doi:10.14720/aas.2025.121.2.19925 Review article / pregledni znanstveni članek

Brassica oilseed crops in Japan: cultivation, consumption, and cultivars

Shinya NAKUI [1], Tetsuo MIKAMI [2, 3]

Received October 08, 2024; accepted April 18, 2025
Delo je prispelo 8. oktober 2024, sprejeto 18. april 2025

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Abstract: *Brassica* oilseed crops are the third most important source of edible vegetative oils in the world. Among these crops, the cultivation history of *B. rapa* goes back to very ancient times in Japan. Its cultivation area expanded substantially in the 17th century and *Brassica* oil was used as fuel for lamps and cooking oil. *Brassica napus* L. ssp. *napus* was introduced into Japan mainly as an oil crop in the late 19th century, after which it gradually replaced the heirloom *B. rapa* L. ssp. *oleifera* (DC.) Metzg. cultivars used in the production of edible oil. The rapeseed (*B. rapa* and *B. napus*) cultivation area in Japan reached its peak in the 1950s and then decreased rapidly due to increase of imports of inexpensive oilseed crops. In recent years, however, domestic cultivation of *B. napus* has started to increase again. Japanese people consume rapeseed oil well and consider it to be a healthy oil with low levels of saturated fatty acids. This article aims to provide the information about the history, current state, problems, and prospects of rapeseed cultivation in Japan. The paper also describes an overview of agronomic characteristics of representative Japanese cultivars as well as cultural practices.

Key words: *Brassica napus*; *Brassica rapa*; breeding; cultivation history; cultural practices; vegetative oil

Oljarice iz rodu *Brassica* **na Japonskem: gojenje, uporaba in sorte**

Izvleček: Oljarice iz rodu *Brassica* so tretji najpomembnejši vir jedilnega rastlinskega olja v svetovnem merilu. Med njimi se je gojenje oljne repice (*B. rapa*) na Japponskem pričelo že v pradavnini. Površine njenega gojenja so se močno povečale v 17. stoletju, ko se je njeno olje uporabljalo kot gorivo za svetiljke in kuhanje. Oljna ogrščica (*Brassica napus* L. ssp. *napus*) je bila uvedena na Japonsko pretežno kot oljarica v poznem 19. stoletju in je nadomestila sorte oljne repice (*B. rapa* L.ssp. *oleifera* (DC.) Metzg.), ki so se uporabljale za pridelavo jedilnega olja. Površina gojenja obeh vrst je na Japonskem dosegla višek v petdesetih letih prejšnega stoletja in potem hitro upadla zaradi povečanega uvoza poceni jedilnega olja iz teh vrst. V zadnjih letih se domača pridelava oljne ogrščice spet povečuje, ker ga prebivalstvo rado uporablja kot zdravo jedilno olje z majhno vsebnostjo nasičenih maščobnih kislin. Namen članka je podati informacije o zgodovini, sedanjem stanju, problemih in bodočem gojenju oljne ogrščice na Japonskem. Članek daje tudi pregled agronomskih lastnosti japonskih sort kot tudi o načinih gojenja.

Ključne besede: *Brassica napus, Brassica rapa,* žlahtnjenje, zgodovina gojenja, tehnike gojenja, rastlinsko olje

1 LLC OMEGA Farmers, Butoku-cho, Shibetsu, 095-0062, Japan
2 HAL GREEN Co., Ltd., 193-6 Toiso, Eniwa, 061-1405, Japan
3 Corresponding author, e-mail: tm-mars@fgbb.jp

1 INTRODUCTION

Brassica crop species are of particular importance in agricultural production within the Brassicaceae family and have undergone extensive domestication (Gulden et al., 2008; OECD, 2016; McAlvay et al., 2021). Among these, *B. napus* L. ssp. *napus* (oilseed rape), *B. rapa* L. (syn. *B. campestris* L., turnip rape), *B. juncea* (L.) Czern. et Coss. (Indian mustard), and *B. carinata* Braun (Ethiopian mustard) form the oilseed group, and in Japan, rapeseed chiefly refers to *B. napus* and *B. rapa* (MRC Institute for Environment & Health, 1997; Zając et al., 2016; Kawasaki et al., 2022). As a side note, *B. juncea* is grown as an oilseed crop mainly in India as well as in some regions of China, and the cultivation of *B. carinata* is basically limited to Northeast Africa (Zając et al., 2016). In this paper, "rapeseed" is used to collectively designate *B. napus* and *B. rapa*.

