DEVELOPMENT AND TESTING OF THE PRE-PRODUCTION WMi WILD BLUEBERRY HARVESTER

VÝVOJ A TESTOVANIE PROTOTYPU KOMBAJNU WMi NA ZBER LESNÝCH ČUČORIEDOK

Kevin J. Sibley, Nabil M. Rifai

Abstract

The wild blueberry is grown as a commercially managed crop in the Northeastern region of the United States and from Ontario eastward in Canada. It is one of the most important horticultural commodities in this region, generating nearly 250 million dollars annually in economic activity. This project involved the development and testing a pre-production tractor-mounted harvester prototype that advances the state-of-the-art of wild blueberry harvesting. The picking performance of the harvester was tested in a variety of field conditions (Plots 1 through 4) in the Wood Islands and Souris areas of Prince Edward Island during the 1996 harvest season. As well, the picking performance of the harvester compared to a hand raking crew was tested. The mean picking loss for the harvester in Plot 1 was determined to be 9.9% and the hand-raking crew had a loss of 13%, but there was no statistical difference between these means. There was no statistical difference in picking loss for the field conditions tested, except for Plot 2. The overall mean picking loss for Plots 1, 3, and 4 was 9.3% compared to 16.2% for Plot 2. Since Plot 2 had heavy weed conditions, the significantly higher picking loss found was to be expected. Even so, the harvester performed quite well in the weedy conditions. The pre-production WMi harvester performed well in the field, thus advancing the technological state-of-the-art of wild blueberry harvesting. Its development should continue to commercial manufacture.

Key words: blueberry harvester, computer-aided functional analysis, field testing.

Introduction

The wild blueberry (Vaccinium Angustifolium Ait.) is grown as a commercially managed crop in Maine, USA and from Ontario eastward in Canada. Over the past fifty years, the wild blueberry industry has developed into one of the most important horticultural commodities in the region. Current total industry production is in the order of 60 million kilograms annually, with a farm-gate value of approximately $60 million. Total economic benefit of the industry to the economy is estimated at about $250 dollars annually.

Wild blueberries have traditionally been harvested manually using the Tabbut hand rake developed in 1883. Raking by hand is a backbreaking, tedious job that requires many people for short two-week harvest season. In the early through mid 1900's, cranberry harvesters were tried as mechanical blueberry harvesters (Peters 1906; Stankavich et al. 1952; Getsinger 1954; Getsinger 1956; Furford 1957; Furford 1960; Darlington 1954).

In the 1960's, the threat of shortages of manual labour and the ever increasing need for reducing harvesting costs spurred many researchers to try and develop mechanical harvesters specifically for wild blueberries (Brooks 1960; Rhodes 1961; Abdalla 1963; Soule 1969; Quick 1972; Grant and Lamson 1972; Gray 1974; Burton 1975; MacAulay 1976; Richard and Sibley 1982, Grant and Nason 1988; Robichaud 1995).

Contact Address

Prof. Kevin J. Sibley, Dr. Nabil M. Rifai, Department of Engineering, Nova Scotia Agricultural College, PO Box 550, Truro, Nova Scotia, Canada, B2N 5E3.

The only tractor-mounted harvester commercially produced in the industry since 1982, however, has been the Bragg harvester, manufactured by Doug Bragg Enterprises Ltd., Collingwood, Nova Scotia (Bragg and Weatherbee 1989a, 1989b, 1991). The Bragg harvester has proven to be a reliable machine and it's picking effectiveness can be as high as 86.2% under ideal conditions (Sibley 1993). However, general usage picking efficiency is in the range of 60 to 65% of what hand rakers harvest (Marra et al. 1989, Sibley 1994). The harvester has capacity issues in heavy crop conditions, and cannot pick at all in weedy conditions. These are two important considerations as crop yields continue to increase as a result of growers using better cultural management practises and reducing the use of herbicide weed controls.

Objective

The objective of this project was to develop and test a pre-production tractor-mounted wild blueberry harvester prototype that would overcome the limitations of the Bragg harvester, thus advancing the technological state-of-the-art of wild blueberry harvesting. The resulting harvester, if successful, would be manufactured by Weatherbee Manufacturing Inc., Charlottetown, Prince Edward Island.

