, N., Hara, T., Hara, T & Satoh, R. (2023b). Characterisation of starch properties and physical characteristics in buckwheat (*Fagopyrum esculentum* Moench.) mutant lacking accumulation of 'granule - bound starch synthase a'. Plant Breeding. https://doi.org/10.1111/pbr.13135

Suzuki, T., Kurokoh, R., Murakami, S., Takahashi, N., Matsuura, A., Katsu, K. & Murata, K. (2023c). Rutin Concentration and Characterization of Rutinosidase in Perennial Buckwheat (*Fagopyrum cymosum*) and Its Application in Foods, Foods,12 (7): 1417-1427. DOI 10.3390/foods12071417

IZVLEČEK

Raziskovalna ustanova The Kyushu Okinawa Agricultural Research Center je eno od znanstvenih in razvojnih središč pri Agriculture and Food Research Organization (NARO) na Japonskem. Namen te ustanove je pospeševati razvoj in uporabo tehnologij NARO v kmetijstvu.