Brassica rapa was one of the first *Brassica* species to be domesticated (Guo et al., 2014). Mizushima and Tsunoda (1969) hypothesized that *B. rapa* originated in cold uplands near Turkey from where it migrated into the flatlands of Europe and Siberia. However, the exact center of origin of *B. rapa* has been debated; proposed centers of origin include Europe (Zhao et al., 2005), Central Asia (Ignatov et al., 2008; Qi et al., 2017), and East Asia (Song et al., 1988; Zhao et al., 2005). *Brassica napus* (2n = 38) is an amphidiploid with an AACC genome, and evolved through the spontaneous hybridization between *B. rapa* L. (2n = 20) with an AA genome and *B. oleracea* L. (cabbage/kale; 2n = 18) with a CC genome (OECD, 2016; Quezada-Martinez et al., 2021). It seems likely that the southwest European Mediterranean region, where the wild forms of the two parental species exist, is one of the places where this hybridization event occurred (Prakash and Hinata, 1980; Rahman, 2013).

Rapeseed oil, which is low in saturated fatty acids (e.g., less than 4 % palmitic acid), with relatively high levels of oleic acid (55-68 %) and linolenic acid (7-10 %), is thought to offer health benefits (MRC Institute for Environment & Health, 1997; Fujimura-Ito et al., 2011; Huang et al., 2015). Linolenic acid has valuable nutritional functions in humans (Nakui and Mikami, 2024), and oleic acid provides thermal stability, making rapeseed oil desirable for cooking oil. High oleic-acid oil also tastes better (Cartea et al., 2019). Nevertheless, *Brassica* seeds generally contain more than 40 % erucic acid in oil, and more than 100 µmoles of glucosinolates per gram of the oil-free meal (Rahman, 2013). Oil with high erucic acid content has anti-nutritional properties and is considered unsuitable as a source of food for humans (Rahman, 2013; Cartea et al., 2019). Additionally, glucosinolates are considered nutritionally undesirable since the presence of glucosinolates limits the use of this protein-rich meal in animal feed (Rahman, 2013). Intensive breeding efforts have been made to develop elite cultivars with low erucic acid, low glucosinolate content, and increased yields. The resulting improved crop is called "double-low" rapeseed or "canola" and has become one of the most important oilseed crops in the world (Quezada-Martinez et al., 2021). Recently, rapeseed oil has drawn Japanese consumers' attention because of its healthful properties (Japan Oilseed Processors Association, 2024). Among vegetable oils, the food-use consumption of rapeseed oil is the highest in Japan, followed by palm oil and soybean oil (Yagi et al., 2023).

In the present article, we review literature to provide an up-to-date summary in relation to the history, current state, problems, and perspectives of rapeseed cultivation in Japan. The paper also focuses on the agronomic characteristics of representative Japanese cultivars and cultural practices.

2 HISTORY OF RAPESEED CULTIVATION IN JAPAN

2.1 *Brassica rapa* L.

Brassica rapa exists in various forms such as oilseed, leafy (e.g., Chinese cabbage, mizuna) and root (e.g., turnip) type vegetables, and feed for livestock (e.g., fodder turnip) (Guo et al., 2014). The history of *B. rapa* cultivation goes back to very ancient times in Japan (Nishizawa et al., 2010). The initial use of the *B. rapa* crops introduced into Japan seems to have been as leafy vegetables rather than as an oilseed crop (Nishizawa et al., 2010). It remains unclear as to when oil production from *B. rapa* seeds began in Japan, but *Brassica* oil is believed to have been already utilized as lamp fuel in the end of the 16^{th} century (Japan Oilseed Processors Association, 2015; Tokyo Oil Inquiry House Market, 2016). In those days, the oil market was monopolized by a group of merchants and the oil extracted from oil perilla (*Perilla frutescens* (L.) Britt. var. *frutescens*) was the major source of lamp fuel in the country (Japan Oilseed Processors Association, 2015; Nakui and Mikami, 2023). Perilla seed oil was also widely used as drying oil for waterproofing paper umbrellas, polishing or coating wood, and in the manufacture of lacquer wares (Nitta et al., 2003; Yamanaka Aburaten, 2023).

After the 17^{th} century, rapeseed was recognized to have high economic value; *B. rapa* seeds were crushed more readily for oil in comparison with oil perilla seeds, and the light produced by burning rapeseed oil was brighter than that of perilla oil (Yamanaka Aburaten, 2023). Rapeseed oil production was officially encouraged and the cultivation areas of *B. rapa* then expanded substantially (Tokyo Oil Inquiry House Market, 2016). We would like to add that *B. rapa* was also grown for cooking oil alongside sesame, as western-influenced fried foods including tempura (deep-fried fish and vegetables) and hiryouzu (deep-fried tofu fritter) became popular from the 17th to the 19th centuries (Ohashi, 2007).

2.2 *Brassica napus* L. ssp. *napus*

Unlike *B. rapa*, the cultivation of *B. napus* in Japan is fairly recent, with a European cultivar being first introduced into the southwestern area of the country in 1878 (Nishizawa et al., 2010; Kawasaki et al., 2022). This cultivar was known as the name of 'Daichosen' and was characterized by late maturity and high plant height. Afterwards, 'Hamburg' was introduced from Germany into the northernmost island, Hokkaido in 1886 (Nishizawa et al., 2010).

