The diversity of horticulture in Japan – fruit and vegetable production

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In Japan, the production of edible crops such as fruit and vegetables is differentiated into three main categories: staple crops, oil-processing crops and forage crops. While staple foods, including rice, meat and fish are primarily intended for carbohydrate and protein intake, fresh fruit and vegetables provide essential vitamins, minerals and dietary fiber.

In recent years, the importance of functional foods that lead to the prevention of lifestyle-related diseases has been emphasized, and the importance of fresh fruit and vegetables that contain an abundance of these components has been increasing. Vegetables are indispensable as a side dish, and are enjoyed for their color, taste, and aroma. While fruit is often considered a luxury in Japan, they are important as gifts, but they are also used in daily life as snacks and desserts.

Compared to the cultivation of major cereal crops, horticulture generally involves intensive cultivation on relatively small plots of land. There are two types of cultivation: open field cultivation and protected cropping, which may be either heated or unheated, using glass or plastic film during periods when open field cultivation is difficult. In the case of protected cropping, soil cultivation, hydroponics, rockwool and other substrates are used. In addition to temperature control, growers may also utilize supplementary lighting to maintain photosynthesis or manipulate flowering time through the control of day length. Such highly sophisticated cultivation systems are one of the characteristics of horticultural production in Japan, where plant factories and smart technology may help solve some of the problems associated with an aging workforce and labor shortages.

In 2022, agricultural output in Japan was worth approximately JPY 9 trillion. While the value of the food industry was estimated to exceed JPY 100 trillion (Agriculture, Forestry and Fisheries Basic Data Collection), the importance of agriculture cannot be measured solely in monetary terms. Agriculture has a critical role to play in food security and environmental sustainability. Today, the value of vegetable production exceeds JPY 2 trillion, with fruit production contributing around JPY 900 billion: about 35% of the total value of agricultural outputs.

By region, in 2022, Hokkaido was the leading producer of fresh vegetables (JPY 222.8 billion) (10.0%), followed by Ibaraki (7.2%) and Chiba (6.0%) in Kanto Prefecture, Kumamoto (5.6%) in Kyushu, and Aichi (5.0%) in the Chubu region (Figure 1). As for fruit production, the Tohoku and Hokuriku regions dominate, with Aomori (11.4%), Nagano (9.8%), Yamanashi (8.8%), Yamagata (8.3%) and Nagano (4.9%) making up the top five prefectures.

In 2023, on the basis of the wholesale market throughput, cabbages (1,130,000 t), onions (1,010,000 t), and Chinese cabbage (800,000 t) accounted for the greatest quantities, while strawberries (JPY 175.3 billion), tomatoes (JPY 140.9 billion), and cucumbers (JPY 138.5 billion) were the most valuable crops. By volume, tangerines (480,000 t), apples (390,000 t) and bananas (320,000 t) were the major fruit crops traded in the wholesale markets. Grapes ranked fifth in terms of volume, but third in terms of value because, like strawberries, their price is significantly higher than other fruit crops. By contrast, most of the bananas are imported.

Vegetable production in Japan

In pursuing its agenda to be self-sufficient, given that most vegetable crops have only a limited shelf life, vegetable production in Japan occurs all year round. Depending on the region and the season, cultivation systems and the selection of varieties are

