BREEDING OF *LONICERA CAERULEA* L.

FOR SASKATCHEWAN AND CANADA

University of Saskatchewan

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ABSTRACT

Only the University of Saskatchewan is breeding blue honeysuckles in Canada. Our goal is to develop cultivars adapted to mechanical harvesting and processing. We are interbreeding lines from Russia, Japan, and the Kuril Islands to bring together traits desirable for mechanization. Russian germplasm is most valuable for uniform ripening, early fruiting, and easy to detach fruit, but fruit is often tubular shaped and small. Japanese germplasm has heavier, more rounded fruit but usually is hard to detach and ripens unevenly. Kurile Island fruits can be large and round but these accessions have low productivity but have good disease resistance. Good flavour is very important, but can be found all 3 germplasm pools above.

Farmers are growing half the seedling from our program in a cooperative project. Perhaps 30,000 seedlings from controlled crosses have been planted in the last 5 years, but 95% of these are first generation hybrids. We recently released two cultivars we consider superior for our location, but expect more improvements in future generations.

Collecting wild *Lonicera caerulea* from the boreal forests of Canada began in 2007. So far, 650 accessions have been gathered from 131 sites in 6 provinces. Plants and leaves are quite variable in the collection. The few plants that had berries on them when collected tasted good but were small. It will be a few years before these plants are large enough to evaluate their usefulness for breeding.

BACKGROUND & HISTORY

Our fruit program was established in 1920. It is the northern-most and coldest location where fruit is being bred in Canada. We are located in hardiness zone 2 with winter lows around -40^{o}C each winter. In addition to *Lonicera*, we maintain a collection of 17 fruit crops on 15 hectares. We breed most of the crops in our collection on a small scale but in recent years we have emphasized breeding of blue honeysuckles, grapes, sour cherries, apples, and interspecific strawberries.

Almost half of Canada's tillable land is located in Saskatchewan but our farmers mainly produce grain, meat and dairy products. Fruit is a very minor crop in this part of Canada, but there is much potential because of the availability of fertile cheap land. But since we have relatively sparse population we do not have the labour force like other fruit growing regions. For this reason, crops with potential for mechanical harvesting and processing are emphasized in our program.

We began growing blue honeysuckles in 1998, but began doing crosses in 2002. Grants specifically for *Lonicera* breeding from the Government of Saskatchewan began in 2007 and will continue through 2011. These grants have allowed us to greatly increase our breeding efforts with this crop.

Currently, Dr. Bob Bors heads the program, and we have two full time technicians R. Sawatzky and T. Sander, and one part time technician V. Oster. In the summer we hire 2 or 3 students. We have one part time graduate student Jon Treloar working on *Lonicera*.

We are the only fruit breeding program on the Canadian Prairie, other than hobbists, and we work closest with Saskatchewan, Alberta, and Manitoba growers. But we also work with nurseries and growers growing our varieties in northern regions of most provinces.

Growing Blue honeysuckles is new to Canada. Perhaps 150 farmers are trying them commercially and 10s of thousands of home gardeners. 29 farmers are involved in the 'Grower Assisted Fruit Breeding Program'. In this program, farmers each grow 300 to 600 seedlings from controlled crosses and are involved in selecting the best ones. We produce more seedlings than we can plant at the University, and the excess plants go to the farmers. They buy the plants at a low price which almost covers the

cost of planting all seedlings for the program. We also have a one day plant sale where we sell directly to the public. In recent years perhaps 1000 people show up for this sale. Some of our growers have formed a nationwide group "Haskap Canada" to help promote the development of this crop. They maintain the website www.haskap.ca.

We have a strong volunteer base consisting of farmers and master gardeners. Volunteers typically plant more than half of our seeds in the greenhouse and have helped with cross pollinating, planting, pruning, and harvesting fruit. We have even trained some volunteers to do tissue culture.

Undergraduate students at the University often have labs or projects dealing with *Lonicera*, in plant propagation, greenhouse management, and fruit science classes. It was class projects that first propagated our new varieties in tissue culture and made wine from *Lonicera caerulea*.

We are also the only program breeding Blue Honeysuckles in Canada. We work closely with Dr. Maxine Thompson, who has the only breeding program in the U.S. Dr. Thompson has given us many accessions and seeds while we have sent personnel to assist her to evaluate fruits at harvest. We have also shared germplasm with Dr. T. Suzuki and had accessions evaluated for health properties by Dr. M. Ukai, both are from the University of Hokkaido, Japan.