'Hamburg' was a very late maturing cultivar that was well adapted to a cold climate (Nishizawa et al., 2010). At the beginning of the 20th century, two *Brassica* oilseed crops, viz., *B. napus* and heirloom *B. rapa* were cultivated throughout the country, but the acreage of *B. napus* cultivars gradually increased because these cultivars exhibited higher seed and oil yield as well as resistance to a major disease, *Sclerotinia* stem rot (Shiga, 1970). In a 5-year average from 1926 to 1930, rapeseed (*B. napus* and *B. rapa*) was harvested from ca. 72,000 ha with a total yield of ca. 73,000 metric tons annually in Japan (Fig. 1).

Planned rapeseed improvement by Japanese public research institutions commenced in the 1930s (Chen et al., 2017). The methods of breeding rapeseed were actually pure line selection and interspecific hybridization. The interspecific crossing was aimed at introducing early maturity from *B. rapa* into *B. napus* cultivars. Public breeding program also included the introgression of moisture resistance from *B. rapa* into *B. napus* (Shiga, 1970). This was because a number of farmers in southwestern Japan grew rapeseed after the rice harvest in the paddy fields with the purpose of raising farm incomes (Nishizawa et al., 2010). Breeding and intensive selection for desirable agronomic traits led to the generation of various *B. napus* cultivars, some of which gained wide acceptance commercially. Consequently, *B. napus* cultivars replaced conventional *B. rapa* (Nishizawa et al., 2010).

Domestic rapeseed production ranged between ca. 77,000 tons and 132,000 tons in the 1930s, but production decreased sharply during World War II (Fig. 1). Following the war, the rapeseed acreage increased again and

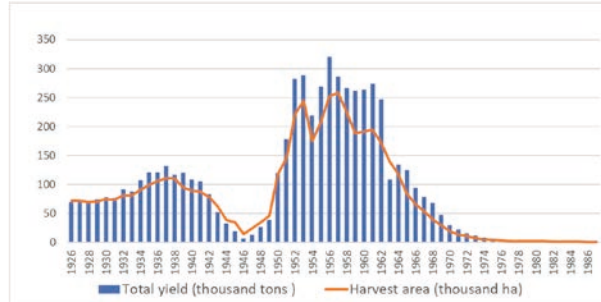

Figure 1: Production and cultivation area of rapeseed (*B. napus* and *B. rapa*) from 1926 to 1987 in Japan. Source: MAFF (1963, 2024a)

the largest total production of 320,000 tons was achieved in 1956. Thereafter, the cultivation areas and production of rapeseed decreased rapidly (Fig. 1). There are several reasons for this, of which the most important one must be that the import volume of inexpensive oilseed crops including rapeseed and soybean jumped sharply due to the import liberalization (Kawasaki et al., 2021).

3 CURRENT STATE OF DOMESTIC OILSEED RAPE CULTIVATION

3.1 PRODUCTION

Japan's oilseed rape production nearly disappeared from the 1980s to the 2000s. In the 2000s, the average annual consumption of oilseed rape in Japan was ca. 2.2 million tons (Saiwai Shobo, 2011), and the domestic demand was almost entirely met by imports mostly from Canada and Australia (MAFF, 2024a). Apart from being used as edible oil, rapeseed oil has been utilized for several purposes in industry, including chemical manufacturing, paint, cosmetics, and pharmaceuticals (USDA, 2023). Almost all the rapeseed imported as edible oil material was of canola quality [low erucic acid (less than 2 % in the oil), low glucosinolate content (less than 30 μmoles per gram in the oil-free meal)] (CODEX, 2001; OECD, 2001).

In recent years, however, oilseed rape acreage and production in Japan have started to increase again. As shown in Table 1, average production per year from 2018 to 2023 inclusive was ca. 3,600 tons. The limited recovery in oilseed rape production is undoubtedly due to the subsidies granted by the Japanese government to farmers who grow oilseed rape and other crops (e.g., wheat, barley, soybean), with the aim of encouraging stable farm management (Kawasaki et al., 2022). Moreover, this ten-

Table 1: Production and import of oilseed rape from 2018 to 2023 in Japan

	2018	2019	2020	2021	2022	2023
Harvest area (ha)	1,920	1,900	1,830	1,640	1,740	1,740
Total yield (t)	3,120	4,130	3,580	3,230	3,680	3,680
Import volume (t)	2,337,350	2,359,212	2,252,378	2,342,162	2,100,818	2,021,557

Source: MAFF (2024a), Statistics Bureau of Japan (2024)

dency is partly owing to the choice of health-conscious people to use more domestic produces, in order to ensure safety of the foods they consume on a daily basis.