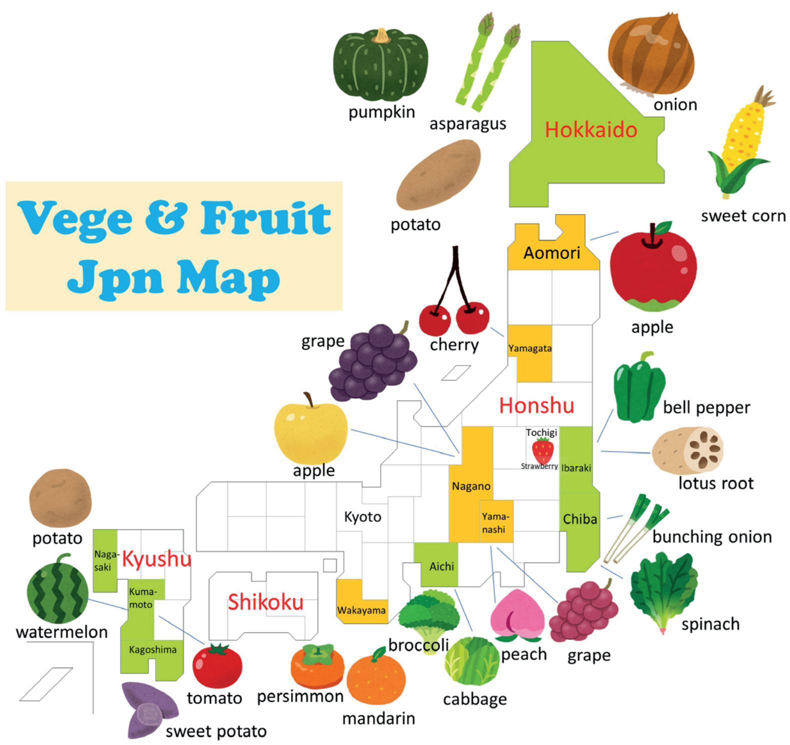

Figure 1. Japanese prefectures that are known for their high production of edible horticultural crops.

Figure 2. Tomato production in Kagoshima at the end of September (2018) (A) and in Nagano at the start of August (2018) (B).

adapted to local soil and climatic conditions. Depending on the type of vegetable and the region, vegetable production can be classified into one of two types: variety-utilizing and facility-utilizing. Under a facility-utilizing cropping regime, vegetables with a narrow temperature adaptation range are cultivated in greenhouses with supplementary environmental control to provide heat and where appropriate, supplementary light and carbon dioxide enrichment to extend the cultivation period. Conversely, under a variety-utilizing cropping regime, in either open fields or plastic tunnels, the ecological differences between varieties are exploited and referred to by seasonal names such as "spring sowing" or "winter harvesting," depending on the sowing and harvesting seasons. Most leafy green vegetables and root vegetables fall within this classification.

Open field culture is a cropping system where vegetables are grown under natural or near-natural conditions for the majority of their growing season. Rain sheltered cultivation is included in open field cultivation because it only protects against rainfall and does not aim to regulate temperature.

Semi-forced vegetable cultivation includes the use of plastic tunnels or rain sheltered greenhouses. Under this cropping type, seedlings are grown in heated facilities and then transplanted into tunnels or rain sheltered greenhouses to accelerate harvesting. For semi-forced cultivation in plastic tunnels, the plastic is removed after the risk of late frost has passed, and cultivation shifts to open field culture.

Forcing culture describes those cultivation systems where vegetable crops are kept warm or heated in a greenhouse for most of the low-temperature period from late fall to spring or during the entire growing period in order to harvest the crop even earlier than semi-forcing culture.

Delayed-start culture is a cropping type in which vegetables are harvested later than those in the open field culture. This can be divided into two types: "delayed-start culture using greenhouse," which keeps or adds heat during the latter half of the growing period, and "delayed-start culture in open field" which takes advantage of mild weather in late fall and cool weather in mid-summer (Figure 2).

Tomato production in Japan

Tomato was first introduced to Japan via China in the late 17th to early 18th centuries. At that time, it was mainly used for ornamental purposes, but in the 1930s, its production for table consumption increased, and today it is cultivated year-round throughout Japan, primarily in greenhouses. In Japan, large tomatoes with a fruit weight of around 200 g, mini-tomatoes with a fruit diameter of 2-3 cm and a fruit weight of around 30 g, and medium-sized tomatoes with a fruit diameter of 5 cm and fruit weight of 50-100 g are produced. Tomato cropping types are not fixed and are constantly changing even in the same production region, depending on various factors such as varieties, cultivation techniques, and economic conditions. In Japan, semi-forced culture in greenhouses (with transplanting in December and harvesting from February to June) and delayed-start culture (transplanting in July and harvest from August to December) are common (Figure 3).

In order to advance and extend the harvesting period, to reduce production costs and to meet the demands of institutional buyers, some production areas have introduced modern greenhouses with high eaves, and are adopting an overwintering cropping regime, with transplanting in September and harvesting from October to June (a 9-month harvest period). Under this cropping system, improved summer seedling cultivation techniques utilizing the direct planting of cellular seedlings may allow harvest to occur one month earlier and higher yields can be anticipated.

In contrast, a number of short-term cultivation methods are employed in some growing regions. Low-truss dense planting describes a cultivation method where seedlings are planted densely but only one to three trusses are harvested, allowing for up to four crops per year (with three-truss harvesting) (Figure 4). Here it is important to raise the seedlings in artificial growth chambers and to select varieties that are appropriate for the season.

