

## New Varieties of Blueberry Released by US in 2018 and Analysis of Breeding Trends

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**Abstract** In 2018, the United States Department of Agriculture (USDA-ARS), the Clemson University, and the University of California jointly announced 40 new varieties of blueberry, including 12 varieties of northern highbush blueberry, 21 varieties of southern highbush blueberry, and 7 varieties of ornamental blueberry. Based on the analysis of the comprehensive characteristics of the announced blueberry varieties, this paper summarizes the current development trend of global blueberry breeding. The results have been shown that: 1) the cultivation of southern highbush blueberry is still the main direction of blueberry breeding, and the number of new ornamental blueberry varieties has increased. 2) The main breeding direction for northern highbush blueberry is to cultivate new varieties with early maturity, large fruit, hard texture, and good storability. 3) The breeding trend of blueberries in the southern highbush blueberry is mainly focused on cultivating new cultivars with the low chilling requirement and have comprehensive characteristics such as early maturity, large fruit, and good fruit quality. 4) The main direction of ornamental blueberry breeding is to pay attention to the diversification of fruit color and the leaf color that changes with the season for use in Garden potted plants and landscaping. 5) In recent years, China has made rapid progress in blueberry breeding except for the traditional breeding countries such as Europe and America. The breeding trend described in this paper will point out the direction for blueberry breeding in China in the future and have important practical reference value.

**Keywords** Blueberry; New variety; Variety characteristics; Breeding trend

Blueberry is a small berry fruit tree belongs to Ericaceae, *Vaccinium* L., Cyanococcus. Its fruit is rich in anthocyanins, vitamins, amino acids and other nutrients, with strong antioxidant capacity and eye protection. It is a kind of small berry with high nutritional and health value (Li et al., 2006; Zhao et al., 2016). Blueberry cultivars are mainly divided into three types: highbush blueberry, rabbiteye blueberry and lowbush blueberry. Among them, the high bush blueberry can be subdivided into northern highbush blueberry, half-high blueberry, and southern highbush blueberry according to the different chilling requirement (Sun and Li, 2014). Since the early 20<sup>th</sup> century, North America began to use wild *Vaccinium* to breed new blueberry varieties (Song and Hancock, 2011), breeding work has been nearly 120 years. With the continuous development of global blueberry industry, problems such as insufficient stress resistance, poor adaptability, and the high chilling requirement have begun to emerge. The single-trait blueberry variety is clearly unable to meet people's needs, and it is not conducive to the expansion of blueberry cultivation range (Lobos and Hancock, 2015). Therefore, it is particularly important to speed up the development of new blueberry varieties with multiple excellent traits. Blueberry has been introduced into China since the early 1980s (Wang et al., 2010), and progress of breeding work is slow. Until the last 20 years, with the continuous development of China's blueberry industry, the introduced varieties showed a variety of problems, which prompted Chinese blueberry breeders to speed up the breeding process, committed to cultivate new blueberry varieties with independent intellectual property rights in China and suitable for different regional environments. At present, according to relevant statistics, 157 national plant variety rights have been accepted from 2016 to 2019, of which 19 are authorized (data from China Forestry Intellectual Property: <http://forest.ckcest.cn:8080/43.html>).

Since 1991, USDA-ARS (U.S. Department of Agriculture-Agricultural Research Service) has published 292 new blueberry varieties (Cummins, 1991; Clark et al., 2006; 2010; Finn et al., 2008; 2012; Gasic et al., 2014; 2016; 2018; Okie, 1997; 1999; 2002; 2004), has been optimized and improved in terms of the fruit size, flavor, texture, high yield, chilling requirement and maturity traits (Hancock et al., 2008). Especially in recent years, it has become an inevitable trend to cultivate southern highbush blueberry with early maturity, extremely low chilling requirement, large to very large fruit, good fruit quality, and high yield. In 2018, USDA-ARS and other units jointly announced 40 new blueberry varieties from the United States, Australia, New Zealand, Canada and China, including northern highbush, southern highbush and ornamental blueberry types. Based on the summary and analysis of the characteristics of these new blueberry varieties in this study, the breeding trend of blueberry at home and abroad was clarified, which provided reference for blueberry breeding in China.

## 1 Results and Analysis

### 1.1 New blueberry varieties and their characteristics announced in 2018

In 2018, USDA-ARS and other departments jointly announced 40 new blueberry varieties, including 12 varieties of northern highbush blueberry, 21 varieties of southern highbush blueberry, and 7 varieties of ornamental blueberry. According to the published data, the current blueberry breeding work focuses on the cultivation of new varieties of southern highbush blueberry, followed by northern highbush blueberry and ornamental blueberry.

