I Introduction

Japanese blue honeysuckle (haskap) is the earliest fresh fruit harvested in Hokkaido starting in late June. In Japan’s small-scale orchards, farmers carefully harvest haskap berries by hand so as to avoid losing any juice from the delicate peel. To improve harvesting efficiency with minimal additional cost, we developed new methods employed either plastic pipe or jigsaw for separating the fruit, converted umbrella, plastic net or light pipe with tarp for collecting, and used electric fan or mesh net with water for cleaning. After testing various combinations of separating, collecting and cleaning methods, the harvesting rate was increased from 1.45 kg/h (conventional hand picking) to a maximum 10.36 kg/h. Therefore, it is possible to improve haskap harvesting efficiency at low cost.

[Keywords] haskap, separating, collecting, cleaning, high efficiency, low cost

Fig. 1 Fruit of Japanese blue honeysuckle (haskap)
Haskap production in Hokkaido is traditional and has good prospects. The fruit is handpicked and sorted manually two times before being sent for processing. However, this method is labor intensive, tedious and highly repetitive, and must be accomplished within the short harvesting season from late June to early July, which is the busiest period for farmers in Hokkaido. Although haskap is much appreciated in the region, the acreage for its production has declined over the years due to Japan’s high labor cost and aging farmers. On the other hand, recent successful promotion and high appreciation of haskap processed products has led to an increase in demand that exceeds the current production. Therefore, developing an easy, labor-saving methodology for harvesting and selecting haskap berries would encourage more farmers to grow this fruit on a large scale. Recent studies that have tackled haskap harvesting include those by Konno et al. (2009a, 2009b, 2010) who modified a vacuum cleaner to suck up haskap berries with the assistance of a rake, and envisaged a vertical column to separate haskap berries and leaves during harvesting.

Most haskap varieties have upright shrubs and are similar in size and shape to commercial highbush blueberry cultivars among the well-known berry varieties. In comparison with highbush blueberries, haskap varieties ripen all at once while blueberries must be selectively harvested three to five times within a period of four weeks. Also, less pulling force is required to detach haskap berries. On the other hand, their delicate peel requires very careful harvesting. Moreover, the elongated shape of haskap berries causes difficulties in the cleaning and sorting lines compared to the round blueberries. Also, most orchards in Japan are small and sloped, unsuited for large mechanized harvesters.

In addition to haskap, there is also an increasing demand to develop efficient, low-cost harvesting methods for blueberries in Japan where planted areas have been growing at the rate of 90 ha each year since 2000, reaching 853 ha in 2007 (MAFF, 2007). Yamagishi et al. (2002a, 2002b) made a special mechanical vibrator to determine the degree of force required to dislodge the fruit from the pedicel and to dislodge the pedicel from the peduncle. They also found that ripe blueberries were dislodged most efficiently at a 30-mm stroke and 7.5-Hz frequency. Akase et al. (1999, 2000) tested the pull resistance force between the spurs and the fruit. However, these studies did not cover the entire harvesting system, which includes collecting and cleaning methods. The method that we developed for harvesting haskap is expected to also be suitable for blueberries, which are handled more easily.

The main objective of this research was to develop an efficient, low-cost harvesting method for fresh market quality haskap berries. Considering the small scale of orchards in Japan, and the limited budget that farmers would invest on haskap, it would be impractical to develop a totally new, and thus costly, machine. The optimal methodology would be to make use of items commonly available in farm sheds or easily found in the market, by adapting them to berry harvesting.

II Materials and Methods

This research was conducted at the Yoichi Orchard (43°10’N, 140°46’E) of Hokkaido University in Hokkaido Prefecture, Japan from 2008 to 2010. The orchard covers 57,939 square meters, and is planted with apples, pears, grapes, cherries, blueberries and haskap. Haskap shrubs were transplanted in 1995 from wild varieties, and they cover an area of 3,300 square meters.

Prior to our harvesting experiment, Hoshino et al. (2003) measured the physical properties of haskap berries in the Yoichi Orchard. They randomly chose 42 haskap shrubs, and randomly selected 12 fruit from each shrub. The results are shown in Table 1.

The harvesting trials started with time and motion studies of the conventional hand picking method. The purpose was to determine which phases of the harvesting operation could be improved. In conventional hand picking, farmers carefully picked haskap berries one by one using both hands at first, and then put them into a small bucket placed on the ground, which was followed by removing visible foreign material.

The harvesting tasks for haskap include three phases: separating, collecting, and cleaning. In our new methods, fruit separating equipment was used to remove haskap berries from the shrubs. At the same time, collecting devices must be provided to gather the separated fruit. After that, fruit cleaning units were applied to remove foreign material such as leaves, twigs, plant debris, and small unripe fruit from the collected fruit.


In 2008, we separated haskap berries from shrubs by picking and dropping method, applied a modified umbrella to collect the separated fruit, and used a mesh net in water as the cleaning unit.