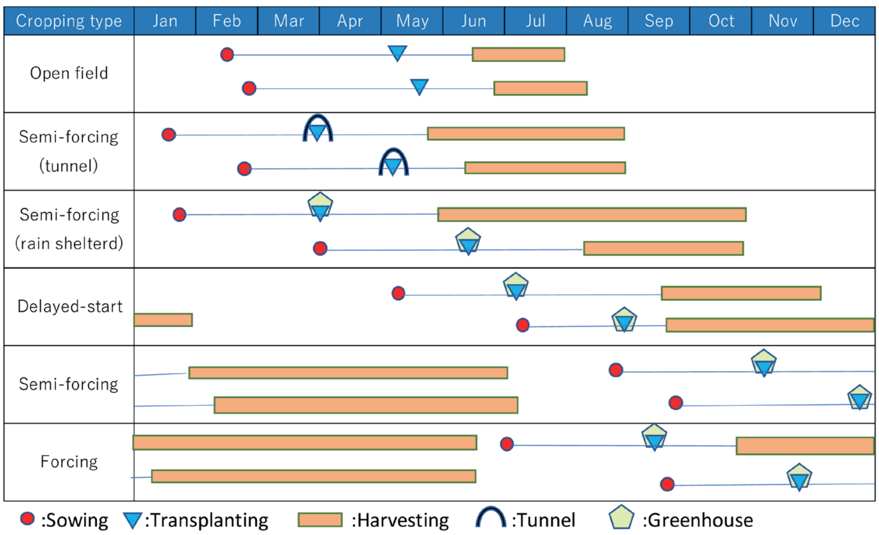

Figure 3. The cropping types of tomato in Japan.

Variety-utilizing vegetable cropping systems

For many leafy/root vegetables such as cabbage and onions, flower bud differentiation, bolting, and flowering are strongly influenced by temperature and day length. These vegetables are usually cultivated in an open field, however, the high temperatures and humidity during the rainy season result in an increasing incidence of pests and diseases. Where climatic differences are extreme, the year-round cultivation of vegetables in open fields requires the use of appropriate varieties, a shift to different growing regions, and the use of complementary materials and facilities.

Figure 4. The low-truss dense planting cultivation of tomato.

Cabbage production in Japan

Cabbage was introduced to Japan in the early 18th century, but it was the non-heading type. It was not until the mid-18th century that heading cabbage was introduced. When first introduced, cabbage was generally sown in cool regions in the spring months for harvest in fall. The subsequent introduction of both early and late varieties greatly extended the harvest period. Late bolting varieties have since made it possible for cabbages to be planted in the warmer regions during fall. In addition, varieties with traits such as heat tolerance, cold tolerance and head formation characteristics even at high/low temperature, have been developed, and from the use of these varieties, year-round production has been realized (Figure 5).

To avoid high temperatures during the head formation period, sowing in February and transplanting in March in warm and temperate regions is widely practiced. It's also possible to sow in March-April and to transplant in April-May in cold regions. Seedlings are grown in greenhouses in cellular trays to avoid frost damage and facilitate rapid plant establishment after transplanting. Harvesting occurs from June to August.

Under this method of cropping, damping-off is common during the rainy season in June. In addition, high temperatures during the head formation phase can easily lead to poor head formation. Varieties for this cropping period must be tolerant of waterlogging, disease resistant, and capable of forming heads even at high temperature.

In cold regions, seeds are sown from June to early August, with harvest occurring from September to January. In warm or temperate regions, while the sowing period can be delayed, if it is delayed too much, poor head formation due to low temperatures can occur. As the sowing and seedling growth periods occur when temperatures are hot, it is necessary to pay close attention to the occurrence of pests and diseases such as damping-off, yellowing disease, diamondback moth, and cutworms, and to cover the seedlings with a tunnel. Early maturing varieties and cold heading varieties are used for cultivation during the hot summer and cold winter, respectively. For harvesting from December to March, late-bolting varieties need to be selected.

For seeds sown in September-October, with transplanting occurring before the end of the year, harvest will occur from February to May. Alternatively, seeds can be sown in November-December, overwintered, transplanted around February, and harvested from April to July. For harvest in early spring, early-maturing varieties with clod-heading characteristics are typically used.

Strawberry production in Japan

Under natural conditions, strawberries initiate flower buds under short-day, low-temperature conditions from late summer to early fall, overwinter in a dwarf (rosette, dormant) state, and then bloom and bear fruit the following spring (April to May). After that, runners emerge under the long-day, high-temperature conditions from early summer. To produce fruit at other times, this life cycle must be manipulated.