About 50 years ago there was a program in Beaverlodge, Alberta, Canada that bred a few *Lonicera caerulea* varieties 'Bugnet'. These were in fact bred as ornamental plants but overly imaginative nurseries called them 'sweet berry honeysuckles' and 'blue honeysuckles' despite them tasting horrible. I believe these poor examples caused complete lack of interest on the part of fruit breeders in Canada. In our program, we have been calling this crop, the ancient Japanese name 'Haskap' to signify that what we are working is quite different from the Beaverlodge varieties, plus it is indicative that we are intensively using stock from Japan in our breeding program.

Goals

We want our Haskap varieties to taste very good and to be adapted to mechanical harvesting and processing. Our farmers have much land but

few labourers so mechanization is very important. Another important goal is to have a wide range or ripening times to spread out harvest. For most of our other fruit crops, cold hardiness is an important goal, but this is not a problem for us with Blue Honeysuckles. Even Japanese Haskap seem to survive well for us. While we emphasize breeding for farmers , we do consider gardeners and have released varieties suitable only for home production.

We are fairly confident that varieties developed in Saskatchewan will be ideal for the cold, fairly dry Canadian Prairie. Of concern are other areas in Canada with high humidity or fluctuating temperatures on the east and west coasts and the Great Lakes region. But we are have 5 test locations outside of the prairies where farmers are growing seedlings which may make it possible to select future varieties adapted to other areas.

Activity Level

From 2002 to 2006 about 3000 seedlings were raised each year with half being planted at the University and half at farmer's fields. In 2007 and 2008, 8000 and 18,000 seedlings were raised, respectively, with half going to farmers each year. However, we are now more selective in early stages by planting only the best looking 50% of seedlings so many plants are discarded.

In the last two years there have been about 120 different combinations of parents used each year. Our germplasm originates from 4 types: Russia (R), Japan (J), Kuril (K), and Canada (C). About 50% of all crosses were R x J, and 25% are R x K. We plant to do more J x K crosses in the near future, but crosses with C will be minimal until that germplasm has been more extensively evaluated.

While we have many seedlings and a fairly large germplasm base, we are in our earliest generations of Honeysuckle breeding. Only about 5% of our seedlings are second generation crosses between Honeysuckles from different regions. We will need a second generation for recombination and the possibility of selecting for desirable recessive traits. Since Blue honeysuckles are tetraploids it will likely take several more generations to bring together the best desirable traits.

The selection process

Selection begins in the greenhouse. Plants with unusually high vigour or particularly promising lineage may be transplanted into larger pots and grown for a season to speed up the time for fruiting. We call this "fast tracking". Fast tracking may be done for 200 plants per season.

But most seedlings are started in plug trays in a greenhouse during January and February and planted in the field in June or August. July is too hot. If there is variation within the seedlings of a particular cross, we plant only the largest healthiest plants. It is quite common for us to reject 30 to 60% of the plants of one cross before planting. In two years of very low funding we planted seedlings as double rows with plants 5 cms apart. In years with funding, plants are 10 cm apart in single rows. Later when exceptional plants are found we will thin out the inferior plants around it.

When plants are about 3 years old we do a field assessment, marking the better plants for each cross with flagging tape. Yield, fruit size, flavour and health of bushes are taken into account. Fruit flavour and health of bushes is most important at this age. It is thought that fruit size and yield can increase dramatically as the plants get older so it is important to compare seedlings to control plants of cultivars that were planted in the seedling orchards for comparison. The flagged individuals are evaluated more closely, using an evaluation sheet (table 1).

The better selections are evaluated further by mimicking mechanical harvesting and processing. We do not have a harvesting machine so we shake bushes by hand into umbrellas or children's swimming pools as in figure 1. Harvested berries are poured into a sorting line (figure 2) and the resulting berries are assessed for damage. Damage is most easily seen as wet and squashed berries that have released juice onto the sorting table.

