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Production, uses and cultivars of common buckwheat in Japan: An overview

Seisuke MOTONISHI[1], Sakio TSUTSUI[1], Tetsuo MIKAMI[1]*

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ABSTRACT

Common buckwheat (*Fagopyrum esculentum* Moench) has attracted much attention due to its high nutritional value and medicinal properties. The crop has a long history of cultivation in Japan, and today, it is used mostly for manufacturing soba noodles which are quite popular in Japanese cuisine. Cultivation of common buckwheat in the country decreased gradually until the 1970's, but has started to increase again in recent years. In this paper, we provide an overview of common buckwheat production in Japan with emphasis on the agronomic characteristics of representative Japanese cultivars and landraces.

Key words: agronomic characteristics; breeding; common buckwheat; cultivar; genetic diversity; landrace; soba noodles

IZVLEČEK

PRIDELAVA, UPORABA IN SORTE NAVADNE AJDE NA JAPONSKEM: PREGLED

Navadna ajda (*Fagopyrum esculentum* Moench) je pritegnila veliko pozornosti zaradi svoje velike hranilne vrednosti in zdravilnih lastnosti. Poljščina ima dolgo zgodovino gojenja na Japonskem in se danes največ uporablja za izdelavo "soba" rezancev, ki so zelo popularni v japonski kuhinji. Gojenje navadne ajde je v državi postopoma upadalo do sedemdesetih let prejšnjega stoletja, a je začelo v zadnjih letih spet naraščati. V prispevku je podan pregled pridelave navadne ajde na Japonskem s poudarkom na agronomskih lastnostih reprezentativnih japonskih sort in lokalnih zvrsti.

Ključne besede: navadna ajda; agronomske lastnosti; žlahtnenje; sorta; genetska raznolikost; lokalne zvrsti; soba rezanci

1 INTRODUCTION

Common buckwheat (*Fagopyrum esculentum* Moench), a member of the Polygonaceae family, has been widely grown for human consumption in Japan (Mazza, 1988; Ohnishi, 1988; Kishima et al., 1995; Murai & Ohnishi, 1996). The crop is not a cereal, but its fruits are expediently classified among the cereal grains because of their similar usage. In fact, buckwheat flour is commonly employed in combination with wheat flour to prepare buckwheat noodles (soba noodles), a popular Japanese dish.

The history of buckwheat cultivation goes back to very ancient times in Asia (Murai & Ohnishi, 1996; Jacquemart et al., 2012). It is now broadly accepted that common buckwheat was initially domesticated in the northwest part of the Yunnan province in China (Murai & Ohnishi, 1996). This crop subsequently spread to Asian countries through two main routes (Murai & Ohnishi, 1996). The first route crossed the Himalayan region and Tibet, and the second ended up in Japan through Northern China. Available evidence suggests that common buckwheat was introduced into Japan via the Korean peninsula from China (Nagatomo, 1984; Ohnishi, 1995; Murai & Ohnishi, 1996). The crop became popular primarily due to its ability to grow well on marginal, infertile land as well as its rapid growth habit. When buckwheat first appeared in records in Japan in the 8th century, it had already been cultivated extensively as a catch crop (Shinoda, 1978; Murai & Ohnishi, 1996).

Although numerous local buckwheat landraces were grown in Japan at one time, common buckwheat culture in this country is currently dominated by only a small number of cultivars (http://www.tokusanshubyo.or.jp/jouhoushi/tokusanshubyo-26.pdf). In this paper, we review literature to provide an overview of common buckwheat production

[1] Hokkaido Agricultural Laboratory for Business Development, Eniwa, 061-1405, Japan *Corresponding author: tm-mars@fgbb.jp

in Japan. Emphasis is placed on the agronomic characteristics of main Japanese cultivars and landraces. The expectation is that the synthesized information from this review will be useful for researchers and other stakeholders interested in the common buckwheat crop in Japan.