#### 1.1.1 Characteristics of new varieties of northern highbush blueberry

A total of 12 new varieties of northern highbush blueberry were cultivated in the United States, Australia, New Zealand and China (Table 1). Among them, the two varieties “OBF0627 (Granite™)” and “ZF08-070 (Valor)” cultivated in the United States are medium-mature varieties with the same fruit maturity period, which are suitable for mechanical harvesting. And the “OBF0627 (Granite™)” is a variety with hard texture flesh, long storage time, small and dry picking scar, moderate sweetness, floral flavor and chilling requirement up to 1 000 h. “ZF08-070 (Valor)” has balanced leaf fruit ratio, large fruit, average fruit weight of 2.5 g, high and stable yield, and good cold resistance. Five new varieties were cultivated in Australia. They are varieties of very early maturity EB 9-2 and EB 9-4, early maturity EB 8-50 and EB 9-12, and middle-late maturity EB 10-1. These new varieties are large fruit ~ extremely large fruit, and the maximum fruit weight is 2.9~5.6 g, with hard texture flesh, low sweetness and acidity fruit, and good flavor. The fruit of “Jaac” cultivated in New Zealand with large fruit, maximum fruit weight of 2.5 g, oblate fruit, high sweetness, Brix% of 16, and crisp taste. 4 new blueberry varieties were cultivated in China, namely “Huiwang No.1” with cold resistance, and “Senmao No.1”, “Senmao No.2” and “Senmao No.7”, which are suitable for fresh eating. Among them, “Huiwang No.1” is an early maturity variety with the maximum fruit weight of 2.3 g and Brix% of 12.7. “Senmao No.1” and “Senmao No.2” are both early maturity varieties with large to extremely large fruit, maximum weight of 6.6 g, good flavor, hard texture, and good storability. “Senmao No.7” is a middle-late maturity variety with large to extremely large fruits, average fruit weight of 3.4 g, small and dry picking scar, high sweetness, extremely low acidity, good flavor and storability.

#### 1.1.2 Characteristics of new varieties of southern highbush blueberry

21 new varieties of southern highbush blueberry were announced this time. Their overall characteristics are shown in Table 1. Based on the aspect of fruit maturity, FCM12-038 and FF03-178 are very early maturity varieties. A132-926 (Colibri), Patrecia, Winter Bell, FL03-228, FL06-203 (Avanti™), FL 06-377 (Endura™), FL 06-556 (Keecrisp™), FCM12-045 (AtlasBlue™), FCM12-097, FCM12-131 (JupiterBlue™), FF03-015 (CristinaBlue™) are early maturity variety. Ridley 4408 (Masena), “Chaoyue No.1”, “Xinxin No.1” are early-middle maturity variety. According to the size of fruit, there are 3 extremely large fruit types, namely Patricia, FL06-556 (Keecrisp™) and Ridley 1812, respectively. 12 large fruit types, including A132-926 (Colibri), Winter Bell, FL03-228, FL06-203 (Avanti™) and so on, with fruit weight of 2.0~3.0 g. 6 middle fruit types, which are Gumbo, FCM12-045 (AtlasBlue™), FCM12-087 (BiancaBlue™), FF03-015 (CristinaBlue™), “Chaoyue No.1”, “Xinxin No.1”.

### 1.1.3 Characteristics of new varieties of ornamental blueberry

Corablu, FLX-2 (Bountiful Blue), Rosa's Blush, Echo, TO-1088 (Cutie Pie™), VacBri1 (Cabernet Splash™), Vacsid1 (Scarlet Ovation) are the 7 new ornamental blueberry varieties announced this time (Table 1). Corablu is crossed by the *V. myrsinites* and *V. corymbosum*, with small crimson purple fruit, and good drought resistance. FLX-2 (Bountiful Blue) is early maturity variety with medium and light blue fruit, good flavor, texture, and cold resistance, and the chilling requirement is 200 ~ 300 h. Rosa's Blush is an early maturity variety cultivated by *V. darrowii* with small dark blue fruit, and cold resistance. Its leaves are bright pink in spring, blue-green at maturity, slightly pink in summer, and dark purple in autumn, which has good ornamental value. Echo is the only one of these 7 ornamental blueberries that can be secondary-fruited, with small to medium fruit, uniform and oval, soft texture, and mild flavor. TO-1088 (Cutie Pie™) is crossed by the *V. myrsinites* and *V. corymbosum*, with small and dark blue fruit, small and dry picking scar, and the chilling requirement is 400~500 h. VacBri1 (Cabernet Splash™) is middle maturity variety, with medium to large fruit, dark blue, small and dry picking scar, hard texture, suitable sweetness and acidity, and strong aroma. Its leaves in spring are dark purple, and the mature leaves have purple red mottled dark green. Vacsid1 (Scarlet Ovation) is a variety cultivated by *V. ovatum*. It is compact, and its new leaves are bright red. The fruit is deep violet-blue with small to very small size.