(1) Fruit separating method (Picking and dropping)

Instead of repeatedly carrying the fruit by hand to a small

Table 1 Physical properties of haskap in Yoichi Orchard (all values are the mean of 12 fruit from each shrub with standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>19.43±1.25</td>
<td>11.16±0.96</td>
<td>14.60±1.90</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>11.06±1.16</td>
<td>7.05±0.74</td>
<td>9.30±0.96</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>1.01±0.09</td>
<td>0.37±0.05</td>
<td>0.67±0.16</td>
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</table>
bucket as in the conventional hand picking method, we placed a larger collector under the branches in the picking and dropping method. By picking haskap berries with both hands, and dropping them into the larger collector, the harvester could improve the separating efficiency according to the savings in time for manually moving fruit to the collector.

(2) Fruit collecting method (Umbrella)

A vinyl umbrella was used with the picking and dropping method on one’s own. With an opened umbrella placed under the branches, separated haskap berries could be collected. By moving the umbrella around the shrub several times for different branches, all the fruit from that shrub could be separated. There was no damage to the fruit when they dropped onto the canopy. However, haskap berries broke easily when they contacted with the ribs and stretchers or rolled into the gap between the ribs and canopy. Therefore, we covered the stretchers and eliminated the gap with packing tape.

(3) Fruit cleaning method (Sieving with net in water)

The size and shape of the leaves, branches, small unripe fruit, and other twigs are different from that of the berries. A hexagonal mesh net with a diameter of 20 mm was used to remove foreign material that was larger than the fruit, and a square mesh net with 7-mm sides was used to sieve foreign material smaller than the fruit (as shown in Fig. 2).


In 2009, we tried striking branches with a plastic pipe to separate the haskap fruit, applied a converted plastic net as the collector, and used an electric fan for cleaning.

(1) Fruit separating method (Striking with plastic pipe)

Mature haskap berries could be separated from the shrub by striking the branches with a short plastic pipe held in one hand. The results obtained depended upon the nature of the bearing wood, the amount of fruit and the working skills of the pickers.

(2) Fruit collecting method (Plastic net container)

The smallest width of haskap berries in the samples that were taken from the Yoichi Orchard was 7.08 mm. A plastic net with a mesh hole of 7 mm was chosen for building a container, which was placed under the branches for collecting the fruit, in the same way that the umbrella was used. This aid was used by pickers who separated the fruit with the plastic pipe on their own and let them fall into the container. In order to easily pour the fruit and reduce damage, the plastic net container was designed with one side higher than the other side.

(3) Fruit cleaning method (Blowing with electric fan)

An electric fan with three blades in a total span diameter of 30 cm was tested as shown in Fig. 3. It separated foreign material based on specific gravity and surface texture at a rotational speed of 1983 rpm and wind speed of 4 m/s. When the collected fruit was poured out at the top of the electric fan, leaves and other light foreign material were blown away by the force of the air while falling, whereas the berries dropped into a receiver. We used the plastic net container to receive the fruit, where small unripe fruit and plant debris went through the mesh holes, as shown in Fig. 4.

In 2010, we introduced a jigsaw into the fruit separating equipment, applied converted light pipes with a tarp for collecting, and continued using the electric fan for cleaning.

(1) Fruit separating method (Vibrating with jigsaw)

A picking aid made from a wood-cutting jigsaw (Hitachi, CJ65V) that has five dials was constructed and tested. The blade was replaced with a special metal hook (as shown in Fig. 5) that could move through an amplitude of 18 mm at speeds of 400–3200 cycles per minute (cpm). We used dial 2 with a speed of around 1670 cpm in this research. When the hook was held against the main fruit-bearing branches one by one, mature fruit could be separated quickly and completely. This unit was powered by a small electric generator.

(2) Fruit collecting method (Portable tarp catch)

A tarp-covered collecting unit approximately 2 m in diameter was developed. It included two identical collectors that surrounded the haskap shrub with tarps connected by laundry clips (as shown in Fig. 6). The unit could be placed under an individual shrub or several shrubs at once by extending its length. The frame was constructed with light pipes connected by fittings. It can be separated into parts after the harvesting season and easily reassembled for collecting.

Among the new harvesting methods, the jigsaw is the most expensive piece of equipment. However, considering that nearly all farmers, especially fruit growers, use a jigsaw for making farming devices, the only extra investment would be in making the metal hook to replace the blade. Nevertheless, buying a new jigsaw would cost approximately $200, which is still cheap for farmers in Japan, provided that the other devices are easily obtainable without much added cost.

III Results and Discussion

Table 2 compares the results achieved when various combinations of separating, collecting and cleaning methods were tested in the Yoichi Orchard. The data shows that the picking aids used in the trials increased the average per-worker production from 1.45 kg/h (conventional hand picking) to as much as 10.36 kg/h.

