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# Evaluation and Breeding of Haskap in North America

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**Abstract**

Blue honeysuckle (*Lonicera caerulea* L.) plants from several geographic sources were evaluated. These included botanical varieties *edulis*, *kamtchatica*, *altaica*, and *boczkarnikovae* from Russia, *edulis* and *boczkarnikovae* from northeast China, and *emphyllocalyx* from Hokkaido, Japan. It became clear that the Japanese variety *emphyllocalyx* has superior adaptability in Oregon. Therefore, a breeding program utilizing this variety was initiated in 2003 in Oregon with collaboration in Idaho. Breeding objectives, breeding methods, variability of important horticultural traits, and the scope of the program are presented. Advanced replicated trials of outstanding selections are underway in expectation of identifying superior individuals to release as cultivars that will form the basis for a new berry industry in the Northwestern United States.

Blue honeysuckle (*Lonicera caerulea* L.) is a very popular berry crop in Russia and is gaining interest in some northern European countries due to its very early maturity, unique flavors, high nutritional values, and ease of cultivation (2, 6). It was domesticated in the Soviet Union during the latter half of the 20th century and many cultivars have been released. That this berry has attracted attention in North America only recently is partly due to lack of access to the Soviet Union during the period of haskap domestication and partly to limited exchange of plant materials during most of this period. Also, although there have been abundant research reports, these are written in Russian publications not readily accessible in the West. However, during the past several years, One Green World Nursery in Mollala, Oregon has introduced and marketed several Russian cultivars in North America under the common name of "honeyberries". Although these plants are well adapted to cold northern regions, performance has been disappointing in most regions of the U.S. Because of the abundant diversity among the several botanical varieties of *Lonicera caerulea* there appeared the possibility of finding some forms adapted to moderate, temperate climate regions. Therefore, a research program was initiated in 1997 to evaluate germplasm from several geographic regions with the goal of discovering some elite selections to use either directly or as parents in a breeding program. In 2002, Prof. Danny L. Barney at the University of Idaho Research and Extension Center in Sandpoint, Idaho became a collaborator, thereby extending the scope of the program. The Idaho site provides an opportunity to evaluate the adaptation of seedlings and selections in a colder environment. In 2004, Prof. Bob Bors at the University of Saskatchewan in Saskatoon, Canada, who already had established a sizable collection of Russian cultivars, also became a cooperator with the Oregon/Idaho program. The Saskatoon site will provide information on cold hardiness and adaptability of the Japanese variety in a continental climate with low temperatures of -40° C most winters.

By 2004, it became clear that the Japanese variety, *emphyllocalyx,* (common name 'haskap') appeared to be well-adapted in Oregon and Idaho. Therefore, several outstanding plants of this group were used as parents in the first controlled crosses of the breeding program. The goal is to develop adapted cultivars with high quality, early-

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ripening berries with high nutritional values that will form the basis for a new berry industry in the Northwest. As the Japanese have already demonstrated, there is a high-value niche market for the uniquely-flavored, exceptionally fine processed products.

As the goal of releasing cultivars for the berry industry approaches, use of the name "haskap" is preferred over "Japanese blue honeysuckle" for several reasons: to recognize the origin as the Ainu name for this fruit in its native home; to continue the appellation used by the Japanese berry industry; and, although a foreign word, it is simple and easy to pronounce and spell. Also, in North America the name "honeysuckle" creates a mental image of an ornamental vine with inedible fruit. Finally, it is important to distinguish this new berry from the inferior or poorly-adapted blue honeysuckle plants (sometimes called "honeyberry") currently available in North American nurseries.