Table 1 General characteristics of new blueberry varieties released by US in 2018

Variety type	Number	General characteristics of varieties
Northern highbush blueberry	12	Vigorous, growth habit semi-upright, early season, larger fruit, firm, picking scar small and dry, flavor good, store well
Southern highbush blueberry	21	Vigorous, growth habit upright, early season, larger fruit, firm, picking scar small and dry, flavor good, yield excellent, low-chill
Ornamental blueberry	7	Growth habit low-growing, compact; Leaf color changes with season, small size, very good color, picking scar small and dry, flavor good, firm, drought-tolerance, cold-resistant, low-chill

## 1.2 Analysis of breeding trends of new blueberry varieties

### 1.2.1 New varieties of northern highbush blueberry

Among the 12 announced blueberry varieties, majority are the semi-erect type, which accounting for 41.67%, followed by the erect type and open type, accounting for 33.33% and 25.0%, respectively. As for the fruit size, majority are large size, accounting for 58.33%, followed by the very large size, accounting for 33.33%. Among them, the maximum fruit weight of "Senmao No.1" was 6.6 g, and that of "EB 8-50" and "EB 10-1" exceeded 5.0 g (Figure 1). As for the fruit ripening period, the early maturity varieties are the most, accounting for 50.0%, followed by the very early maturity, middle maturity, and mid-late maturity, accounting for 16.6%, respectively (Figure 2). In addition, among these new announced varieties, the hard texture flesh is more, accounting for 50.0%, one is extremely hard, namely "OBF0627 (Granite™)", accounting for 8.33%, and two with medium hardness, accounting for 16.67%. According to the above data analysis, the main breeding direction for northern highbush blueberry is to cultivate new varieties with early maturity, large fruit, hard texture, and good storability.

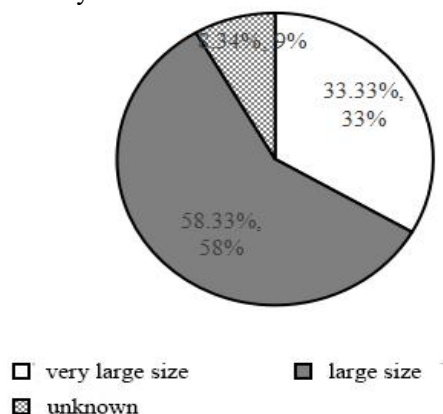


Figure 1 Proportion of fruit size of new northern highbush blueberry varieties

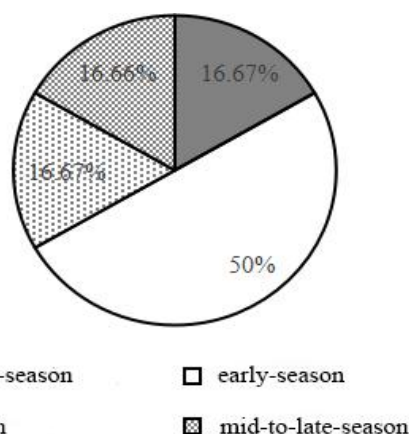


Figure 2 Proportion of fruit maturity of new northern highbush blueberry varieties

### 1.2.2 New varieties of southern highbush blueberry

Among the southern highbush blueberry varieties announced this time, majority are the erect and semi-erect type, accounting for 42.86% and 38.09%, respectively. And minority is open type, accounting for 19.05%. There are three types of fruit size, including very large, large, and medium size, accounting for 14.29%, 57.14%, and 28.57%, respectively (Figure 3). As for the fruit ripening period, majority are the early maturity varieties, and very early maturity varieties accounted for 9.52%, early maturity accounted for 52.38%, early-mid accounted for 14.29%, middle maturity accounted for 4.76%, and late maturity accounted for 14.29%. And about the fruit texture hardness, the hard texture flesh is more, accounting for 52.38%, followed by the extremely hard, and accounting for 28.58%. Among them, the flesh texture of “FL 06-377 (Endura<sup>TM</sup>)”, “FL 06-556 (Keecrisp<sup>TM</sup>)” is very hard (Figure 4). The chilling requirement of southern highbush blueberry was low. It can be seen from the announced variety introduction that the chilling requirement was mainly concentrated in 150~200 h, and the chilling requirement of some varieties was 350~400 h. In addition, southern highbush blueberry varieties generally have characteristics of good flavor, suitable sweetness and acidity, good storability, small and dry picking scar. According to the analysis of the characteristics of new varieties of southern highbush blueberry, the main breeding direction for southern highbush blueberry is to cultivate new varieties with early maturity, large fruit, very low chilling requirement, good fruit quality, and high yield.

### 1.2.3 New varieties of ornamental blueberry

Compared with the previously published new blueberry varieties, the number of ornamental blueberry varieties announced in 2018 was the largest, with a total of 7. The majority crown is semi-erect type, and the plants are low-growing, compact. Most of the fruits are small fruit type, accounting for 71.43% of the total ornamental blueberries, followed by the medium fruit type, accounting for 28.57%. Most of the fruits are blue-purple. Only drought resistance cultivar Corablue has dark red-purple fruit. The mature period of different blueberry varieties is different. FLX-2 (Bountiful Blue) and Rosa’s Blush are the variety with early maturity and cold-resistance. VacBri1 (Cabernet Splash<sup>TM</sup>) is middle maturity variety. One of the most distinctive varieties is Echo, which can be secondary-fruited. Its first mature period is earlier than that of Duke, and the second mature period begins in mid-August. In addition, the new leaves of Rosa’s blush and Vacsid1 (Scarlet Ovation) are bright red, and the leaves of VacBri1 (Cabernet Splash<sup>TM</sup>) are dark purple, which have ornamental value and are suitable for garden potting. Therefore, the main direction of ornamental blueberry breeding is to pay attention to the diversification of fruit color and the leaf color that changes with the season for use in garden potted plants and landscaping.