The optimal growing temperature for strawberries is 15-25°C. Below 15°C, the plant becomes dwarf under short-day conditions and goes dormant below 5°C. However, unlike tree buds and bulbs, it continues to grow slightly, even outdoors in winter. When entering endodormancy, vegetative growth such as the emergence of runners and leaf elongation are suppressed by high temperature and long-day conditions. Endodormancy is broken by the low temperatures of winter, transitioning to ecodormancy, and growth resumes in spring as temperatures rise with flowering and fruiting. For the year-round

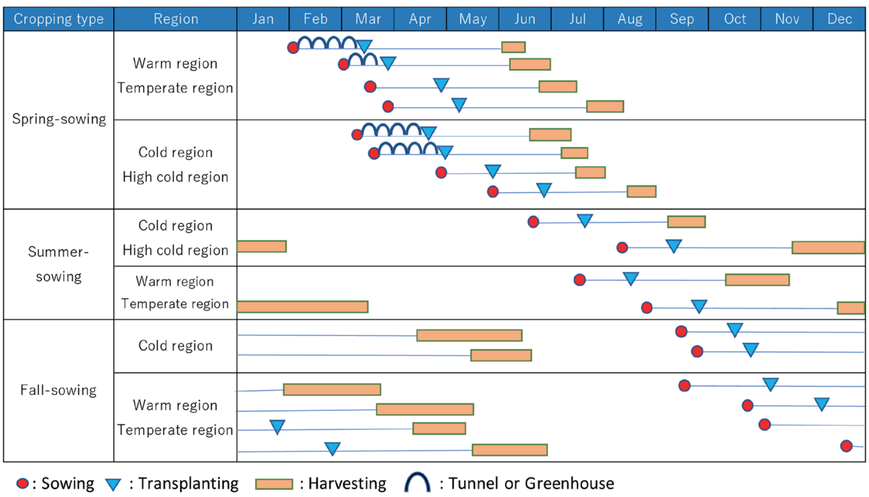

Figure 5. The cropping types of cabbage.

production of strawberries, controlling flower bud initiation and dormancy is crucial.
The main cropping system for strawberries in Japan is forced culture. Seedlings that have undergone flower bud initiation through various methods are planted, and heating begins before they enter dormancy due to low temperatures and short days (Figure 6). By maintaining a semi-dormant state through extending the daylength and controlling temperature, flower buds can be continuously initiated, allowing harvesting to continue until early summer (around the end of May).
Under a semi-forced cropping regime, early cropping is facilitated by erecting low tunnels after the dormant plants have met the minimum chilling requirement. Because the temperature is low and the amount of sunlight is insufficient, vegetative growth is poor. In semi-forcing regions like the Tohoku area, low temperature cut cultivation is practiced, during which the plants are kept warm enough not to bloom in winter, and the period of exposure to low temperatures is adjusted to initiate flower buds.
For strawberries, the chilling requirement for breaking dormancy and the photoperiod and temperature needed for flower bud initiation vary greatly depending on the variety. For forcing, varieties that have early flower bud initiation and a short dormancy (requiring less chilling and having excellent cold elongation) are used, while varieties with a long dormancy are used for semi-forcing cultivation in cold regions and open field cultivation. New cultivars such as 'Benihoppe' and 'Kaorino' have excellent low-temperature elongation and are often grown without lighting. The cultivation of everbearing varieties is limited to summer and fall harvests in cold regions, whereas, under forced cultivation systems, single-harvest varieties, which are superior in quality, are utilized.

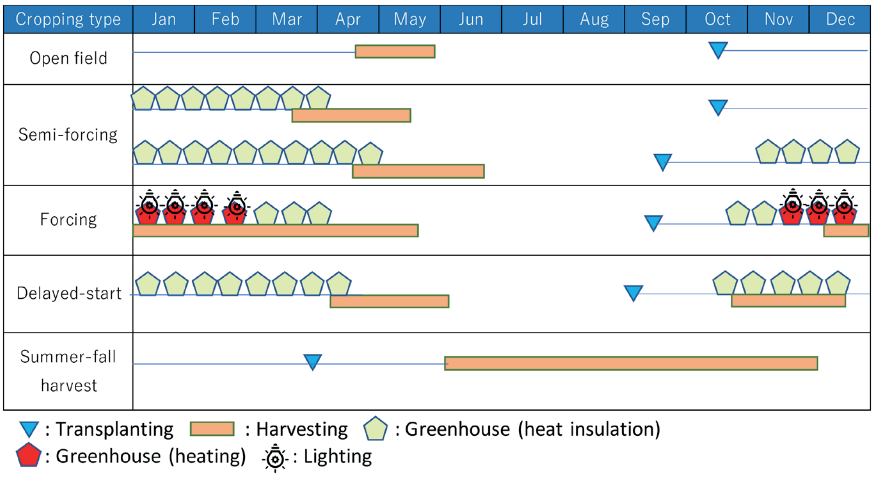

Figure 6. The cropping types of strawberry.