Details on different types of germplasm

Russian Accessions From 21 Russian cultivars we did not find any perfectly suitable for mechanized harvesting and processing, but several are closer to the ideal than others. We believe that within our collection of *Lonicera* accessions it will be possible to breed desirable attributes into new cultivars suitable for mechanization. The Russian cultivars we evaluated are most desirable for even ripening, high productivity and early

fruiting. But common difficulties are elongated shape of berries (which do not roll on the sorting table) and fruit weight often less than a gram (which tends to get stuck on the sorting line belt). Both these shortcomings could likely be overcome by using superior 'K' or 'J' accessions to create varieties with larger rounder fruit. I have seen photos of round-shaped Russian cultivars in books given to me by Alla Kuklina and Artem Sorokin which depict desirable shaped fruit, but these cultivars are not in our collection. Our favourite Russian cultivars to use in breeding are Lebedushka, Suvenir, and Pushkinskaya. These three always seem to be high on our list when we evaluate our accessions. However we have used about half of our Russian cultivars as parents in the breeding program.

Japanese Accessions Until 2008 our only source of Japanese accessions were plants and seeds given to us by Dr. Maxine Thompson. Decisions on which to use in breeding were based on evaluations done in Oregon when Dr. Bors or students visited her to assist in harvesting and plant evaluations. For several years we were afraid that such material could not survive our winters so we kept clonal material in pots and used them as males in breeding. These potted plants were moved to a storage facility during winter so they would not face the extreme cold. In the field we planted large numbers of seedlings, expecting few to survive. However, almost all Japanese seedlings have survived. Only in 2008 did we plant our Japanese clonal material in the field.

In 2008, Dr. Bors visited Hokkaido and collected 16 seedling lines. Of these 12 lines are considered to have commercial potential and 4 lines are from wild types. 6 of the commercial lines are from specific clones while the rest are bulked from many plants.

The general opinions about Japanese germplasm listed in table 2 are mainly based on visits of a week or two at Dr. Thompson's program over several years and a 10 day trip to Hokkaido in 2008. It is too early to tell if any of the characters described will be different in our location. Saskatchewan climate changes rapidly from winter to summer, and we have dramatically hot day temperatures and cool nights in summer. We are hoping that these environmental conditions will lead to a faster, shorter bloom period and quicker accumulation of sugars in fruit and lead to even ripening in Japanese germplasm.

Kuril Accessions Our 6 Kuril accessions seem almost indistinguishable except for one important factor. When fruit is picked in mid July, most will bleed where the berry was attached to its pedicel. This may be an indication of being not being fully ripe. The exceptions are F-1-9-58 and Kiev # 8 which are a bit earlier ripening than other Kuril types and which taste better at that time. Those two accessions were used more often in our program a few years ago. In 2008 we are used all our Kuril accessions as parents.

Canadian Accessions Dr. Bors is currently on a sabbatical to gather wild Canadian *Lonicera caerulea.* Plants collected during this sabbatical and those collected the year before are summarized in table 4. More will be gathered in 2009 in spring and early summer. Dr. Artem Sorokin of the Vavilov Institute participated in the Ontario expedition and has some seeds from that trip.

Wild Canadian accessions have not been evaluated other than in notes taken when they were gathered. The collecting expeditions focused on capturing the diversity of plants at each location. Wild *Lonicera caerulea* was found in: seasonal streams, openings in deciduous boreal forest where fallen trees were decomposing, high calcium soils, and disturbance areas near road construction. It was never observed to be a dominant species and was not as common as other *Lonicera.* Mainly it grows in areas where trees are doing poorly, in wet areas and usually partly shaded areas. It may be an understory plant adapted to low light levels in central and western Canada. But in eastern Canada it grows in widely open areas with few or stunted trees. It seems highly unlikely that this species will ever be invasive, which is important to know. Many government agencies are quite worried about such matters.

High diversity was noted among wild accessions gathered in Canada. Variation in leaf size, disease resistance, plant height was noted. Some plants were found close to salt water and most berries tasted were good flavoured. Compared to cultivars, wild plants had very small fruit, which will likely be a major problem with this group of germplasm. But less than 5% of the plants had fruit at the time of collecting so more evaluations are needed under cultured conditions. It is hoped that these plants will be valuable in providing hybrid vigour, disease resistance, and adaptation to Canadian growing conditions.

Tissue culture research

Our program also uses tissue culture to propagate new varieties and does limited research to provide information to nurseries working with us. *Lonicera caerulea* is relatively easy to propagate in tissue culture. We do not publish this information but we do provide it to our propagators.