3.2 CULTIVAR DEVELOPMENT

Since the 1980s, oilseed-rape breeding programs in Japan have focused on the development of cultivars with low erucic acid, low glucosinolate content, and increased yields, because there were no domestic cultivars which did meet the canola standards (Kawasaki et al., 2022). Attempts have also been made to breed the genotypes with improved winter hardiness and high resistance to diseases, and a number of cultivars have been released. Agronomic characteristics of representative Japanese cultivars are described below.

3.2.1 'Kizakinonatane'

'Kizakinonatane' was produced by crossing 'Tohoku 72' as the seed parent with 'Rapora' as the pollen parent , and registered as an erucic acid-free cultivar in 1992 (Okuyama et al., 1994). This cross was made with the aim of combining the high yield potential of 'Tohoku 72' and the zero-erucic acid trait of 'Rapora', and 'Kizakinonatane' was developed using pedigree method. It is a high-yielding and medium-maturing cultivar with resistance to lodging and *Sclerotinia* stem rot. The cultivar also exhibits tolerance to cold and snow damage, and is recommended for northern Japan where the climate has long, cold winter.

3.2.2 'Nanashikibu'

This cultivar was derived from a cross of 'Morishi 148' x 'Oominatane', and registered as 'Nanashikibu' in 2002 (Kato et al., 2005). It is characterized by high seed-yield potential, zero erucic acid content, good lodging resistance, and moderate resistance to *Sclerotinia* stem rot. 'Nanashikibu' is a relatively early-flowering cultivar and its seeds can be harvested before the rainy season (commonly from beginning of June to mid-July in Japan with the exception of Hokkaido where there is no rainy season) begins; this cultivar has been predominantly grown in temperate central and southwestern Japan.

3.2.3 'Kirariboshi'

'Kirariboshi' originated from a cross between 'Morikei 188' and 'Karat', and in 2004, it was registered as the first Japanese high-yielding, double-low cultivar (Ishida et al., 2007). This cultivar is medium-maturing, and resistant to lodging and *Sclerotinia* stem rot. Tolerance to cold and snow damage is relatively high.

3.2.4 'Kirakiraginga'

'Kirakiraginga' is a high-yielding cultivar free of erucic acid and with low glucosinolate content (Honda et al., 2017). It resulted from hybridization of 'CASCADE' with 'Kirariboshi', and was released in 2014. The cultivar is useful both for the edible oil and livestock feed markets. 'Kirakiraginga' has resistance to lodging and is tolerant to cold and snow damage; it grows well in cold northern climates.

3.2.5 'CR Nanashikibu'

This clubroot resistant (CR) cultivar was produced by introducing two CR loci, *Crr1* and *Crr2*, from Chinese cabbage (*B. rapa*) into 'Nanashikibu' via DNA marker-assisted selection and backcrossing (Kawasaki et al., 2021, 2022). It was registered in 2022. 'CR Nanashikibu' has desirable characteristics similar to those of 'Nanashikibu', e.g., zero erucic acid content, lodging resistance, and moderate resistance to *Sclerotinia* stem rot.

3.2.6 'Penokanoshizuku'

The cultivar originated from a cross between 'OZ028-2' and 'Kizakinonatane' (Kawasaki et al., 2022). The release of 'Penokanoshizuku' in 2019 provided the industry and growers with high-yielding and double-low rapeseed. This cultivar exhibits resistance to *Sclerotinia* stem rot. It is also tolerant to cold and snow damage, and adapted to cold northern climates.

4 CULTURAL PRACTICES

Oilseed rape requires well-drained, loose fertile soil with a pH of 5.8-6.5 (Mori, 2009). In Japan, feral rapeseed populations are found throughout the country (Nishizawa et al., 2010; Chen et al., 2020). Oilseed rape can outcross to the feral rapeseed if they are in close proximity and there is synchrony of flowering. In order to ensure the seed purity, the commercial seeds should be multiplied not by growers themselves but by certified seed-production agencies. Time of seeding plays an important role for successful harvest and good yield of the crop. In northern Japan, the optimum time of sowing is between mid-August and mid-September, while in warmer central and southwestern Japan, sowing normally occurs from late September through early November (MAFF, 2024b). The seed sowing depth should be around 2-3 cm for best germination. Seeding rates vary by seeding methods, genotypes, seeding date and moisture status of the soil. Seeding is mostly done using drill seeder at 300-600 g per 10 a in the country. Oilseed rape competes poorly with weeds during the early stage of growth, making early weed control essential. An effective weed control program includes both cultural and herbicidal approaches. Post emergence herbicides can be used to control grassy weeds such as annual bluegrass, leading to minimizing yield decreases.