**Assembling germplasm**

This *Lonicera caerulea* L. research program began with evaluation of blue honeysuckle seedlings grown from seeds of open-pollinated varieties *edulis* Turc. ex Herder and *boczkarnikovae* Plekh. collected in northeastern China in 1996 and seeds of varieties *edulis*, *kamtschatica* Sevast., and *altaica* Pall. obtained from Russia in 1998 and 2000. After five years' observations of 3400 seedlings and 24 clonal cultivars/selections in Oregon, we corroborated what the leading Russian *Lonicera* scientist had reported: although Russian blue honeysuckle plants are extremely cold-hardy and well adapted to northern regions, they can not be grown successfully in the more moderate climate regions of southern Russia (5). The problem lies in the very short rest period, ending in October-November. When completed, warm temperatures cause a loss of cold hardiness so that when even moderately cold temperatures resume, there can be considerable freeze damage to dormant buds. Another difficulty is that these northern plants bloom too early in temperate climates, at a time when it is too cold for bee flight, resulting in poor yields due to inadequate cross-pollination of these self-incompatible plants. Therefore, work with Russian blue honeysuckle plants has been essentially discontinued in Corvallis, Oregon.

In 2000, seeds were obtained from plants in Sweden and Latvia that originated from plants that had been collected in the Kurile Islands by Russian scientists (4). Boczkarnikova (1) originally considered them to be var. *emphyllocalyx* but Plekhanova (4) later concluded that they were a form of var. *kamtschatica.* Observations on the limited germplasm available in our collection suggest that these plants are distinctly different from either of those varieties. The possibility of these island forms being a distinct variety needs to be verified by more extensive studies of local populations.

The focus of the program was redirected when it was observed that the Japanese variety, *emphyllocalyx* Nakai, blooms about one month later than the Russian forms. This trait suggested that these plants have a longer rest period and, therefore, would not exhibit the weaknesses of Russian varieties in moderate, temperate climates. This unique variety, locally called 'haskap', is native to Hokkaido and northern Honshu. Characteristics of this plant are described, the history of domestication, and development of the berry industry in Japan is discussed in a recent paper (10). During a trip to Japan in 2000, seeds from ten different sources were collected, brought to Oregon and planted in a greenhouse in January 2001. Resultant seedlings provided the foundation for the current evaluation and breeding program. Recently, seeds from six additional sources in Japan have been acquired and planted. Seedlings are still too young to have been evaluated.

### Relative value of plants from different sources

Seeds from northeastern China (Jilin and Heilongjiang) were collected from unselected wild plants from five sources and seedlings were of no value. Plants bloomed very early and there was a great deal of winter freeze damage to buds. Some young plants froze to the ground each winter and then sent up new shoots in spring. Overall, they produced very few, very small berries. Of 517 seedlings evaluated, only one (0.2%) was saved. Although fruits are very small and not abundant, at 5 years old, this bush was about twice the size of others and did not suffer freeze damage.

Weaknesses of Russian varieties are described above. Thirty eight of 3225 seedlings (1.2%) have been saved for possible use in breeding for early fruit maturity.

Plants originating from the Kurile Islands and the Japanese variety, *emphyllocalyx*, share one important trait, late blooming. Most of these seedlings tend to have too spreading a growth habit: some form low mounds and some are more upright, but with wide-angled branches. Stems are generally thick and rather pubescent. A few seedlings have large, attractive fruits with distinctly different flavors, although most are very small, not very tasty, and often misshapen. Eighteen of 672 plants (2.7%) have been saved for possible use in breeding for fruit size and quality and late blooming. They are also being considered for edible ornamentals because some have attractive, rounded bush shape and late retention of green leaves in autumn.

Clearly, the Japanese variety, *emphyllocalyx*, with 202 of 1411plants (14.3%) saved, is far superior to all others evaluated in this program. Bushes are vigorous and plants productive of tasty berries, many of large size. Four progenies with a high percentage of good seedlings originated from seeds of forms selected by the Japanese and currently growing on farms or at the Plant Genetic Resource Center in Hokkaido. These four maternal plants have provided us with high quality initial germplasm exhibiting considerable variability in all traits desired. By contrast, among six progenies that originated from unselected wild plants there are very few or no seedlings of value. The few saved represent a very small fraction of the total number of *emphyllocalyx* seedlings evaluated.

### Breeding objectives

The objectives of the breeding program are to develop cultivars suitable for both commercial plantings and for home gardens or small U-pick operations. Certain selections will be more desirable for processing while others will be preferred for fresh consumption.

1) For all uses, plants should be productive annually with good tasting berries and high nutritional values.

2) Bush growth habit must be vigorous and upright for mechanical harvesting, whereas for home gardens bushes may be less vigorous and more spreading.