Accomplishments

Two varieties were named and released in 2007. Characteristics are listed in table 5. All of these are from the same cross: Kiev#8 x Tomichka. The variety 'Borealis' is recommended for the home gardeners. It had the largest fruit and best flavour but is too fragile for mechanization. 'Tundra' was the best of those that that have mechanization potential. Its fruit is at least 50% larger than blue honeysuckles varieties currently available in Canada. It had the highest rating for firmness which is a fairly rare trait for large fruited blue honeysuckles. But Tundra is a bit slow to propagate, so 9-15, 9-91, and 9-92 were released for further testing. We have been recommending 'Berry Blue' (Czech#17) as a pollinator because it is unrelated to either parent and this variety is very fast growing.

During 'Haskap Day' in 2006, the growers and nurserymen were quite impressed with the row of 'Kiev#8' x 'Tomichka' seedlings and they insisted that the best from that row be selected and released as new varieties. The convincing argument given at the time was that inferior cultivars were finding their way into the marketplace which could discourage growers and consumers from this crop. Growers were aware that even better cultivars would be produced by the program in perhaps 5 years, but most felt they would rather learn to grow with these new plants than with inferior ones. In 2008, after extensive tasting of more Japanese and Russian Cultivars, these seedlings are very high on our evaluations for flavour. In a sample of berries from 43 accessions sent to Dr. Ukai of the University of Hokkaido, 'Borealis' was selected as the best tasting. Also when Dr. Bors visited Hokkaido in 2008, he brought berries of this family to Hokkaido which received very favorable comments on the flavour.

We also developed tissue culture recipes for our propagators. Recipes for Haskap and other fruit crops are often improved by students in Dr. Bors' propagation course.

Challenges and areas for cooperation

The goals of flavour and mechanized harvesting go well together. If a crop can be mechanically harvested quickly, then the growers can let the fruit fully ripen before harvesting. The fruit would taste better and be more acceptable to the average consumer. But if growers are only picking by hand and have limited labour, picking may start too early and continue too late in the season. If there is uneven ripening, pickers will tend to pick all berries within reach, even if some are still partly red.

Varieties bred for mechanization could be useful for farmers who do not have machinery. A simple collection device like umbrellas or children's swimming pools could reduce the time to harvest fruit by 90% or more. But only varieties bred for this type of harvesting would be still be good condition.

An important challenge for us is to select varieties that are firm when fully ripe. Otherwise, a problem could happen where growers would mechanically harvest unripe berries to increase firmness. Another question in this area is understanding optimal fruit size. Perhaps the largest berries will always be more fragile.

There seem to be many papers in Russia, Japan and elsewhere that have extensive evaluations of many traits of Blue Honeysuckles. Fruit size and shape are often studied, but other attributes important for mechanization are not usually discussed. So far we have only evaluated varieties by subjecting varieties to shake harvesting and putting them through a sorting line and visually inspecting the fruit. We are investigating texture analysis machines and pull force meters that could give us quantitative data rather than using a subjective scale.

Table 1. Evaluation sheet for Haskap. This sheet is used on advanced selections and to evaluate cultivars that may be useful as parents.

Haskap evaluation sheet

Accession #	_____	Evaluators		Jon & Tyler			
Bush	vigour	low	slight	average	more	very	
	canopy	weeping		spreading		upright	
	productivity	low	slight	average	more	very	
Fruit Retention		holds on tightly	holds on slightly	optimum	detaches easily	falls off	
Scar wetness		Skin tears	oozing without squishing	oozing with squishing	slight oozing with squishing	dry	
Frequency of wetness		0%	25%	50%	75%	100%	
Fruit size		very small	small	average	large	very large	
shape	football	cylinder	bullet	oval	long oval	square	round
side view		flattened		slightly flattened		not flattened	
length		short		medium		long	
texture (in hand)		very soft	soft	average	firm	hard	
Distal end	shape	pointed		belly button		rounded	
	opening	small		medium		large	
	hairs	very heavy	heavy	some	slight	none	
Skin texture		smooth		irregular		bumpy	
Bloom		none	some	moderate	above avg	heavy	
Sweetness		none	slight	moderate	above avg	heavy	
Sour		none	slight	moderate	above avg	heavy	
Bitterness		none	slight	moderate	above avg	heavy	
Aroma		none	slight	moderate	above avg	heavy	
Texture (in mouth)		very soft	soft	average	crisp	chewy	
Overall	one of the worst	bad	poor	bland	good	excellent	one of the best

Table 2. General characteristics of *Lonicera caerulea* germplasm as observed in Canada, Oregon and Hokkaido. Traits important for breeding a crop adapted for mechanized harvesting are included.