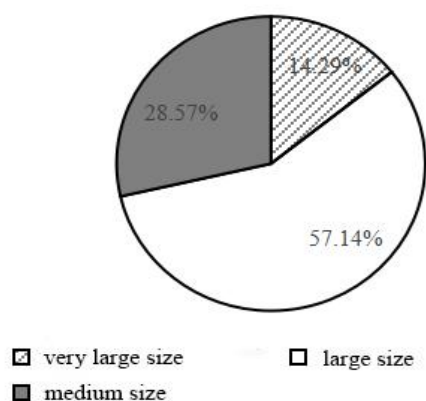


Figure 3 Proportion of fruit size of new southern highbush blueberry varieties

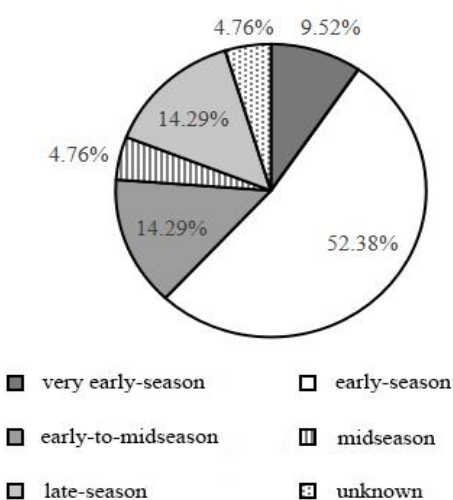


Figure 4 Proportion of fruit maturity of new southern highbush blueberry varieties

## 2 Discussion

Since 1991, USDA-ARS has published 292 new varieties of blueberries, including 80 northern highbush blueberries, 145 southern highbush blueberries, 42 rabbiteye blueberries, 10 half-high blueberries, 6 lowbush blueberries, 8 ornamental blueberries and 1 pentaploid blueberry. It can be seen from the published data that the most new varieties of southern highbush blueberry have been developed, which is the main breeding direction of blueberry breeding at present. Especially, among the 58 new blueberry varieties announced in 2016, including 42 southern highbush blueberries, which accounting for 72.41% of the total varieties of this year (Gasic et al., 2016). In recent years, the breeding trend of southern highbush blueberries is to cultivate blueberry varieties with different excellent characters, mainly focused on fruit size, hardness, flavor, storability, adaptability, and high yield. Besides, by comparing the data in recent 10 years, it was found that the number of rabbiteye blueberry is decreasing, and has dropped from 9 in 2012 to none. The main reason for this is that rabbiteye blueberry has the disadvantages of smaller fruit size (compared with highbush blueberry), more and larger seeds, and poor taste, which leads to the decrease of market demand and hinders the breeding research and development process. While, the successful breeding of a new pentaploid seedless blueberry variety “Heinooga” is of great significance for the breeding of new varieties of rabbiteye blueberry. In addition, through data analysis, it can be seen that the number of new ornamental blueberry varieties is increasing year by year, among which 7 ornamental varieties were cultivated in 2018, accounting for 17.5% of the total in 2018. The increase of this type of varieties also further shows that the current blueberry breeding direction is constantly changing and extending, and has begun to pay attention to the breeding work of potted ornamental, landscape greening and other aspects, to fully tap the potential value of blueberry, broaden the commercial field of blueberry, and cultivate new blueberry varieties with ornamental, ecological and economic value.

At present, among the blueberry varieties published by the USDA-ARS, there are 13 very early maturity varieties, 73 early maturity varieties, 36 early-mid maturity varieties, 59 middle maturity varieties, 12 mid-late maturity varieties, and 32 late maturity varieties. Among the northern highbush blueberry varieties, majority are the middle maturity varieties, accounting for 32.5%, followed by the early maturity varieties, accounting for 25%. Both the early-mid maturity varieties and late maturity varieties accounted for 13.75%. The mid-late maturity varieties accounted for 10%, and the very early maturity varieties just accounted for 5%. Among southern highbush blueberry varieties, early maturity varieties accounted for 36.55%, middle maturity varieties accounted for 22.76%, early-mid maturity varieties accounted for 17.24%, late maturity varieties accounted for 14.48%, very early maturity varieties accounted for 6.21%, and mid-late maturity varieties just accounted for 2.76%. Through data analysis, it was found that the maturity period of new blueberry varieties mainly concentrated in early maturity and middle maturity stage. The maturity stage of northern highbush blueberry varieties mainly concentrated in the middle maturity stage, followed by the early maturity varieties. Among southern highbush blueberry varieties, majority are the early maturity varieties, followed by the middle maturity varieties. The early maturity stage (mid-June) varieties are put on the market ahead of time and the price is relatively high, which is of great significance to improve the benefit of fruit farmers. And the middle maturity varieties (early-July) have better quality, and moderate price, which are popular among consumers. Most rabbiteye blueberries are late maturity varieties, and most of them mature in late August. Rabbiteye blueberry filled the blank period of the market for its characteristic of very late maturity. And because of the sufficient illumination and large temperature difference between morning and evening, its fruits have characteristics of good quality, high sweetness, low acidity, and storability (Xu et al., 2015). Therefore, the combination of early, middle and late maturity can prolong the harvest time of blueberry, to achieve the purpose of long-term supply to the market. And on the other hand, it can also avoid the shortage of labor force. In addition, very early and late maturity blueberry varieties avoid the peak season of fresh fruit listing, with higher economic benefits, which is one of the current blueberry breeding trends.