Materials and Methods

The WMi Harvester Concept. The picking head (Fig. 1) consists of two parallel endless chains running along support framework. Equidistantly spaced along the chains, and attached thereto perpendicularly between them, are a series of specially designed picking rakes. The chains are driven such that the picking teeth engage the crop while moving in the same direction as forward travel, similar as is done when hand raking.

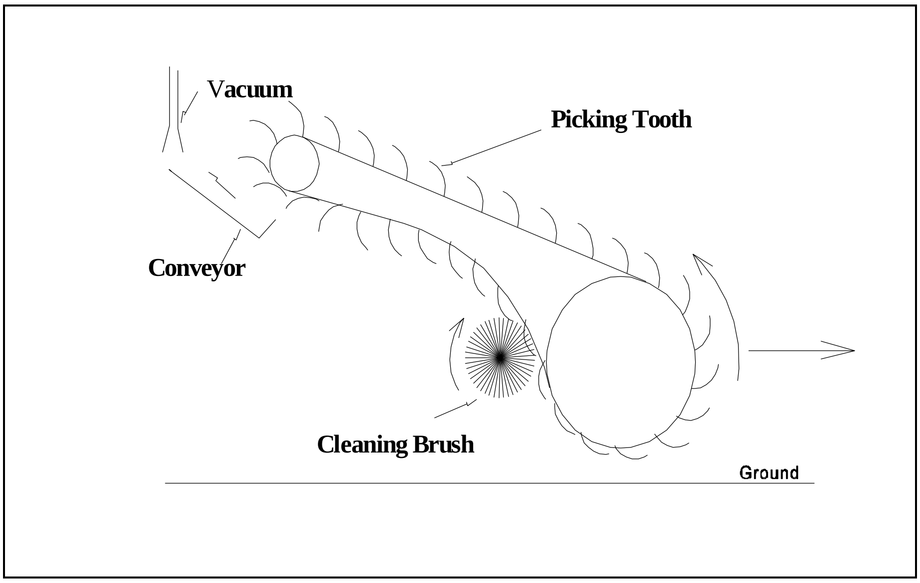

Fig. 1: WMi harvester concept picking head.

Cam mechanisms are utilized to orient the picking teeth to effect picking and dumping into a full width berry transport conveyor located at the rear of the picking head. Together these components essentially form a flighted picking conveyor, which combines the picking, conveying and elevating functions found on current harvesters.

Photographs of the harvester prototype working in the field are shown in Figs. 2 and 3.

Fig. 2: WMi harvester prototype operating in the field – front view.

Fig. 3: WMi harvester prototype operating in the field – rear view.

The picking head rides on the ground on four support wheels attached to a walking-beam suspension system. The picking head is floatingly attached to an overhead boom-arm to allow it to closely follow ground contours during operation and to be lifted clear of obstructions.
A rotating brush located at the lower rear of the picking section of the head removes debris from the picking teeth and deposits it on the picked ground to the rear of the harvester. A pneumatic cleaning system (vacuum), located at the rear of the picking conveyor, removes field debris. A box rack for handling empty and full field boxes, and storing the harvester when not in use or for road transport is attached to the tractor's 3-pt. hitch.

Design and Development. A computer-aided functional analysis was conducted using SigmaPlot™ and Mechanical Desktop™ CAD software. Using the combined spreadsheet, math transform programming language, and graphing capabilities of SigmaPlot™, a mathematical ellipse-function model of the picking head's raking motion was created. The model enabled critical operating/design parameters to be experimented with to see what effect they had on raking motion, and to finally optimize the motion. In addition, both relative and absolute tooth velocities were able to be determined which aided in the design/selection of mechanical components for the prototype.

A bench-top model was designed, constructed, and subjected to alpha-testing. The bench-top model consisted of a transparent-sided experimental picking head and a forward motion and plant simulator conveyor system. This enabled viewing and videotaping of the picking action using 1/10,000 s shutter speed for motion analysis. Tests were performed at various simulated forward speeds, chain-speed-ground-speed ratios, and picking heights. Simulated bush density was also varied. The videotape was analyzed frame-by-frame in slow motion. Refinements to the design were made, and its operation was re-analyzed to optimize functional performance. The final design of the cam-followers and tracks allowed the picking teeth tip to follow its root through the bottom of the picking cycle, to shoot out horizontally at the base of the plants, and then to pick vertically up through the plants without disturbing the horizontal orientation of the plants.