In the early 1990s, high-altitude areas such as the foothills of Mount Fuji and Senjogahara in Nikko were widely used for highland seedling cultivation. In these regions, seedlings initiate flower buds through natural cold stimulation, which are then used for forcing in lowland areas. However, in more recent times, as strawberry production has moved to the 'Nyoho' and 'Toyonoka' regions, techniques have been developed to promote flower bud initiation through low-temperature treatment at 10-15°C. In 'Nyoho', seedlings are placed in a short-day night cooling device for 16 hours and are exposed to natural temperature and light conditions for the remaining 8 hours. This process is continued for 10-20 days to induce flower bud initiation. While the effect of night cooling and short-day treatment is high, it does require a significant investment in night cooling equipment. In the production areas of 'Toyonoka', seedlings are placed in commercially available refrigerators for 10-15 days for low-temperature treatment. This method can be undertaken at relatively low cost. However, this method requires the cultivation of bigger seedlings, and the treatment effect is unstable, often resulting in lower yields.
More recently, a technique called intermittent refrigeration treatment has been established and is expected to become widespread. This involves repeating the process 2-3 times, where photosynthesis is promoted under natural conditions after refrigeration at 15°C in darkness for 3-4 days.

Fruit production in Japan

The development of fruit cultivation in Japan has followed a unique trajectory, shaped by the nation's distinctive geographical features and cultural heritage. The Japanese archipelago, stretching from north to south, encompasses many diverse climatic zones ranging from subtropical to subarctic, enabling the establishment of specialized fruit production systems tailored to each region's characteristics. In Okinawa, tropical fruits such as mangoes and pineapples are cultivated, whilst Kyushu and the western regions of Honshu specialize in citrus, particularly the Satsuma mandarin. In the colder regions of Tohoku and Hokkaido, deciduous fruit trees, including sweet cherries and apples, are predominantly grown, exemplifying the principle of cultivating crops best suited to local conditions.
A notable characteristic of Japanese fruit cultivation is the extraordinary emphasis placed on fruit quality, which has led to the development of sophisticated cultivation techniques. However, the traditional Japanese fruit growing system currently faces significant challenges from climate change and labor shortages due to the rapid population decline.
A remarkable feature of Japanese fruit cultivation is the production of luxury fruit intrinsically linked to the nation's gift-giving culture. In Japanese society, fruit has tradi-

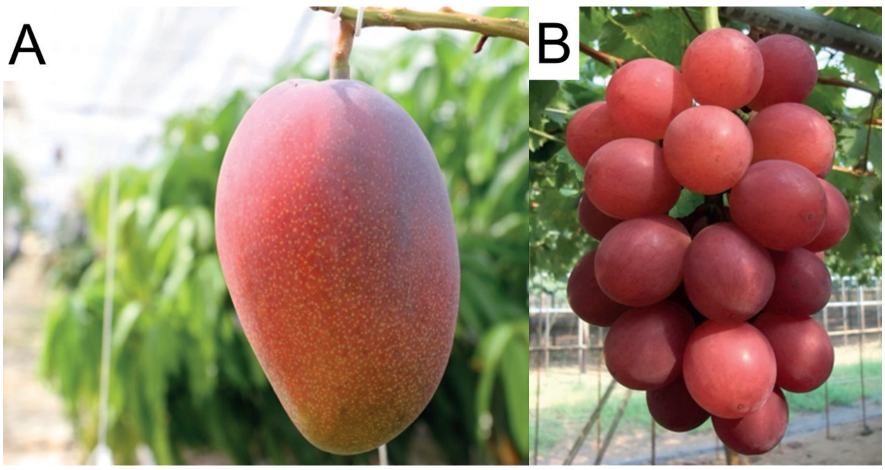

Figure 7. Mango 'Aikou' (A) and grape 'Ruby Roman' (B) are traded as premium fruits for gift-giving. It is believed that the higher the price of the fruit, the better it conveys the sender's feelings, and these command prices incomparably higher than fruits normally consumed for eating.