In terms of fruit size, among the 292 published blueberry varieties, there are 22 very large fruit types, 117 large fruit types, 115 medium fruit types, 11 small fruit types and 2 minimal fruit types. And among the northern highbush blueberry varieties, there are 8 very large fruit, accounting for 10%, 31 large fruits, accounting for 38.75%, 36 medium fruits, accounting for 45%, 5 small fruits, accounting for 6.25%. Among the southern highbush blueberry varieties, there are 13 very large fruit, accounting for 8.97%, 71 large fruits, accounting for 48.97%, 58 medium fruits, accounting for 40%, 3 small fruits, accounting for 2.06%. According to the statistics of fruit size, we can find that the main blueberry varieties developed at present are large fruit type and medium fruit type. Among the northern highbush blueberry varieties, majority are the medium fruit, followed by the large fruit. While among the southern highbush blueberry varieties, majority are the large fruit, followed by the medium fruit. Fruit size is a very important trait in the evaluation of blueberry appearance quality. It is also one of the important indexes of market grading of high-quality fruit, which directly affects the commodity value and economic benefits. According to the different commercial uses, large and medium fruit blueberry varieties are more suitable for sale as fresh fruit, while small to medium fruit blueberry varieties, which are easy to be harvested by machine are more suitable for processing. Therefore, on the one hand, we should carry out the breeding work of large fruit blueberry varieties to meet the demand of blueberry fresh food market. On the other hand, we should strengthen the breeding work of small and medium blueberry varieties with high anthocyanin content, consistent maturity, and easy mechanical harvesting, so as to broaden its processing field, improve market competitiveness and obtain greater economic benefits.

In terms of chilling requirement, among the published blueberry varieties at 7.2°C, there are 56 blueberry varieties with very low chilling requirement (<300 h), 108 blueberry varieties with low chilling requirement (300~600 h), 22 blueberry varieties with medium chilling requirement (600~900 h) and 81 blueberry varieties with high chilling requirement. Among them, northern highbush blueberry varieties with medium-low chilling requirement accounted for 3.75%, varieties with medium chilling requirement accounted for 6.25%, varieties with high chilling requirement accounted for 90%. While southern highbush blueberry varieties with medium-low chilling

requirement accounted for 35.17%, varieties with low chilling requirement accounted for 55.17%, varieties with medium chilling requirement accounted for 8.97%, varieties with high chilling requirement accounted for 0.69%. Rabbiteye blueberry varieties with medium-low chilling requirement accounted for 11.91%, varieties with low chilling requirement accounted for 59.52%, varieties with medium chilling requirement accounted for 9.52%, varieties with high chilling requirement accounted for 19.05%. It can be seen from the above data that the low chilling requirement varieties are the most, followed by the high chilling requirement varieties among the present blueberry varieties. The low chilling requirement varieties are mainly southern blueberry and rabbiteye blueberry. Among southern blueberry varieties, majority are low chilling requirement varieties, followed by the very low chilling requirement varieties. While among northern blueberry varieties, nearly 90% varieties are high chilling requirement blueberries. Under the trend of global warming, the varieties with high chilling requirement often suffer from the problem of insufficient cold and temperature caused by warm climate, resulting in irregular flowering, low flower bud germination rate, and low fruit setting rate (Yang et al., 2020). On the one hand, the low chilling requirement varieties can reach their chilling requirements ahead of time under the controllable conditions of greenhouse cultivation, avoid long-term dormancy in warm winter climate, and greatly advance the listing time of blueberry. On the other hand, it breaks the cultivation boundary and expands the planting range of blueberry. Therefore, the main development direction of blueberry breeding is to cultivate new varieties of southern highbush blueberry with low and very low chilling requirements.