3) A seasonal succession of cultivars ranging in fruit maturity from early to late is desired, especially for small plantings and fresh market use.

4) For all uses, attachment of ripe fruits to the pedicel should be tight enough so fruits do not fall prematurely, but loose enough so they can be removed easily at harvest.

5) Concentrated fruit maturity, or earlier ripening fruit remaining attached until later ones are mature, is especially important for commercial plantings where mechanical harvesters are used. By contrast, a spread in maturity to extend the fresh fruit season may be desired in home gardens.

6) Fruit size, appearance, firmness, and degree of sweetness or acidity are not so critical for processing cultivars. Total yield per plant is more important than fruit size. As berries for processing will no doubt be

frozen shortly after harvest, soft fruit is not a problem unless it is so soft that it cannot withstand cleaning and processing. The degree of tartness desired varies with the ultimate use: higher acid berries may be desired for certain processed products. In contrast, these berry quality factors have high priority for cultivars for home garden or fresh markets. Berries for fresh consumption must have a high sugar:acid ratio so taste is not too tart. Berries should be large (1.5 to 2.5 g per berry), have uniform shapes and sizes, and be attractive with a smooth surface without blemishes or open apices. Firm fruits with extended cold storage capability are desired to extend the fresh fruit marketing season.

## The breeding program

Initial populations evaluated consisted, of necessity, of open-pollinated seedlings. As these plants came into bearing, outstanding forms were chosen to use as parents in breeding. Controlled pollinations are made by enclosing the maternal parent in a cylinder of chicken wire covered with insect netting to exclude bees. When flowering is completed, netting is removed and the wire cylinder retained to exclude bird predation. To avoid contamination by bees visiting flowers, pollen is collected by cutting branches with advanced flower buds, but not yet open, forcing flowers indoors and removing anthers to a sheet of paper to dry overnight. Collected pollen remains sufficiently viable throughout the flowering season if stored in a refrigerator. Because plants are essentially self-incompatible, pollinations are made without emasculating flowers. For precise genetic studies, emasculation would be necessary. However, for creation of hybrid populations to select cultivars the amount of potential error due to selfing is balanced against the tedious, time-consuming emasculation process. Pollination is effected with a small camel hair brush. Pollinations are made two times on the same branches due to the range in flower opening. Hundreds of seeds can be easily produced because for each stigma pollinated, 30-40% develop fruits having an average of seven seeds per fruit.

The scope of the breeding work from 2003 to 2006 is given in Table 1. Portions of the hybrid seedlings produced in Corvallis were distributed to Sandpoint in the first three years and to Saskatoon in the past two years. In this

**Table 1.** The scope of haskap breeding populations in Corvallis, OR and Sandpoint, ID, October, 2006.

| | Corvallis | | Sandpoint | | |
|---|---|---|---|---|---|
| Sowing Year | No. of crosses | No. of seedlings | No. of crosses | No. of seedlings | Current status |
| 2003 | 45 | 2546 | 14 | 300 | 3rd year in field |
| 2004 | 55 | 1950 | 11 | 374 | 2nd year in field |
| 2005 | 24 | 750 | 24 | 700 | 1st year in field |
| 2006 | 15 | 391 | 0 | 0 | to be planted Oct. 2006 |
| Total | 139 | 5637 | 49[z] | 1374 | |

[z] included among the 139 crosses made in Corvallis

latter site, several hundreds of seedlings are in the early stages of growth. A small portion of hybrid seeds produced in 2005 have been planted in Corvallis only, and no crosses were made in 2006 due to lack of field space and resources to grow more seedlings. Extra seeds were placed in a freezer at -19°C to prolong their viability for possible future use. Seeds are germinated in flats, transplanted to pots, and maintained in a greenhouse the first year to obtain large size for field planting in fall. The selection process begins during this first season by saving plants with good vigor and erect growth habit, while discarding plants with low vigor or a spreading growth habit.