2 COMMERCIAL PRODUCTION

According to FAO statistics, the world buckwheat production in 2016 was approximately 2,396,000 metric tonnes (FAO, 2017). Russia and China were the largest producers, collectively accounting for ca. 65 % of global production that year. Japan ranked tenth in total buckwheat production (FAO, 2017).

In Japan, buckwheat production reached a maximum (139,000 tonnes from 165,000 hectares) in 1907 (Suzuki, 2003). Thereafter, it continuously declined until the 1970’s (e.g., 18,000 tonnes from 18,000 hectares in 1975), because a number of farmers shifted their acreage from lower-yielding buckwheat to higher-yielding crops such as rice (Suzuki, 2003). In recent years, however, buckwheat acreage and yield have started to increase again. As shown in Table 1, average production per year, from 2012 to 2016 inclusive, was ca. 34,500 tonnes (MAFF, 2017). This recovery tendency is undoubtedly due to the Japanese government subsidies to farmers who grow buckwheat, with the aim of decreasing the amount of excessively produced rice. It should also be added that Japan imports 65-75 % of its domestic demand, mostly from China and the United States (MAFF, 2017).

Table 1: Production and cultivation area of buckwheat in Japan. Source: MAFF. (2017)

	2012	2013	2014	2015	2016
Cultivation area (ha)	61,000	61,400	59,900	58,200	60,600
Total harvest (t)	44,600	33,400	31,100	34,800	28,500

3 USES

Although the small leaves and shoots are also edible, common buckwheat fruits, generally considered as seeds are by far the most important for Japanese consumers. Harvested seeds are dehulled after drying, and the remaining part, called groats, is ground into flour. As mentioned above, buckwheat flour has traditionally been used in the preparation of soba noodles. The noodles play a major role in Japanese cuisine and are easily available in dried form in supermarkets throughout the country. Soba noodle dishes are served either cold with dipping sauce, or in hot broth as noodle soup.

Common buckwheat is also processed to various value-added products such as cakes, tea, beer and other local alcoholic beverages. The crop produces good quality of honey, whereas several buckwheat extracts are utilized for pharmacological and dietetics purposes (Bavec et al., 2002; Jacquemart et al., 2012; Kreft et al., 2016). In particular, flavonoids (mainly rutin and quercetin), D-chiro-inositol and proteins derived from buckwheat are in increasing demand, due to their biological and physiological activities including anti-oxidant, anti-inflammation and anti-hypertension properties (Jacquemart et al., 2012; Suzuki et al., 2012a; Giménez-Bastida & Zieliński, 2015; Kreft et al., 2016).

4 JAPANESE CULTIVARS

Common buckwheat exhibits a floral dimorphism known as distyly: each individual plant in a given cultivated population bears either pin (long pistil and short stamens) or thrum (short pistil and long stamens) flowers (Campbell, 1997; Woo et al., 2010). Both flower morphs are self-incompatible, and interfertile. Seed production thus depends upon insects and wind that mediate cross-pollination between pin and thrum plants. Owing to obligatory outcrossing characteristics, each cultivated population is expected to maintain a large amount of plant-to-plant variation. Almost all of the Japanese common buckwheat cultivars released to date have been developed from selection within locally grown landraces, and are not the products of controlled crosses.

Japanese common buckwheat cultivars are generally classified into three agroecotypes: summer, autumn (late-summer), and intermediate types (Matano & Ujihara, 1979; Namai, 1990; Hara et al., 2011; Hara &

Ohsawa, 2013). Summer-type cultivars are mainly grown in high-latitude regions, and seem non-sensitive to photoperiod. Autumn-type cultivars are grown in low-latitude regions and behave as facultative short-day plants. Intermediate-type cultivars show moderate photoperiodic sensitivity. The agroecotype and principal characteristics of representative Japanese buckwheat cultivars are presented in Table 2.