Blueberry breeding is mainly achieved by interspecific hybridization. However, most of the existing northern highbush blueberry varieties have some problems such as inbreeding and narrow genetic basis, and the cultivated plants have weakened tree vigor and poor adaptability (Brevis et al., 2008). For example, the common northern highbush blueberry varieties, such as Jersey, Coville, Berkeley, Lateblue and Elliott, have only *V. corymbosum* in their genetic background. American blueberry breeders have formulated corresponding breeding objectives according to the characteristics of different regional environments. They have successively integrated many wild blueberry genes, such as *V. darrowii*, *V. angustifolium*, *V. constablaei*, into the northern highbush blueberry varieties to improve fruit flavor, storability, maturity, enhance diseases and insects resistance, and cold resistance (Hancock et al., 1995; Ballington, 2009). Besides, with the successful breeding of new blueberry varieties using wild blueberry in the United States, some European countries began to use their local resources to cultivate new blueberry varieties with more cold resistance, short growth season and high antioxidant activity (Yu and He, 2013). The genetic background of northern highbush blueberry varieties is mainly composed of *V. corymbosum*, *V. angustifolium*, *V. ashei* syn. / *V. virgatum*, *V. darrowii*, *V. tenellum*, and *V. constablaei*. While, *V. uliginosum*, *V. pallidum*, and *V. simulatum* have potential value in improving early maturity, drought resistance, cold resistance and adaptability of northern highbush blueberry (Luby et al., 1991). The genetic background of southern highbush blueberry varieties is the most complex. It is mainly composed of *V. corymbosum*, *V. angustifolium*, *V. darrowii*, *V. ashei* syn. / *V. virgatum*, *V. tenellum*, *V. elliotii*, and *V. constablaei*. Some varieties also contain *V. myrtilloides*, *V. myrsinites*, *V. arboretum* and *V. simulatum* (Hancock et al., 1997; Ballington et al., 2006). Among the genetic background of southern highbush blueberry varieties, *V. darrowii* and *V. ashei* syn. are the main gene sources of low chilling requirement, heat and drought resistance, while the minor gene sources are *V. tenellum*, *V. elliotii*, and *V. constablaei*. Compared with the highbush blueberry, the genetic background of the seven new ornamental blueberry varieties was mainly composed of four wild blueberries, *V. corymbosum*, *V. darrowii*, *V. myrsinites*, and *V. ovatum*. Therefore, in the future blueberry breeding, we should strengthen the development and utilization of wild blueberry germplasm resources, fully develop the excellent characteristics of wild blueberry, introduce excellent genes of wild resources, and improve the fruit quality of commercial blueberry varieties, so as to expand the planting range of blueberry and promote the rapid development of blueberry breeding.

At present, blueberry breeding is no longer limited to the United States, Canada and other countries of origin. Blueberry breeding in Australia, New Zealand, Japan, Europe and China also has gradually achieved success. According to statistics, since 1991, among the new blueberry varieties released by the USDA-ARS, 208 new varieties are cultivated in the United States, 28 in Australia (including 10 new varieties were co-bred with America), 25 in New Zealand, 9 in Romania, 7 in Japan, 6 in China, 5 in Canada, 2 in Sweden and 2 in Latvian.

At present, northern highbush blueberry breeding work is mainly carried out in New Jersey, Michigan, Oregon and other places in the United States, while some are carried out in Australia, New Zealand, Chile, Japan and China. And varieties of Bluecrop, Duke, Cara's Choice, Draper, Hannah's Choice, Liberty and Huron are widely used in commercial cultivation. In addition to the USDA-ARS, private breeding teams such as Berry Blue in Michigan, Fall Creek Farm & Nursery in Oregon, Driscoll's in California, University of Talca in Chile and Vital Berry are also actively engaged in the research and development of new north high bush blueberry varieties. Southern highbush blueberry breeding is mainly conducted in Arkansas, California, Florida, Georgia, Mississippi, Australia, Chile and Spain. The blueberry varieties Emerald, Jewel, Misty, Star and Camelia are of great commercial value. And Florida Foundation Seed Producers, Atlantic Blue in Spain, Berry Blue in Michigan, Driscoll's in California, Mountain Blue Orchards in Australia and Vital Blueberry in Chile and other company teams also participated in the breeding of southern highbush blueberry varieties. In addition, lowbush blueberry breeding is mainly carried out in the United States and Canada and other countries. Kentville Research Center (NS) of the Ministry of Agriculture of Canada has successively cultivate new varieties of lowbush blueberry, such as Augusta, Blomidon, Brunswick, Chignecto, Cumberland, Fundy and Novablue, which are suitable for local planting. The breeding of half-highbush blueberry varieties was mainly conducted in the University of Minnesota in the United States. Northblue, Northsky, Northcountry, St.Cloud and MNPink1 Pink Popcorn were successively cultivated one after another. The cultivation of new varieties of rabbiteye blueberry is mainly carried out in the United States, New Zealand and Japan. The main varieties are Climax, Tifblue, Brightwell, Bonita and Premier. China started late and there is still a big gap with North America and other countries of origin. But China has made some achievements through continuous efforts. Dalian University and Dalian Senmao Modern Agriculture Co., Ltd. have successively cultivated 4 new northern highbush blueberry varieties one after another, "Senmao No.1", "Senmao No.2" (Lei et al., 2019), "Senmao No.3" (Peng et al., 2019) and "Senmao No.7". The Institute of Botany, Chinese Academy of Sciences of Jiangsu Province, has successively released three new varieties of blueberry, namely "Zhaixuan 4", "Zhaixuan 7" and southern highbush blueberry "Chaoyue No. 1" (<http://forest.ckcest.cn:8080/43.html>). Therefore, as one of the major contributors of blueberry in Asia, with the growing scale and industrialization of blueberry production, we should learn from foreign blueberry breeding research experience, analyze the global blueberry breeding trend in recent years, and carry out the research and development of new blueberry varieties suitable for different regions in China. At the same time, we should strengthen the collection, evaluation and utilization of wild blueberry resources in China, and combine with modern molecular biological means to excavate its excellent characters, and introduce them into the existing blueberry varieties, broaden the genetic basis of the existing blueberry varieties in China, so as to develop new blueberry varieties suitable for China's local regional environment and with China's independent intellectual property rights, to promote the rapid and healthy development of China's blueberry industry.