In Japan, oilseed rape is cultivated as an autumn-planted winter crop that needs vernalization (winter chilling) to flower. Flowering usually begins around late February (southwestern Japan) or late April (northern Japan) of the second growing season and continues for three to four weeks. Oilseed rape is ready to harvest when the plant is well dried and there are no more green pods (Mori, 2009). Harvesting too early results in too many immature seeds and low-quality seed oil, whereas late harvesting can cause excessive shattering and yield loss. Traditional mechanical pressing method is commonly applied to edible-oil extraction from rapeseed in Japan (MAFF, 2024b). Pressing oil retains the nutritional value, natural golden color, and inherent flavor of the oil. Additionally, mechanical pressing does not need solvents and chemicals, making it a simple and safe process. However, this method usually results in low oil yield.

For optimum crop yields and disease control, growers should not plant oilseed rape in the same field more often than once in three years. It is also important to avoid planting oilseed rape after cruciferous crops. In Japan, oilseed rape is commonly rotated with soybean, wheat, common buckwheat, and sugar beet (Mori, 2009).

5 DISEASE AND PEST PROBLEMS

Sclerotinia stem rot has been the most widespread and serious disease of rapeseed in Japan. It is caused by the soil-borne fungus *Sclerotinia sclerotiorum* (Libert) de Bary and has resulted in considerable yield losses. In the fields having a history of *Sclerotinia* infestations, crop rotation and selection of resistant cultivars (see preceding section) should be followed. Other major diseases that can cause crop losses include clubroot (caused by *Plasmodiophora brassicae* Woronin) and root knot [caused by *Meloidogyne arenaria* (Neal, 1889) Chitwood]. Clubroot has a wide host range and can attack almost all *Brassica* crops. The disease is difficult to manage by disease control practices such as crop rotation, increasing soil pH, and use of agricultural chemicals (Kawasaki et al., 2021). Thus, the most effective way to control this disease is by sowing resistant cultivars; as mentioned above, Japanese breeders released a promising clubroot-resistant cultivar 'CR Nanashikibu' carrying two resistant genes, *Crr1* and *Crr2* (Kawasaki et al., 2021).

Rapeseed insect pests include cabbage armyworm (*Mamestra brassicae* (L., 1758), small cabbage white (*Pieris rapae crucivora* Boisduval, 1836), and cabbage aphid *(Brevicoryne brassicae* (L., 1758)). It is important to protect the plants via insecticide application or other integrated pest management strategies. In addition, timely scouting is recommended for early detection and best management of insect pests.

6 CONCLUDING REMARKS

In the early 2010s, the Japanese government decided to promote the cultivation of oilseed rape by allocating subsidies, and then the rapeseed production area has increased gradually (Kawasaki et al., 2022). However, Japan still only produces ca. 0.2 % of what it consumes (see Table 1), and hence it is becoming essential to make the country self-sufficient even a little by increasing oilseed rape yields via the development of high-yielding cultivars. According to the statistics available (MAFF, 2024a; USDA, 2024), the rapeseed yield (2,110 kg ha^{-1} in 2023) in Japan is considerably lower than that (3,310 kg ha^{-1} in 2023) in the European Union where hybrid cultivars predominate. Hybrids seem likely to be the best method of enhancing yields (Ma et al., 2000; Gehringer et al., 2007). Lefort-Buson et al., (1987) previously reported that the

F1 hybrids between Japanese and European winter-type rapeseed cultivars exhibited high levels of yield heterosis.

Meanwhile, all Japanese rapeseed cultivars currently grown are derived from pedigree selection (Kawasaki et al., 2022). In the country, therefore, oilseed rape has yet to benefit from enhanced yield through hybrid breeding. Cytoplasmic male sterility (CMS) among cruciferous crops has been broadly investigated to implement it as a low-cost, efficient and reliable system for the production of F1 rapeseed hybrids (Kamiński, 2013; Yamagishi and Bhat, 2014). Several hybrid breeding systems are available at present, of which the Ogu-INRA CMS system is widely used in Europe and North America, and the Pol CMS system is preferentially utilized in China (Li et al., 2022). Dominant genic male sterility may be also usable for hybrid breeding in the crop (Li et al., 2022). Efforts are required to establish hybrid breeding program of oilseed rape using appropriate male sterility systems in Japan.

Moreover, winter damage remains a significant barrier for oilseed rape cultivation in the main producing area, Hokkaido where the crop is usually grown under thick snow cover from winter to spring. Thick snow cover acts as a heat insulator between the atmosphere and the soil, suppressing soil freezing; snow cover protects the plants from low temperature stress in winter (Shimoda et al., 2023). During recent years, oilseed rape has often suffered from a severe freezing injury in eastern Hokkaido, due to the late onset of snow cover and less snow fall. Because of that, some farmers are reducing rapeseed plantings and diverting more land under other crops which give them better return. There is an urgent need to identify cold-resistant germplasm and to develop oilseed rape cultivars with robust cold hardiness.