Although most plants have some fruits the first year in the field at Corvallis, they are not evaluated until the second year because berries are relatively few and smaller than on older plants. Due to slower plant maturation in the cool, short growing seasons of the northern Rocky Mountains and south central Canada, evaluation and selection in Sandpoint and Saskatoon require at least three years from sowing. Harvest of second-year plants in 2006 in Corvallis represents the first evaluation of seedlings from controlled crosses. This population of hybrids has demonstrated superior individuals as compared to previous seedlings from open pollination. For example, a few crosses had a high percentage of seedlings with high to very high yield estimates. One outstanding, upright-growing plant had 434 g of fruit that averaged 1.5 g. Crosses between two large-fruited parents have resulted in many large-fruited offspring, with size ranging up to 2.7 g per berry. Time of fruit maturity has been extended in seedlings from crosses between two late parents. In 2006, many promising selections have been identified for more intensive evaluation and potential propagation next year. These first-year results indicate that there is good potential for genetic improvement with further breeding.

**Variability in important horticultural traits**

The germplasm currently available exhibits wide genetic variability. All of the traits needed to fulfill the objectives for new cultivars have been observed in different individual seedlings. The challenge remains to incorporate all of them into elite individuals.

Yield varies considerably but, for most seedlings in Corvallis, can only be estimated due to bird predation and incomplete harvesting. Plants of special interest must be netted in order to collect the berries. The highest yield recorded for a 6$^{th}$ year seedling in Corvallis was 2.2 kg. One outstanding seedling in Sandpoint, ID produced 2.1 kg in the 4$^{th}$ year. Not only did it yield 60% more than the next highest yielding plant, it had the largest fruit size (1.9 g). The highest yield of a netted, vegetatively propagated selection in the third year in the field at Corvallis was 1.5 kg. Potential yield of mature plants is unknown as yet because plants are still too young.

Plant vigor ranges from very vigorous, tall plants to dwarfs. The latter bush type may be useful in home gardens as an edible ornamental. Branch angles, which determine bush shapes, range from very narrow (30°) to very broad (90°). Bushes with narrow angles are very upright but also too dense, whereas those with too wide an angle are very spreading, or drooping. Plants with medium-upright growth are preferred for commercial use, whereas a lower, wider bush appearing as a procumbent mound may be acceptable in home gardens.

Bloom dates are influenced by spring temperatures. Russian continental types respond more quickly than haskap to early warm weather. In Corvallis, with mild weather in January-February, Russian selections will begin to bloom in early February while haskap and Kurile Islands plants begin to bloom 3-5

weeks later, in March. In warm springs, mid-bloom is near the end of March for haskap and Kurile Islands forms, but with cooler temperatures it is delayed until mid-April. In Sandpoint, haskap reaches full bloom in early to mid-May. In general, haskap blooms during the same period as apple; that is, somewhat later than cherries and plums, and at a time when bees are active. The annual variation in mean mid-bloom dates for all three types of blue honeysuckle in Corvallis is given in Table 2.

Haskap berries ripen very early, before most strawberries. The duration of harvest among the Corvallis plantings varied with the season. In 2003, harvest began April 28 with the earliest Russian types and ended June 7 with the latest Japanese haskap. In 2004 and 2005, it began April 27 and finished June 1. In the cool spring of 2006, the earliest plants were harvested May 7 and the latest June 18. Due to the cooler weather during the fruit development period in 2003 and 2006, harvest lasted almost six weeks and in warmer years, four and a half to five weeks. On a given plant, fruits ripen over varying periods of time. For example, in 2005, on one seedling in Corvallis, all fruits were harvested May 6 and on another there were five harvests over a 3-week period, from May 5 to May 26. In the colder climates of Sandpoint, ID and Saskatoon both bloom and harvest occur at least one month later.

Berries on a few bushes are so tightly attached that fruit ruptures when picked. On others, fruits are so loosely attached that they release from the plant at a slight touch. Encouraging results for fruit retention were obtained on 25 pairs of 3-year old netted selections: harvest was delayed until all fruits had developed good dark color and, although they did not all reach maturity at the same time, very few had fallen.