### **3 Materials and Methods**

#### **3.1 Materials and main experimental sites**

In this study, 40 new blueberry varieties jointly released by Clemson University, USDA-ARS and University of California in 2018 were used as materials. These varieties are mainly from the United States, Australia, China, New Zealand, Canada, etc. The new blueberry varieties in the United States are mainly carried out in Hartmann Nursery Cooperative Company in Michigan, Horticultural Crop Research Group of the USDA-ARS, Fall Creek Farm & Nursery, Oregon Blueberry Farms and Nursery in Oregon, and Florida Foundation Seed Producers. And there are also a few cultivated in Mississippi, Georgia and Washington. The blueberry varieties cultivated in Australia mainly carried out in Jundale City and Mountain Blue Orchards in New South Wales. In this study, the 6 independently developed blueberry varieties in China are from Jiangsu Institute of Botany, Chinese Academy of Sciences, Nanjing, China, Anhui Agricultural University, Anhui Huiwang Agricultural Co., Ltd., Dalian University and Dalian Senmao Modern Agriculture Co., Ltd. In addition, Gordon in Waikato, New Zealand, and Sidhu & Sons Nursery in British Columbia, Canada is also breeding experimental sites for new blueberry varieties.



### 3.2 Analysis method

We consulted and sorted out the new blueberry varieties and their characteristics released in the United States in 2018. At the same time, we summarized the relevant literature on blueberry breeding and comprehensively analyzed the breeding trends at home and abroad in recent years. Finally, Microsoft Excel was used to sort out and analyze the data.

#### Authors' contributions

WHX conceived of the study. XGH directed of this study, guide its draft, and revision of the manuscript. ZMJ translated English materials related to this study. LL drafted the manuscript. AQ, ZLN, and LGL performed the statistical analysis. All authors read and approved the final manuscript.