In Japan, more than 600 rapeseed germplasm accessions, including Japanese landraces and cultivars as well as overseas accessions, are maintained at the Genetic Resources Center of the National Agriculture and Food Research Organization (Chen et al., 2017). This collection is expected to harbor huge genetic variation and provide opportunities for trait improvement. Nowadays, genomics takes an important position in genetics and plant breeding. Through the use of whole-genome sequencing technology and diverse molecular markers, the genomics studies in *B. napus* have achieved great progress (Quezada-Martinez et al., 2021; Gu et al., 2024). The availability of various genomic resources allows the breeders to better understand agronomic traits at the genetic level, which will facilitate the generation of novel oilseed rape cultivars with improved traits.

7 ACKNOWLEDGEMENTS

We are grateful to Mr. Hidetoshi Nakajima (LLC OMEGA Farmers) for support throughout this work.

Conflicts of interest

The authors declare no conflict of interest.

Data availability

Original data are available from the corresponding author upon reasonable request.

8 REFERENCES

Cartea, E., Haro-Bailón, A.D., Padilla, G., Obregón-Cano, S., del Rio-Celestino, M., Ordás, A. (2019). Seed oil quality of *Brassica napus* and *Brassica rapa* germplasm from northwestern Spain. *Foods*, *8*(8), 292. https://doi.org/10.3390/foods8080292

Chen, R., Hara, T., Ohsawa, R., Yoshioka, Y. (2017). Analysis of genetic diversity of rapeseed genetic resources in Japan and core collection construction. *Breeding Science*, *67*(3), 239-247. https://doi.org/10.1270/jsbbs.16192

Chen, R., Shimono, A., Aono, M., Nakajima, N., Ohsawa, R., Yoshioka, Y. (2020). Genetic diversity and population structure of feral rapeseed (*Brassica napus* L.) in Japan. *PLoS ONE, 15*(1), e0227990. https://doi.org/10.1371/journal.pone.0227990

CODEX. (2001). Codex standard for named vegetable oils. CX-STAN 210-1999. *Codex Alimentarius*, *8*, 11-25.

Fujimura-Ito, T., Ando, M., Otsuka, K., Mukai-Kubo, K., Kobayashi, A., Tsuyuguchi, S., … Nishiike-Wada, T. (2011). Cooking characteristics of domestic rapeseed oil: Comparison with canola oil. *Journal of the Japanese Society for Food Science and Technology*, *58*(7), 309-317. (in Japanese)

Gehringer, A., Snowdon, R., Spiller, T., Basunanda, P., Friedt, W. (2007). New oilseed rape (*Brassica napus*) hybrids with high levels of heterosis for seed yield under nutrient-poor conditions. *Breeding Science*, *57*(4), 315-320. https://doi.org/10.1270/jsbbs.57.315

Gu, J., Guan, Z., Jiao, Y., Liu, K., Hong, D. (2024). The story of a decade: Genomics, functional genomics, and molecular breeding in *Brassica napus*. *Plant Communications*, *5*(4), 10084. https://doi.org/101016/j.xplc.2024.10084

Gulden, R.H., Warwick, S.I., Thomas, A.G. (2008). The biology of Canadian weeds. 137. *Brassica napus* L. and *B. rapa* L. *Canadian Journal of Plant Science*, *88*(5), 951-996.

Guo, Y., Chen, S., Li, Z., Cowling, W.A. (2014). Center of origin and centers of diversity in an ancient crop, *Brassica rapa* (turnip rape). *Journal of Heredity*, *105*(4), 555-565. https://doi.org/10.1093/jhered/esu021

Honda, Y., Kawasaki, M., Yamamori, M., Kato., M. (2017). A new winter double low rapeseed (*Brassica napus* L.) cultivar, 'Kirakiraginga', that offers high oil yield and multi-use of seeds. *Bulletin of the NARO Agricultural Research for Tohoku Region*, *119*, 1-16. (in Japanese)

Huang, Z., Suzuki, K., Ikemoto, A. (2015). Evaluation of safety and quality of rapeseed oil made in China and Japan. *Memoirs of the Faculty of Education and Human Studies, Akita University (Natural Science)*, *70*, 99-110. (in Japanese)

Ignatov, A.N., Artemyeva., A.M., Hida, K. (2008). Origin and expansion of cultivated *Brassica rapa* in Eurasia: linguistic facts. *ISHS Acta Horticulturae*, *867*, 81-88.