Among the separating methods, there was no significant difference in the ‘picking and dropping’ method compared to ‘conventional hand picking’. However, the ‘striking with plastic pipe’ and ‘vibrating with jigsaw’ methods could separate haskap berries at 8.76 and 19.35 kg/h, respectively; both methods show a significant difference from any other separating method. In addition, haskap berries were easy to separate from the shrubs compared to leaves during vibrating, and little foreign material was collected using the ‘vibrating with jigsaw’ method, whereas when the plastic pipe was used to hit the branches, stems and leaves were also struck and they fell off into the collector, which affected the cleaning. Therefore, the average ‘blowing with electric fan’ cleaning rate of the haskap berries separated by the ‘vibrating with jigsaw’ method (22.90 kg/h) was higher than the ‘striking with plastic pipe’ method (15.54 kg/h), despite applying the same cleaning method. The disadvantage of the ‘vibrating with jigsaw’ method was that the jigsaw was relatively heavy and hence difficult to hold in the shrubs for a long period. Nevertheless, it was acceptable to use the jigsaw at approximately 1-min intervals for each shrub.

For collectors, the umbrella and plastic net container did not work well with the jigsaw, as they could not be controlled simultaneously on one’s own while the vibrated fruit were flying around. However, the plastic net container could sieve small unripe fruit and little bits of plant debris, playing a more important role as a receiver during cleaning than as a collector during separating. On the other hand, the portable tarp catch collected almost all the vibrated fruit without damaging them. Nevertheless, it would not be able to encircle all the shrubs for gathering the fruit at once if it were on a large scale. Under those circumstances, part would have to be cut for
Table 2 Results of ANOVA for different harvesting methods

<table>
<thead>
<tr>
<th>Year</th>
<th>Separating</th>
<th>Collector</th>
<th>Cleaning</th>
<th>Number of trials</th>
<th>Separating &amp; collecting rate (kg/h)</th>
<th>Cleaning rate (kg/h)</th>
<th>Total harvesting rate (kg/h)</th>
</tr>
</thead>
</table>
|      | Conventional hand picking | Plastic bucket   | -                         | 15               | 1.45 (0.52)  
| 2008 | Picking and dropping      | Umbrella          | Sieving with net in water | 5                | 3.49 (0.38)  
|      | Striking with plastic pipe | Plastic net container | Blowing with electric fan | 6                | 8.76 (3.23)  
| 2010 | Vibrating with jigsaw    | Portable tarp catch | Blowing with electric fan | 8                | 19.35 (4.78)  

Mean (standard deviation), the fruit was weighed after it had been cleaned.

**Note.** Different letters (a – c) determine the significant difference between different separating & collecting, cleaning, and total harvesting methods; the same letter in the same columns indicates no statistical significance between them ($p < 0.05$).

During cleaning, the mesh net caused some damage to the fruit during sifting to allow the fruit to go through the net. Furthermore, water cleaning was limited to fruit destined to be processed since fresh market fruit should be dry, and also water has a harmful effect on subsequent sorting. The ‘blowing with electric fan’ method proved effective for accomplishing the task, but additional grading was needed to remove the large unripe fruit. Therefore, we are considering designing a grading system based on the RGB camera and image processing technology to sort haskap berries.

Fruit quality was another important factor to consider in this research. However, it was difficult to evaluate haskap berries before the standards of grading haskap berries were published. Instead, a brief quality evaluation of haskap berries for different harvesting methods is given here. Conventional hand picking had the best quality fruit. The second was the ‘vibrating with jigsaw’ method, which did not apply direct force on the fruit during separating. On the contrary, the ‘picking and dropping’ method applied force on the haskap berries from the fingers; while the ‘striking with plastic pipe’ method inevitably hit some of the berries. The only force applied on the haskap berries in the ‘vibrating with jigsaw’ method was the interaction with the collector when the berries dropped into it, which also occurred in the other methods.

Whether or not the non-hand-picked fruit can be sold successfully on the fresh fruit market is yet to be determined. Quality control and consumer acceptance studies will have to be conducted before adopting any new harvesting method.

Therefore, the next step should be to investigate the effect on the quality of the product.

**IV Summary and Conclusions**

In order to improve the harvesting efficiency of haskap berries with minimal added cost, we developed three new harvesting methods by making use of items that are usually available in farm sheds or easily found in the market. In 2008, haskap berries were separated by picking and dropping method, collected by modified umbrella, and cleaned by sieving with a mesh net in water. In 2009, haskap berries were separated by striking with a plastic pipe, collected by plastic net container, and cleaned by blowing with an electric fan. In 2010, haskap berries were separated by vibrating with a jigsaw, collected by portable tarp catch, and still cleaned by blowing with an electric fan.

Among the new harvesting methods, vibrating with a jigsaw was the most efficient way to separate haskap berries from the shrubs, reaching 19.35 kg/h with fruit collected by the portable tarp catch. Blowing with the electric fan was the optimal way to clean foreign material and small unripe berries from collected haskap berries, which achieved 22.90 kg/h by using the plastic net container as the receiver. However, additional grading was required to separate large unripe berries, berries with insect damage, and bruised berries.

This study indicates that when effective methods of separating and collecting are combined with adequate cleaning, harvesting efficiency can be improved from 1.45 kg/h (conventional hand picking) to as high as 10.36 kg/h (2010 harvesting method). This means that the new harvesting method at an affordable added cost would make it possible to
harvest a given amount of fruit with less than $1/7$ the number of workers required when picking by hand.

References


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