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#### Reference

- Ballington J.R., 2009, The role of interspecific hybridization in blueberry improvement, *Acta Horticulturae*, 810: 49-60  
<https://doi.org/10.17660/ActaHortic.2009.810.2>
- Ballington J.R., Rooks S.D., Bland W.T., and Draper A.D., 2006, The role of interspecific hybridization in the North Carolina State University blueberry breeding program, *Proc. 10th North Amer. Blueberry Res. & Ext. Workers' Conf.*, pp. 6-13
- Brevis P.A., Bassil N.V., Ballington J.R., and Hancock J.F., 2008, Impact of wide hybridization on highbush blueberry breeding, *Journal of the American Society for Horticultural Science*, 133(3): 427-437  
<https://doi.org/10.21273/JASHS.133.3.427>
- Clark J.R., and Finn C.E., 2006, Register of new fruit and nut varieties list 43, *HortScience*, 41: 1106-1107  
<https://doi.org/10.21273/HORTSCI.41.5.1101>
- Clark J.R., and Finn C.E., 2010, Register of new fruit and nut varieties list 45, *HortScience*, 45(5): 721-723  
<https://doi.org/10.21273/HORTSCI.45.5.716>
- Cummins J.N., 1991, Register of new fruit and nut varieties, *HortScience*, 26(8): 951-986  
<https://doi.org/10.21273/HORTSCI.26.8.951>
- Finn C.E., and Clark J.R., 2008, Register of new fruit and nut varieties list 44, *HortScience*, 43(5): 1324-1325  
<https://doi.org/10.21273/HORTSCI.43.5.1321>
- Finn C.E., and Clark J.R., 2012, Register of new fruit and nut varieties list 46, *HortScience*, 47(5): 540-542  
<https://doi.org/10.21273/HORTSCI.47.5.536>
- Gasic K., and Preece J.E., 2014, Register of new fruit and nut varieties list 47, *HortScience*, 49(4)  
<https://doi.org/10.21273/HORTSCI.49.4.396>
- Gasic K., Preece J.E., and Karp D., 2016, Register of new fruit and nut varieties list 48, *HortScience*, 51(6): 625-628  
<https://doi.org/10.21273/HORTSCI.51.6.620>
- Gasic K., Preece J.E., and Karp D., 2018, Register of new fruit and nut varieties list 49, *HortScience*, 53(6): 755-758  
<https://doi.org/10.21273/HORTSCI536register-18>
- Hancock J.F., Erb W.A., Goulart B.L., and Scheerens J.C., 1997, Blueberry hybrids with complex genetic backgrounds evaluated on mineral soils: cold hardiness as influenced by parental species and location, *VI International Symposium on Vaccinium Culture*, 446: 389-396  
<https://doi.org/10.17660/ActaHortic.1997.446.57>
- Hancock J.F., and Galletta G.J., 1995, Dedication: Arlen D. Draper: Blueberry Wizard, *Plant Breeding Reviews*, 13: 1-10  
<https://doi.org/10.1002/9780470650059.ch1>  
PMid:20377122
- Hancock J.F., Lyrene P.M., Finn C.E., Vorsa N., and Lobos G.A., 2008, Blueberries and Cranberries, *Temperate Fruit Crop Breeding*, 115-150  
[https://doi.org/10.1007/978-1-4020-6907-9\\_4](https://doi.org/10.1007/978-1-4020-6907-9_4)
- Lei L., Wang H.X., Xu G.H., Peng H.C., Liu G.L., Zhang M.J., and Wei B.K., 2019, A new blueberry cultivar 'senmao 2', *Yuanyi Xuebao (acta horticulturae sinica)*, 46(S2): 2756-2757
- Li Y.D., Liu H.G., Zhang Z.D., and Wu L., 2006, Thoughts on the development of *Vaccinium* industry in China, *Zhongguo Guoshu (China Fruits)*, (01): 46-47
- Lobos G.A., and Hancock J.F., 2015, Breeding blueberries for a changing global environment: a review, *Frontiers in plant science*, 6: 782  
<https://doi.org/10.3389/fpls.2015.00782>  
PMid:26483803 PMCID:PMC4588112
- Luby J.J., Ballington J.R., Draper A.D., Pliska K., and Austin M.E., 1991, Blueberries and cranberries (*Vaccinium*), *International Society for Horticultural Science*, pp 391-456  
<https://doi.org/10.17660/ActaHortic.1991.290.9>



- Okie W.R., 1997, Register of new fruit and nut varieties list 38, HortScience, 32(5): 787  
<https://doi.org/10.21273/HORTSCI.32.5.785>
- Okie W.R., 1999, Register of new fruit and nut varieties list 39, HortScience, 34: 184-185  
<https://doi.org/10.21273/HORTSCI.34.2.181>
- Okie W.R., 2002, Register of new fruit and nut varieties list 41, HortScience, 37: 252-253  
<https://doi.org/10.21273/HORTSCI.37.2.251>
- Okie W.R., 2004, Register of new fruit and nut varieties list 42, HortScience, 39: 1509-1510  
<https://doi.org/10.21273/HORTSCI.39.6.1509>
- Peng H.C., Wang H.X., Xu G.H., Lei L., Liu G.L., Yan D.L., and Zhao L.N., 2019, A new blueberry cultivar 'Senmao 3', Yuanyi Xuebao (Acta Horticulturae Sinica), 46(S2): 2758-2759
- Song G.Q., and Hancock J.F., 2011, *Vaccinium*, Wild Crop Relatives Genomic & Breeding Resources, 197-221  
[https://doi.org/10.1007/978-3-642-16057-8\\_10](https://doi.org/10.1007/978-3-642-16057-8_10)
- Sun H.Y., and Li Y.D., 2014, Overview of blueberry breeding in the world, Dongbei Nongye Daxue Xuebao (Journal of Northeast Agricultural University), (9): 116-122
- Xu G.H., Wang H.X., and Gao X.M., 2015, Resources and characteristics of new blueberry varieties in the United States in recent ten years, Zhongguo Nanfang Guoshu (South China Fruits), 44(4): 138-144
- Wang H.L., Zhang H.Q., Xiao J.P., and Xie M., 2010, Overview of blueberry breeding research, Zhejiang Nongye Kexue (Journal of Zhejiang Agricultural Sciences), 1(3): 474-481
- Yang Y.C., Wei X., Sun B., Zhang D., Wang X.D., Liu Y.C., Wei Y.X., Tian Y., and Liu C., 2020, The research and analysis of the low chilling requirement of different blueberry varieties, Nongye Keji Tongxun (Bulletin of Agricultural Science and Technology), 2020(01): 178-181
- Yu H., He S.A., 2013, Status of the world's blueberry industry and research, Luoye Guoshu (Deciduous Fruits), 45(3): 19-22
- Zhao L.N., Wang H.X., Xu G.H., and Chen Y.M., 2016, The latest *Vaccinium* cultivars and their characteristics released by the United States, Zhongguo Nanfang Guoshu (South China Fruits), 45(05): 174-180