The important problem in common buckwheat cultivation is low and unstable yield. Breeding efforts have been made to improve seed yields. Most of the Japanese cultivars listed in Table 2 are actually larger-seeded genotypes (a grain mass of 32-38 g/1,000 seeds, http://www.maff.go.jp/tohoku/seisan/soba/pdf/25soba_manual.) with better grain yields. Additionally, common buckwheat reaches lower plant height and has been considered as more resistant to lodging. The cultivar 'Kitawasesoba' is an example of such a plant habit (Inuyama et al., 1994, see Table 2). In this crop, indeterminate seed setting and remarkable seed shattering make it difficult to determine the appropriate time for harvesting. It goes without saying that seed shattering causes serious yield losses. To overcome the problems there has been increasing emphasis upon the improvement of seed shattering and uniformity in ripening among seeds (Funatsuki et al., 2000; Matsui et al., 2003, 2004; Suzuki et al., 2012b).

Table 2: List of representative common buckwheat cultivars grown in Japan

Cultivar (Agroecotype)	Parentage and agronomic characteristics
Kitawasesoba (Summer)	Selected from a landrace 'Botansoba' and released in 1989. High-yielding and early maturing cultivar with lodging resistance and good market acceptability.
Hashikamiwase (Intermediate)	Selected from a locally grown buckwheat population and released in 1933. Large-seeded, nice flavor when cooked, but easy seed-shattering at maturity.
Dewakaori (Intermediate)	Developed in 1995 using a locally grown landrace 'Mogamiwase' for increased grain mass and improved taste. Moderately resistant to lodging.
Hitachi-akisoba (Intermediate)	Produced in 1985 using a local landrace as breeding material. Large-seeded and high-yielding cultivar with good taste.
Shinano No.1 (Intermediate)	Selected from a locally grown landrace and released in 1944. High-yielding genotype with good taste, but having the problem with lodging.
Oonozairai (Autumn)	High-yielding landrace having desirable flavor and sweetness upon cooking, and good market acceptability.
Miyazakiootsubu (Autumn)	Tetraploid cultivar bred using a locally grown landrace and released in 1982, having increased lodging resistance, but the problem with late maturity.

5 LANDRACE 'BOTANSOBA'

Over the past two to three decades, Japanese buckwheat landraces have been replaced with improved cultivars that give better groats yields and are more or less genetically uniform (Campbell, 1997, 2003; Woo et al., 2010). Nevertheless, it is quite interesting to observe that a small number of landraces are still being cultivated to a limited extent. The landrace 'Botansoba' is a case in point (Figure 1). 'Botansoba' was selected by the National Agricultural Research Center for Hokkaido Region, Japan from a heterogeneous population grown in Date town (latitude: 42º28´N, longitude: 140º51´E) in Hokkaido, and released for cultivation in 1930 (Campbell, 2003). This landrace exhibited the high adaptability to local agroclimatic conditions in northern Japan, and was the most cultivated in the Hokkaido district until the release of an advanced cultivar 'Kitawasesoba (see Table 2)' in 1989 (Inuyama et al., 1994; Campbell, 1997).

'Botansoba' has problems such as higher plant height, and low and unstable yield (as seen in Table 3, 'Botansoba' had apparently higher plant height and lower grain yields than 'Kitawasesoba'), but has high market acceptability; soba noodles made from 'Botansoba' flour actually gain a good reputation for their delicate, appetizing flavor as well as for their characteristic sweetness. The content of rutin in the groats of 'Botansoba' was found to range from 15.5 to 18.6 mg 100 g^{-1} (S. Motonishi, unpublished), comparable to that of Japanese common buckwheat cultivars such as 'Kitawasesoba' and 'Shinano No.1' (Kitabayashi et al., 1995).

The seeds of 'Botansoba' have been multiplied not by seed certifying agencies but by farmers for a long time. It is thus reasonable to assume that the farmers in question have not always used the seed-parent plant population large enough to represent a true sampling of the genetic variation present in the source population of