Figure 8. Japanese pear trees cultivated under a joint training system. The main branches extend horizontally and are joined to adjacent trees by grafting. The fruiting positions can be seen arranged in a planar layout.

tionally held a significant position as a gift for celebrations, visiting the ill, and seasonal gift-giving occasions such as "Oseibo" (year-end gifts) and "Ochugen" (midsummer gifts). Premium fruit such as mangoes and rock melons are often priced above JPY 10,000 (approximately 60 EUR) per fruit and grape clusters can cost tens of thousands of JPY (Figure 7). These ultra-premium fruits must meet exacting standards not only in taste, but also in size, color, and shape: aesthetic demands that have driven the development of sophisticated cultivation techniques.

For instance, table grape cultivation employs meticulous management practices, including limiting cluster numbers to one or two per shoot, whilst combining shoot-tip pinching and lateral shoot management to enhance photosynthesis and sugar translocation to the fruit. Additionally, techniques such as gibberellin treatment for seedless fruit production, peduncle trimming for cluster shape adjustment, and precise berry thinning are applied with extraordinary attention to detail.

Fruit bagging, a technique developed in Japan for preventing pest damage and blemishes to fruit, has now been adopted worldwide for various fruit crops including apples, peaches and pears (Sharma et al., 2014; Ali et al., 2021). In citrus cultivation, the "mulch-drip" system (year-round mulching and drip irrigation/fertigation system) has been established for water stress control, enabling the production of high-quality Satsuma mandarins with a sugar content exceeding 12 °Brix (Shimazaki and Nesumi, 2016).

As many of these premium fruit production techniques are labor intensive, there is growing interest in technological innovation to achieve labor-saving measures, mechanization and automation in the future.

In Japan, where approximately 70% of the land is mountainous terrain, much fruit cultivation occurs on slopes, resulting in significantly lower operational efficiencies compared to flat terrain, and opportunities for mechanization are limited. Moreover, the agricultural sector faces intensifying challenges from an ageing workforce and a shortage of young farmers. Under these circumstances, labor saving and productivity enhancement have become urgent priorities in fruit cultivation, spurring various technological innovations.

The introduction of smart agriculture is regarded as one of the solutions to these challenges. Initiatives to quantify and visualize the tacit knowledge and experience of skilled farmers through AI image analysis, creating comprehensive databases, show promising potential for technical knowledge transfer. Whilst drones for pesticide application and autonomous harvesting robots have been successfully implemented in rice cultivation and some vegetable crops, their practical application in fruit cultivation requires further technological advancement. In fruit cultivation, the three-dimensional and complex tree architecture presents a significant obstacle to implementing smart agriculture technologies, making the development of mechanized harvesting particularly challenging. The joint training system (Figure 8), successfully implemented in Japanese pear and persimmon cultivation, represents an innovative cultivation system where main stems of young trees are trained horizontally and connected to adjacent trees through grafting to create linear composite trees (Shibata and Seki, 2021). This technique simplifies traditionally complex tree forms, enhancing operational efficiency. In pear cultivation, pruning time has been reduced by over 30% compared to conventional methods, with marked increases in yield. The improved joint V-trellis system has also been successfully adapted for persimmon and Japanese apricot, achieving enhanced light conditions and operational efficiency (Shibata and Seki, 2021). These novel training systems, allowing for linear and planar arrangement of branches and fruiting positions, are well-suited for future smart agriculture technology integration.

Addressing climate change

Climate change, a global challenge, is severely impacting fruit cultivation in Japan. As perennial crops, fruit trees are particularly vulnerable to rapid climate change due to the extended time required to develop resilient cultivars and/or species. Since the 2000s, issues such as poor fruit coloration and delayed maturation have become evident in apple, grape and persimmon, whilst pears have experienced flowering disorders due to warming winters (Sugiura et al., 2012; Tominaga et al., 2022). Satsuma mandarin cultivation has seen an increase in rind puffiness (a physiological disorder where the peel separates from the flesh), particularly in late-maturing varieties. Additionally, fruit sunburn, caused by extreme summer temperatures, has become increasingly problematic in many fruit crops.

Climate change simulations predict a significant northward shift of major production areas for Satsuma mandarin and apple by the 2060s (Sugiura et al., 2009), with substantial changes anticipated in suitable cultivation areas for other fruit species. Adaptation strategies through cultivation techniques include modifications to growing seasons, soil improvement, girdling, mist cooling, and environmental control through protected cultivation. Concurrently, strategic crop transitions are underway, such as the introduction of tropical fruits in Kyushu and the conversion from apple to peach production in Aomori Prefecture. In grape cultivation, there is an accelerating shift from pigmented cultivars to green cultivars such as 'Shine Muscat'.