Based on the success of the alpha testing, a fully functioning pre-production prototype was designed and constructed for field testing.

Field Testing. The picking performance of the harvester was tested in a variety of field conditions in the Wood Islands and Souris areas of Prince Edward Island during the 1996 harvest season. Completely ramdomized experimental designs were used for testing. Four test sites (Plot 1, Plot 2, Plot 3, and Plot 4) having four different field conditions (Table 1) were used.

Plot 1 was a first-crop field with a fairly good yield of average sized berries, and heavy density, branchy, very tall plants. The ground was smooth with no hummocks. Weed density was light. Plot 2 was a first-crop field with a very heavy yield of small sized berries, and light density, short plants. Many of the plants in this plot were lying on or very close to the ground, from the weight of the strings of berries on them. The ground was smooth with a few hummocks. Weed density was heavy. Plot 3 was a second-crop field with a heavy yield of small sized berries, and medium density, branchy, little taller than average height plants. The ground was smooth with a few hummocks. Weed density was light. Plot 4 was a first-crop field with a heavy yield of a little smaller than average sized berries, and medium density, average height plants. The ground was smooth with a few hummocks. Weed density was light.

Table 1: Field Conditions Of The Field Test Sites.

Parameter	Plot 1	Plot 2	Plot 3	Plot 4
Ground rating	Smooth	Smooth	Smooth	Smooth
Crop	1st	1st	2nd	1st
Area harvested (m^2)	410	680	1300	4330
Weed rating	Light	Heavy	Light	Light
Plant height (cm)	23 - 33	10 - 15	15 - 25	10 - 20
Mean bush density (stems/m^2)	623	324	498	520
Mean berry size (#/100 g)	1100	1610	1640	1280
Mean pre-harvest losses (%)	17.3	15.0	15.0	13.1
(kg/ha)	953	1316	1174	1036
Mean berries on plants (kg/ha)	4552	7434	6631	6867
Mean total production (kg/ha)	5505	8750	7805	7903
Harvester picking height (cm)	5	5	9	5

In each test plot, the harvester was operated using a chain-speed-ground-speed ratio (CSGSR) of 3.0, a ground speed (GS) of 1.5 km/h, and a roundabout-harvesting pattern. Yield, pre-harvest and ground loss samples were randomly taken to determine the harvester's picking loss (%PL). Samples from an area immediately surrounding Plot 1 where a hand raking crew was working were also taken to enable comparison of the harvester with hand raking. Detailed field test procedures are described in Sibley (1993).

Data Analyses. The test data collected were analyzed using Microsoft Excel and Jandel Scientific SigmaStat™ software packages. Statistical analyses were performed using one-way Analysis of Variance and Student-Newman-Keuls pairwise multiple comparison procedures.

Results and Discussion

The mean picking loss for the harvester in Plot 1 was determined to be 9.9%, and the hand-raking crew had a loss of 13% (Fig. 4).

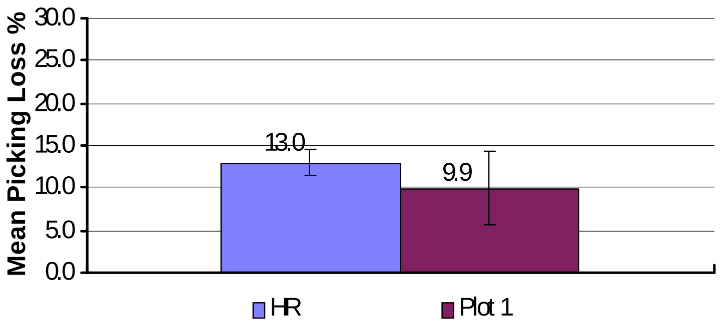

Fig. 4: Mean picking loss for hand raked area and harvester in Plot 1.