Ishida, M., Yamamori, M., Kato, M., Yui, M. (2007). A new double low cultivar of winter rapeseed, 'Kirariboshi'. *Bulletin of the National Agricultural Research Center for Tohoku Region*, *107*, 53-62. (in Japanese)

Japan Oilseed Processors Association. (2015). Origin of vegetative oil production. *Vegetative Oil Information*, *96*. (in Japanese)

Japan Oilseed Processors Association. (2024). *Recent trends in vegetative oils in Japan*. Retrieved from https://www.oil.or.jp>trends>pdf>oilreef (in Japanese)

Kamiński, P. (2013). Development of male sterile broccoli lines with *Raphanus sativus* cytoplasm and assessment of their value for breeding purposes. *Journal of Horticultural Research*, *21*(2), 101-107. https://doi.org/10.2478.johr-2013-0028

Kato, M., Yamamori, M., Yui, M., Ishida, M., Chiba, I., Okuyama, Y., … Sugawara, S. (2005). Breeding of a new zero-erucic acid rape cultivar, 'Nanashikibu' adaptable to temperate climate. *Bulletin of the National Agricultural Research Center for Tohoku Region*, *103*, 1-11. (in Japanese)

Kawasaki, M., Ohara, T., Ishida, M., Takahata, Y., Hatakeyama, K. (2021). Development of novel clubroot resistant rapeseed lines (*Brassica napus* L.) effective against Japanese field isolates by marker assisted selection. *Breeding Science*, *71*(5), 528-537. https://doi.org/10.1270/jsbbs.21014

Kawasaki, M., Ishiguro, K., Nemoto, E. (2022). Oilseed rape breeding in Japan: its history and future prospects. *Tokusanshubyou*, *35*, 2-5. (in Japanese)

Lefort-Buson, M., Dattee, Y., Guillot-Lemoine, B. (1987). Heterosis and genetic distance in rapeseed (*Brassica napus* L.): use of kinship coefficient. *Genome*, *29*(1), 11-18. https://doi.org/10.1139/g87-003

Li, Z., Yuan, R., Wang, M., Hong, M., Zhu, L., Li, X., … Zeng, X. (2022). Development of the PARMS marker of the dominant genic male sterility (DGMS) line and its utilization in rapeseed (*Brassica napus* L.) breeding. *Plants*, *11*, 421. https://doi.org/10.3390/plants11030421

Ma, C., Kimura, Y., Fujimoto, H., Sakai, T., Imamura, J., Fu, T. (2000). Genetic diversity of Chinese and Japanese rapeseed (*Brassica napus* L.) varieties detected by RAPD markers. *Breeding Science*, *50*(4), 257-265. https://doi.org/10.1270/jsbbs.50.257

MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan). (1963). *The document about rapeseed in Japan*. Tokyo, Japan: Ministry of Agriculture, Forestry and Fisheries (in Japanese)

MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan). (2024a). *Statistics on crops*. Retrieved from https://www.maff.go.jp>sakumotu>sakkyou_kome (in Japanese)

MAFF (Ministry of Agriculture, Forestry and Fisheries, Japan). (2024b). *Oilseed rape in Japan*. Retrieved from https://www.maff.go.jp>pdf>soba.natane-2.pdf (in Japanese)

McAlvay, A.C., Ragsdale, A.P., Mabry, M.E., Qi, X., Bird, K.A., Velasco, P., Emshwiller, E. (2021). *Brassica rapa* domestication: untangling wild and feral forms and convergence of crop morphotypes. *Molecular Biology and Evolution*, *38*(8), 3358-3372. https://doi.org/10.1093/molbev/msab108

Mizushima, U., Tsunoda, S. (1969). Origin of *Brassica* crops. *Agriculture and Horticulture*, *44*, 1347-1352. (in Japanese)

Mori, T. (2009). Oilseed rape cultivation in Takikawa city, Japan. *Tokusanshubyou*, *5*, 44-49. (in Japanese)

MRC Institute for Environment & Health. (1997). *Oilseed rape*: *Allergenicity and Irritancy*. Southampton, UK: MRC Institute for Environment & Health

Nakui, S., Mikami, T. (2023). Production, uses, and ancestry of an oilseed crop, *Perilla frutescens* (L.) Britton var. *frutescens* in Japan: An overview. *Agriculturae Conspectus Scientificus*, *88*(2), 93-97.

Nakui, S., Mikami, T. (2024). The history and current state of flax (*Linum usitatissimum* L.) cultivation and use in Japan. *Acta Agriculturae Slovenica*, *120*(1), 1-7. https://doi.org/10.14720/aas.2024.120.1.15093

Nishizawa, T., Tamaoki, M., Aono, M., Kubo, A., Saji, H., Nakajima, N. (2010). Rapeseed species and environmental concerns related to loss of seeds of genetically modified oilseed rape in Japan. *GM Crops*, *1*(3), 143-156. https://doi.org/10.4161/gmcr/1.3.12761

Nitta, M., Lee, J.K., Ohnishi, O. (2003). Asian *Perilla* crops and their weedy forms: Their cultivation, utilization and genetic relationships. *Economic Botany, 57*(2), 245-253. https://doi.org/10.1663/0013-0001(2003)057[0245:APCATW]2.0.CO;2

OECD. (2001). *Consensus document on key nutrients and key toxicants in low erucic acid rapeseed (canola)*. Report No. ENV/JM/MOND (2001) 13.