Fruit size ranges from 0.5 to 2.7 g per berry and many selections produce berries in the desired size range of 1.5 to 1.8 g. Seedlings with fruits less than 1.0 g are rejected unless they have some other outstanding trait that might be useful for breeding. Shapes are mostly acceptable; most are oval, cylindrical or shaped like an American football. Defects that may be occasional or may involve most of the fruit on a bush include bumpy fruit surface or projecting rings of tissue, often with objectionable hairs, at the fruit apex. These ridges are the apical edges of the fleshy bracts surrounding ovaries that do not seal tightly. Deformed fruits result from incomplete closure of these bracts forming a large opening through which the ovaries protrude.

As taste perception is influenced by the relative amounts of soluble solids and acids, a preliminary survey was made of 146 fruit samples from unselected seedlings for °Brix, acidity (reported as g/100 ml citric acid), pH, and °Brix:acid ratios. Since values obtained were influenced by differing stages of fruit maturity and by the fact that samples were not replicated for statistical analysis, our

**Table 2.** Annual variation in mean mid-bloom dates of *Lonicera caerulea* plants from three sources grown in Corvallis, Oregon.

| Source | 2002 | 2003 | 2004 | 2006 | Range (days) |
|---|---|---|---|---|---|
| Russia | March 31 | February 22 | n.d.[z] | n.d. | 37 |
| Kurile Islands | April 13 | March 25 | n.d. | n.d. | 19 |
| Haskap | April 18 | March 27 | March 27 | April 1 | 22 |

[z] no data because plants had been discarded

data may not be an accurate presentation of the genetic differences between selections. However, it does give an overview of the range of the considerable variability present among the seedlings. The mean °Brix value was 9.70, with a range of 6.68 to 12.98. Mean titratable acidity was 3.34 and ranged from 1.91 to 4.86. The mean pH was 2.94, with a range of 2.42 to 3.57. The mean °Brix/acid ratio was 3.06 and ranged from 1.57 to 5.93. Significantly higher Brix values, over 17°, have been reported for selected forms in Japan (8, 9) which demonstrates the potential for sweeter haskap forms than those tested in our survey. In our plot, the seedling with the highest °Brix rating, as well as the highest °Brix:acid ratio, had been previously noted at the time of harvest as having a good, mild flavor. Among one progeny, originating from seeds of a plant chosen in Japan for having tasty fruits, 27 of 115 seedlings had mild-flavored, almost sweet, fruits, suitable for fresh consumption. These were not included in the previous survey but this year the best tasting berries of this progeny will be analyzed and it is expected that Brix values will be considerably higher and/or acids lower, than those reported herein.

Subjective evaluations of fruit firmness are made on all harvested berry samples. No objective test has been used as yet. Some berries are so soft and juicy that they begin to break down shortly after harvest. These may be useful for juice extraction. Oszmianski et al. (3) report that blue honeysuckle (using Russian forms) is exceptionally suitable for juice production. By using a method involving thermal and enzymatic processing, the yield of juice was over 90%. Also, as compared to other fruits, the color and anthocyanin content exhibited high stability in storage. By contrast, some berries are so firm that they remain intact and relatively dry more than two weeks in a refrigerator, a desirable trait for fresh marketing.

In seven years' field observations in Corvallis, no diseases or pests have been significant enough to require control measures. However, in cool, wet springs, *Botrytis* sp., has appeared as scattered dead shootlets on several plants. Death occurred when new shootlets were about 3-8 cm in length. The disease did not spread farther into main shoots and there was no more onset after the weather became warmer. No plants were affected severely enough to cause significant crop loss and mature fruits have not been affected. As yet, no diseases have been observed in the Sandpoint plot. At the Saskatoon site, powdery mildew (*Microsphaera* sp.) has been observed on leaves in July-August, well after harvest. Much variability in sensitivity among seedlings and clones was noted so, should the disease become debilitating, it may be possible to select for resistance, or tolerance. Honeysuckle leaf blight, *Insolibasidium deformans* (C.J Gould) Oberw. and Bandoni, can cause serious problems on most *Lonicera* species in North Central and North Eastern states, but this fungus has not been reported in southern and western states (7). Occasional leaf rollers and aphids are seen, but have not been abundant enough to adversely affect the plants.