Bridging science and practice for fruit improvement

Recent rapid developments in genome analysis technology have enabled the decoding of genomic information for numerous fruit tree species, advancing the efficiency and precision of breeding programs. Whilst genetic analysis of fruit trees had historically lagged behind annual crops, the implementation of next generation sequencing (NGS) technology has facilitated genome-wide association studies (GWAS) and quantitative trait loci (QTL) analyses across many fruit tree species, accumulating valuable genomic information related to important fruit characteristics. These achievements are now entering the practical application phase in breeding programs.

For instance, in apple breeding, methods have been established to accurately predict fruit soluble solids content, mealiness and susceptibility of water-core disorder from genomic information, enabling the implementation of genomic selection (Minamikawa et al., 2024; Kunihisa et al., 2024). In persimmon, researchers have identified the sex-determining locus and genetic regions controlling fruit morphology and astringency (Horiuchi et al., 2023a, b). For pineapple, QTLs associated with important fruit traits such as sugar content, acidity, flesh color, and ascorbic acid content, have been identified (Nashima et al., 2024). Furthermore, the effectiveness of genomic selection has been demonstrated in both Japanese pear and Satsuma mandarin breeding programs.

The practical application of genomic breeding technologies is expected to enhance the efficiency of crossbreeding and accelerate cultivar improvement in fruit trees. Moreover, technological innovations, including advances in genome editing techniques and artificial intelligence-driven high-throughput phenotyping, are progressing at an unprecedented pace. These technological advances are anticipated to significantly reduce the breeding time for new fruit varieties, which have traditionally required more than a decade.

Japanese fruit production has evolved through adaptation to unique natural conditions whilst meeting cultural demands. Moving forward, further technological innovation will be essential to simultaneously address climate change adaptation and labor-saving requirements. The sustainable development of the fruit industry will undoubtedly require both a comprehensive approach to these challenges and strengthened international research collaboration.

A case study: the breeding of Japanese strawberry cultivars

Strawberry (*Fragaria* × *ananassa* Duch. ex Rosier) is one of Japan's most popular fruits. Next to tomatoes, its market size is estimated at JPY 200 billion, and over 300 cultivars are registered or undergoing the registration process.

Historically, domestic wild berries such as *Potentilla* spp., *Rubus* spp. and alpine *F. iinumae*, and *F. nipponica* were used before the first introduction of *F.* × *ananassa* from the Netherlands in the 1830s-50s (the Edo era) and then from other countries in Europe and the USA in the 1870s. This is why the genus *Fragaria* in Japan is named "Oranda-Ichigo (Holland strawberry)." However, this first introduction was largely unsuccessful because consumers were unfamiliar with Western crops. It was not until the 1900s (the Meiji era), with the introduction of some new cultivars ('Excelsior', 'Victoria', etc.) from Europe and the USA, that Western crops were more widely accepted.

The first Japanese bred cultivar, 'Fukuba', was raised from 'General Chanzy' seedlings in 1899 by Baron Fukuba and was mainly grown for the Imperial family and wealthy consumers in restricted fields. 'Fukuba' became popular after permission was granted to plant the runners in normal fields near big cities and it was one of the leading cultivars until the 1960s. As an old cultivar, 'Fukuba' had some defects in yield and fruit quality. 'Kōgyoku', also known as 'Yakumo', was bred from 'Fairfax' in the 1940s to improve sweetness and became popular as an open field cultivar. In terms of yield, as well as fruit quality, 'Donner' was introduced from the USA in 1950 and became very popular in eastern Japan. Today, 'Fukuba', 'Kōgyoku' and 'Donner' provide the basis for most Japanese cultivars.

Open field cultivation using plastic tunnels or mulching began in the 1950s. These simple structures were developed into plastic greenhouses in the 1960s, so from that time onwards, most of the cultivation has occurred in protected cropping systems. The use of protected cropping systems advanced the harvest season, with peak production shifting from April to February in the pursuit of higher prices in the off-season, especially in December. One of the strategies for out-of-season production is the use of less dormant cultivars, which require less chilling conditions after flower initiation. 'Fukuba' was selected for its earliness and was used as a forcing cultivar. However, this cultivar had defects under higher temperatures when adapted to southern Japan. 'Harunoka' was bred as a descendent of 'Fukuba' and 'Donner' in 1967 in Kyushu, and 'Hōkō-wase' was bred from 'Kōgyoku' × 'Tahoe' in 1960 (Figure 9). These two cultivars, especially 'Hōkō-wase', were the leading forcing cultivars in southwest Japan during the 1980s.