OECD. (2016). Brassica crops (*Brassica species*). In: *Safety assessment of transgenic organisms in the environment, volume 5: OECD consensus documents (pp. 151-289)*, Paris, France: OECD Publishing

Ohashi, K. (2007). Cooking oil & fat and their use seen in publications during the Meiji period – Centering on a novel Shokudoraku. *Bulletin of the Institute of Modern Culture, Showa Women's University*, *803*, 84-93. (in Japanese)

Okuyama, Y., Shibata, M., Endo, T., Sugawara, S., Hiraiwa, S., Kaneko, I. (1994). A new zero-erucic rape variety 'Kizakinonatane'. *Bulletin of the National Agricultural Research Center for Tohoku Region*, *88*, 1-13. (in Japanese)

Prakash, S., Hinata, K. (1980). Taxonomy, cytogenetics and origin of crop Brassicas, a review. *Opera Botanica*, *55*, 1-57.

Qi, X., Au, H., Ragsdale, A.P., Hall, T.E., Gutenkunst, R.N., Chris Pires, J., Barker, M.S. (2017). Genomic inferences of domestication events are corroborated by written records in *Brassica rapa*. *Molecular Ecology*, *26*(13), 3373-3388. https://doi.org/10.1111/mec.14131

Quezada-Martinez, D., Addo Nyarko, C.P., Schiessl, S.V., Mason, A.S. (2021). Using wild relatives and related species to build climate resilience in *Brassica* crops. *Theoretical and Applied Genetics*, *134*(6), 1711-1728. https://doi.org/10.1007/s00122-021-03793-3

Rahman, H. (2013). Review: Breeding spring canola (*Brassica napus* L.) by the use of exotic germplasm. *Canadian Journal*

of Plant Science, *93*(3), 363-373. https://doi.org/10.4141/cjps2012-074
Saiwai Shobo. (2011). *The latest information about oils and fats in Japan*. Retrieved from https://www.saiwaishobo.co.jp>yushi (in Japanese)
Shiga, T. (1970). Rape breeding by interspecific crossing between *Brassica napus* and *Brassica campestris* in Japan. *Japan Agricultural Research Quarterly*, *5*(4), 5-10.
Shimoda, S., Terasawa, Y., Kanaya, M. (2023). Control of snow mold damage of winter wheat by snow compaction (Yukifumi). *Soil & Tillage Research*, *225*, 105554. https://doi.org/10.1016/j.still.2022.105554
Song, K.M., Osborn, T.C., Williams, P.H. (1988). *Brassica* taxonomy based on nuclear restriction fragment length polymorphisms (RFLPs). *Theoretical and Applied Genetics*, *75*(5), 784-794. https://doi.org/10.1007/BF00265606
Statistics Bureau of Japan. (2024). *Trade statistics of Japan: Agriculture, forestry and fisheries products*. Retrieved from https://www.e-stat.go.jp>stat-search>files (in Japanese)
Tokyo Oil Inquiry House Market. (2016). *A group of oil sellers provided light in a million city, Edo*. Tokyo, Japan: Saiwai Shobo
USDA. (2023). *Japan: Oilseeds and Products Annual*. Retrieved from https://www.fas.usda.gov/data/japan-oilseeds-and-products-annual-8
USDA. (2024). *European Union: Oilseeds and Products Annual*. Retrieved from https://www.fas.usda.gov/data/european-union-oilseeds-and-products-annual-4
Yagi, K., Takada, S., Funatsu, T., Matsubara, T. (2023). Structural analysis of the food system of imported rapeseed: Toward stable oilseeds procurement in Japan. *Journal of Food System Research*, *30*(3), 163-177. https://doi.org/10.5874/jfsr.23.30.3_8 (in Japanese)
Yamagishi, H., Bhat, S.R. (2014). Cytoplasmic male sterility in Brassicaceae crops. *Breeding Science*, *64*(1), 38-47. https://doi.org/10.1270/jsbbs.64.38
Yamanaka Aburaten. (2023). *About the oils: Japanese oils*. Retrieved from https://www.yoil.co.jp/en/colum-cat/wa
Zając, T., Klimek-Kopyra, A., Oleksy, A., Lorenc-Kozik, A., Ratajczak, K. (2016). Analysis of yield and plant traits of oilseed rape (*Brassica napus* L.) cultivated in temperate region in light of the possibilities of sowing in arid areas. *Acta Agrobotanica*, *69*(4), 1696. https://doi.org/10.5586/aa.1696
Zhao, J., Wang, X., Deng, B., Lou, P., Wu, J., Sun, R., … Bonnema, G. (2005). Genetic relationships within *Brassica rapa* as inferred from AFLP fingerprints. *Theoretical and Applied Genetics*, *110*(7), 1301-1314. https://doi.org/10.1007/s00122-005-1967-y