No winter freeze damage has been noted in Corvallis, or in Sandpoint, ID where minimum field temperature has been -29° C with 38 cm of snow on the ground. In Saskatoon, although low temperatures reached -40° C in winter of 2005-2006, haskap freeze damage cannot be determined as yet because the small, young plants in the field were protected by snow. Due to uncertainty about the cold hardiness of haskap plants to Saskatchewan winters, half of the initial seedlings are planted in the field, whereas the other half are held in a protected shade house to assure their survival for use in future breeding.

### Advanced trial plots and release of cultivars

In Corvallis, each year the most promising selections are propagated and two to four plants placed in a preliminary trial plot for more intensive study. In 2005, several selections, each in limited numbers, were given to a few growers in Oregon, California, and Washington for evaluation in different environments. In October 2006, 12 of the best selections (8 plants each) were distributed to five cooperators to establish replicated trial plots. Test sites include Oregon State University Research and Extension Center at Aurora, OR, a commercial farm in Bandon, OR, University of Idaho Research and Extension Centers at Sandpoint, ID and at Parma, ID, and Washington State University Research and Extension Center at Mt. Vernon, WA. After a few years, and when sufficiently evaluated, selections that exhibit superior performance will be named and released as cultivars to nurseries for propagation and sale.

### Conclusions

Haskap berries from Hokkaido, Japan appear to be very well adapted to western Oregon and northern Idaho. Plants are healthy, grow vigorously, and are productive. Berries are of good size and have varying and especially good, unique flavors. Among our research plots, the large amount of genetic diversity indicates good potential for rapid genetic improvement. With identification and sufficient evaluation of superior forms, there is excellent potential for development of a new berry crop. This berry will fit into a niche market for specialty processed products having unique flavors. Haskap cultivars will also provide an easy-to-grow, very early ripening berry that will extend the fruit season for home gardeners and small U-pick farms, and that is worthy of trials on organic farms.

### Acknowledgement

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## Of "Blue Gold", Models, and Gaps in Knowledge

Water has been labelled "blue gold", and "blue gold" is destined to be the critical issue of the 21st Century. Globally, irrigation is responsible for 80% of the world-wide spending of "blue gold". Development of sustainable irrigation practices will require that we understand better the biophysical processes of root-water uptake in soil, and transpiration from plant canopies. This review paper is divided into four parts: models, measurements, knowledge gaps and policy. First, the authors present a retrospective on root-water uptake models since 1960. Since then, nearly all the models include a term specifically for the distributed uptake of water from soil by the root system. These models fall into two groups based on how the uptake term is handled. The merits and potential of these two schemes are discussed. Second, they present new data on root-water uptake and transpiration by kiwifruit vines, obtained using arrays of time domain reflectometry (TDR) sensors. They also present results obtained with new methods of sap-flow measurement inside the kiwifruit vine's roots. These reveal the uptake dynamics during partial root zone drying, a technique oft-touted to reduce irrigation volumes. Next, they outline future research needs, including better knowledge of the matric potential at the soil-root boundary, the role of reverse flow, better specification of root resistance, and less tiresome measurement techniques for canopy area and architecture. The information is needed to better predict crop water use and irrigation requirements. Finally, they demonstrate how scientific knowledge can be used to develop sustainable irrigation practices. From: S.R. Green et al. 2006. Agric. Water Management 86(1-2):165-176.

## Will That Be Paper or Plastic?

Today's demanding distribution challenges require engineers to choose from various types of materials, design and construction methods, to develop containers that can deliver goods with minimal damage. The challenge is even greater when packing and shipping goods which are perishable and sensitive to both physical and climatic changes in environment. In recent years the type of packaging material used to design and construct containers has undergone more scrutiny than ever, due to environmental challenges. This study focuses on two types of containers that have been designed and are being used to pack and ship fresh fruits and vegetables. The study compares the re-usable plastic containers to single-use display-ready paper corrugated trays. Results show that, based on the scope of this study and comparing 10 different produce items, such as apples, carrots, grapes, oranges, onions, tomatoes, strawberries, etc., the re-usable plastic containers require 39% less total energy, produce 95% less total solid waste and generate 29% less total greenhouse gas emissions. This study focused on the North American market. Major European nations have been using a large number of re-usable plastic containers for these types of fresh produce for the past three decades. From: S.P. Singh et al. 2006. Packaging Technol. Sci. 19(5):279-293.