'Reikō' was bred in 1976 in Chiba Prefecture, eastern Japan, for its good red, conical berry shape from 'Fukuba' × 'Harunoka'. The introduction of 'Reikō' stimulated consumer awareness for good looking fruit. 'Donner' has deeper dormancy, so early season production was difficult for the eastern region. To overcome this, 'Nyohō' was raised from {('Harunoka' × 'Donner') × 'Donner'} × 'Reikō' in 1985 in Tochigi Prefecture and became the leading cultivar in eastern Japan until the 1990s. Meanwhile, the western cultivar 'Harunoka' was replaced by 'Toyonoka', a

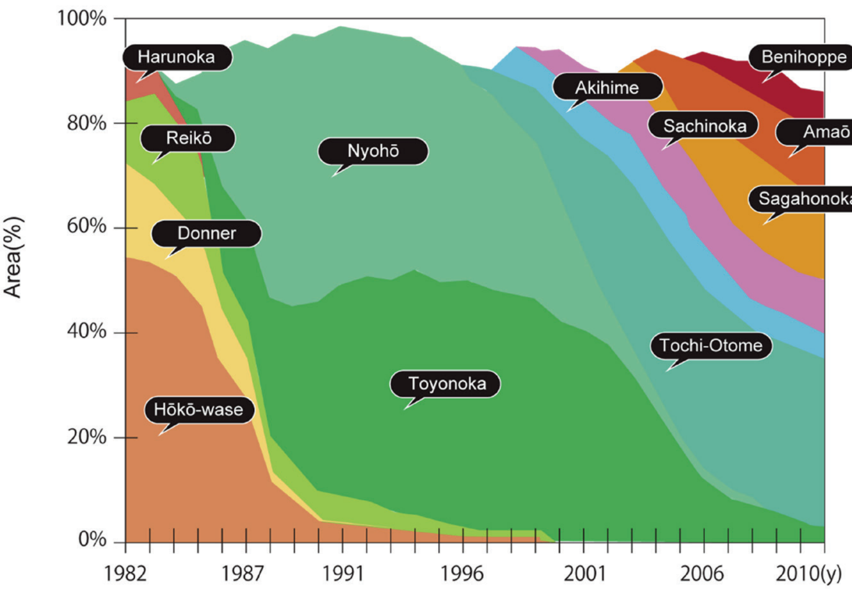

Figure 9. The trend of main cultivars between 1982-2010 (according to NFACA Japan).

descendant of 'Harunoka' and 'Hōkō-wase', and was introduced in 1985. Both 'Nyohō' and 'Toyonoka' had good yield potential and good fruit quality (size, shape and taste). These were the leading cultivars in the eastern and western regions, respectively, until about 2000.

These cultivars were later replaced by 'Tochi-Otome' (1996), 'Aki-Hime' (1992), 'Sachinoka' (2000), 'Sagahonoka' (2001), 'Amaō' (2005) and 'Benihoppe' (2002). In addition, agronomic experimental stations in regions that were not traditional strawberry growing areas launched breeding programs to improve growers' income, attract newcomers, and actively promote local fruit. Their main breeding targets were big fruit sizes, while keeping durability for transportation and off-season production. The rise in growers' average age, in addition to changes in consumers' preferences, might explain why big fruit became the breeding target. Big fruits with fewer fruits per flower truss reduced the workload for growers. On the other hand, as it is a soft fruit, strawberries are difficult to transport over long distances, but many of these new production areas were far from the big cities. Hence fruit hardiness became one of the breeding targets, especially for those areas that aimed to export fruit to South East Asia or the Middle East.

One of the characteristics of the Japanese strawberry market is year-round demand. Even though the introduction of protected cropping systems and early cultivars advanced the harvest season, off-season production was difficult to achieve. Everbearing cultivars provided a possible solution. The Japanese everbearing cultivar 'Ōishi-Shikinari' (a descendant of 'Crimson Monarch') was introduced in 1966. This became the basis of most of the Japanese everbearing progeny. Everbearing also attracted attention from vertical farming, because of a better unit price over leaf vegetables and the suitability of the crop under continuous artificial light. However, strawberry production in vertical farming has a particular issue: pollination. Inventions in instruments, robotics, as well as breeding for vertical farming-friendly lines, may enhance production in vertical farming systems.

Another new trend in Japanese strawberry breeding is the development of F_1 cultivars used as seedlings. Utilization of seedlings rather than clonal runners has advantages in pathogen control, reducing the growers' investment in mother plant protection and plantlet production, in addition to the expected hybrid vigor. These new trends have triggered significant investment from the private sector, so that today, both the private and public sectors are engaged in strawberry breeding.

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