Types	Advantages	Disadvantages	Other
Russian	+Uniform ripening +Most can be harvested by shaking +Upright plants +Productive +Early ripening +Tart flavour common	-Tubular, smaller fruit -Plants quit growing by end of June -some can be bitter	*Variable for flavour and disease resistance
Japanese	+Larger more rounded fruit +Longer period of active growth +Productive +Late ripening +Tends to be resistant to leaf diseases +Upright plants	-Uneven ripening -Most plants hold onto fruit too tightly	*Variable for flavour
Kuril	+Uniform ripening +Late ripening +Sweet pleasant flavour +Larger, round fruit +Highly resistant to leaf diseases +Leaves stay green and healthy through summer + Wide, velvet leaves may hide fruit from birds?	-Low productivity -Short plants - Most plants hold onto fruit too tightly	*most of the good traits seem to be dominant when used in crosses
Canadian	+Early ripening +Some have very bright blue fruit +Most are sweet pleasant flavoured	-Small fruit size -Most plants have drooping branches	*Only recently acquired, there is much we don't know about these.

	+Well adapted to Canada +Mostly round fruit		* variable resistance to leaf diseases

Table 3. U. of Sask. germplasm collection originating from other programs and nurseries, listed by year and source.

1998	***Jim Gilbert / Northwoods Nursery, Oregon, USA***	
	Tomichka (Blue Belle)	Kiev #8 (Blue Velvet)
	Sinyayapitsa (Blue Bird)	Czech #17 (Berry Blue)
2002	***Dr. M. Plekhanova / Vavilov Institute***	
	Altair	Omega
	Amfora	Pushkinskaya
	Kamchadalka	Roksana
	Lebedushka	Slavyanka
	Malvina	Solovey
	Morena	Suvenir
	Narymskaya or Fialka	Volkhova
	Nimfa	
2003	***Jim Gilbert / Northwoods Nursery, Oregon, USA***	
	Zarnitsa (Blue Lightning)	Kamchatskaya (Kamchatka)
	Sergey (Blue Moon)	Magadan (Blue Forest)
	Novinka (Blue Nova)	N-17 (Blue Magic)
	Valery no. 2 (Blue Sky)	Dimka (Smoky Blue)
	F-1-9-58 (Blue Pacific)	
	Alexandre Lebedev / Magma Exports, Quebec, Canada	
	Berel	Lazurnaya
	Gerde	Zolushka (Cinderella)
	Golunoe Vereteno	Ognennyi Opal
	Dr. Maxine Thompson / USDA Genebank	
2004	20 seed lines, controlled crosses	
	1 bulk op seeds from 6 selections	
2005	25 clones	46 lines open pollinated seeds
2006	26 clones	30 lines open pollinated seeds
2007	20 clones	
2008	***Dr. Bob Bors / Sabbatical expedition***	
	16 seed lines from Japan	
	Dr. Artem Sorokin / Vavilov Institute	
	16 seed lines	6 clones

Table 4. Summary of wild Canadian germplasm listed by province and year. Collecting began in 2007 and is the only major collection of accessions na-tive to Canada. At most locations several accessions were gathered. Berries were gathered when present and seeds extracted.

Year	Province	Sites	Sites with Seeds	Clones
2007	Manitoba	23	----	115
	Saskatchewan	5	----	20
2008	Alberta	6	----	30
	Saskatchewan	35	----	175
	Ontario	46	15	230
	Quebec	11	4	55
	Newfoundland	5	3	25
Total		131	22	650

Table 5. Characteristics of University of Saskatchewan cultivars released in 2007. Integrity was based on condition of berries after being subjected to conditions mimicking mechanized harvesting and sorting.

Name	Scar	Fruit Weight (g)	Fruit Shape	Flavour	Integrity
Borealis	Wet	1.62	short flat boxy	sweet tart	c+
Tundra	Dry	1.49	long flat bullet oval	sweet tangy	a
9.15	Dry	1.30	robust short oval	sweet, chewy	b
9.91	Dry	1.41	Flat cylinder	Nice tangy sweet	b-c
9.92	Dry	1.29	long flat oval	tangy sweet	a