'Botansoba'. If the landrace has experienced the genetic bottleneck because of a too small population size, the genetic variation contained in the source population is perhaps fragmented and distributed over the several germplasm resources holdings today. This surmise was supported by morphological characterization of 'Botansoba' stocks preserved in four different seed sources: Breeder's stock, NCSS stock, Urausu-town stock and S-town stock (Honda et al., 2004). As shown in Table 3, S-town stock (source #4) obviously differed from Breeder's stock (source #1) in terms of plant height and days to maturity, whereas no apparent differences were observed among NCSS stock (source #2), Urausu-town stock (source #3) and Breeder's stock for these two characteristics. Moreover, the grain yield of S-town stock was revealed to be higher than that of Breeder's stock. Meanwhile, we cannot rule out the possibility that such differences may be attributable to inter-varietal cross pollination (Adhikari & Campbell, 1998). In order to preserve the purity of genetic resources such as 'Botansoba', the seeds need to be multiplied using effective population size of seed-parent plants, under a suitable isolation procedure (Adhikari & Campbell, 1998).

Figure 2: Landrace 'Botansoba'. Flowering on a farm (left panel) and inflorescence (right panel)

Table 3: Agronomic characteristics of landrace 'Botansoba' preserved in four different seed sources and an advanced cultivar 'Kitawasesoba'. Source: Y. Honda et al. (2004)

Genotype	Days to maturity	Plant height (cm)	Number of branches	Grain yields kg a^{-1}	1,000-seed mass (g)
Botansoba					
Seed source #1: Breeder's stock*	100	142	2.7	11.1	27.0
Seed source #2: NCSS**	100	146	3.0	9.5	27.2
Seed source #3: Urausu town	100	144	3.1	11.7	25.8
Seed source #4: S town	107	161	3.0	13.8	25.7
Kitawasesoba					
Seed source: NARO***	90	123	2.3	15.5	28.3

The study was carried out in 2004 at the experimental field located in Memuro town (latitude: 42º53´N, longitude: 143º03´E), Hokkaido. Seeds were sown on 3 June.
* Hokkaido Prefectural Plant Genetic Resources Center, Japan
** National Center for Seeds and Seedlings, Japan
*** National Agriculture and Food Research Organization, Hokkaido Agricultural Research Center, Japan

6 CONCLUDING REMARKS

In conclusion, two additional points merit comment. First, Tartary buckwheat (*Fagopyrum tatacicum* (L.) Gaertn.), a close relative of common buckwheat, is also cultivated in many areas of the world (Campbell, 1997; Senthilkumaran et al., 2008; Li et al., 2012). This crop, comparing to common buckwheat, is less widespread because of its bitter taste; in Japan, Tartary buckwheat was harvested from only 95 hectares with a total yield of 114 tonnes in 2015 (http://www.tokusanshubyo.or.jp/jouhoushi/tokusanshubyo-26.pdf). However, increased interest has been shown for human consumption of Tartary buckwheat due to some of its components that are very beneficial to human health. For instance, recent evidence indicates that the seed rutin content is approximately 100 times higher in Tartary buckwheat than in common buckwheat (Ikeda et al., 2012; Suzuki et al., 2014). Attempts have been made to improve Tartary buckwheat in Japan, resulting in the development of a promising Tartary buckwheat cultivar ‘Manten-Kirari’, whose flour is rutin-rich and lacks bitterness (Suzuki et al., 2014).

Secondly, buckwheat breeding is a recent endeavor when compared with breeding efforts devoted to major cereals. The use of molecular markers that are tightly linked to commercially important traits is now a widely accepted approach to help expedite the development of improved cultivars (Woo et al., 2010). In common buckwheat, studies have been performed to develop such markers as amplified fragment length polymorphism (AFLP) markers (Yasui et al., 2004), simple sequence repeat (SSR) markers (Konishi & Ohnishi, 2006), expressed sequence tag (EST) markers (Hara et al., 2011), and array-based markers (Yabe et al., 2014). As far as we know, however, the marker-assisted selection approach of the buckwheat crop is still in its infancy. Most recently, Yasui et al. (2016) have generated a draft assembly of the buckwheat genome using next-generation sequencing technology. They have also identified novel candidate genes involved in dimorphic self-incompatibility of the crop. Provided that the substantial buckwheat genome data-base is constructed, genomics-assisted approach will accelerate the genetic improvement of buckwheat.

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