A one way Analysis of Variance (ANOVA) (Table 2) was performed to determine if there was any statistical difference in mean picking losses for the hand raked area and Plot 1. The differences in the mean values of percent Picking loss (%PL) tested were not statistically different (P=0.5212) when tested at the 0.05 level of significance. This is an improvement over the reported hand raking comparisons for the Bragg harvester where general usage picking efficiency is in the range of 60 to 65% of what hand rakers harvest (Marra et al.1989, Sibley 1994).

Table 2: ANOVA Results Of Mean %PL For Hand Raked Area And Harvester in Plot 1.

Source of Variance	**DF**	**SS**	**MS**	**F**	**P**
Between Treatments	1	106.6	106.6	.414	.5212
Residual	111	28589.2	257.6		
Total	112	28695.8			

The mean picking loss for the harvester in Plot 2, Plot 3, and Plot 4 were 16.2%, 8.9%, and 9.0%, respectively. These losses are shown graphically in Fig. 5.

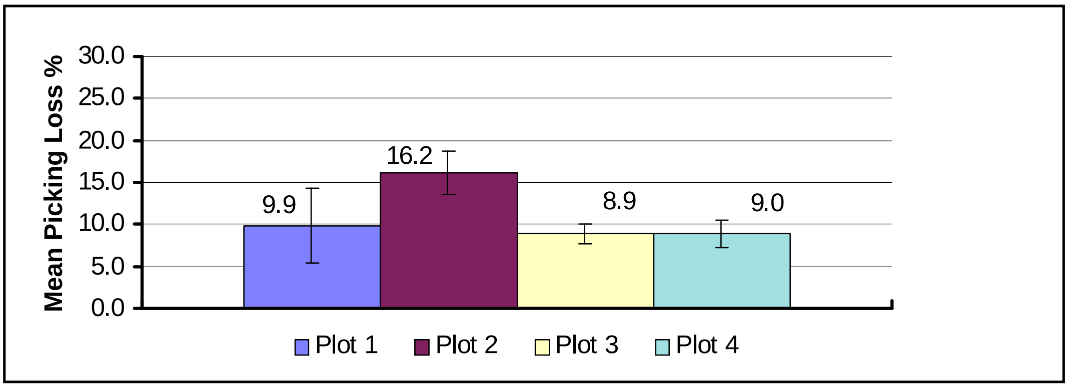

Fig. 5: Mean picking loss for Plots 1 through 4.

A One Way Analysis of Variance (ANOVA) (Table 3) was performed to determine if there was any statistical difference in picking losses due to the varying field conditions of the four test plots. The differences in the mean values of %PL among the Plots tested were statistically different (P=0.0209) when tested at the 0.05 level of significance.

Table 3: ANOVA Results Of Mean %PL For Plots 1 Through 4.

Source of Variance	**DF**	**SS**	**MS**	**F**	**P**
Between Treatments	3	1678.6	559.5	3.34	.0209
Residual	150	25115.3	167.4		
Total	153	26793.8			

The means were further analyzed to determine specifically which ones were different by performing a multiple comparison analysis using the Student-Newman-Keuls Method (Table 4). This method compared pairs of means in a sequential fashion. Plot 2 was found to be statistically different (P<0.05) from both Plot 3 and Plot 4, but not from Plot 1. Plot 1, Plot 3 and Plot 4 were not statistically different from each other. Since Plots 1, 3 and 4 were not different, one would have expected that Plot 1 would have also been different than Plot 2 since Plots 3 and 4 were. The Plot 1 mean, however, had a lower number of samples in the data set compared to the other Plot's data sets. The resulting higher standard error of the mean of Plot 1, then, did not allow the test to statistically detect this difference, even though it is highly likely from looking at the consistently lower standard errors for the other plots, that they are different.

Table 4: Pairwise Multiple Comparison Analysis Of Plots 1 Through 4 %PL Means.

Comparison	**Diff. of Means**	**p**	**q**	**P<0.05**
Plot 2 vs. Plot 3	7.2834	4	4.1574	Yes
Plot 2 vs. Plot 4	7.1977	3	3.3663	Yes
Plot 2 vs. Plot 1	6.2893	2	2.1252	No
Plot 1 vs. Plot 3	0.9941	3	0.3458	No
Plot 1 vs. Plot 4	0.9083	2	0.2906	No
Plot 4 vs. Plot 3	0.0858	2	0.0425	No

The results of this analysis indicate that there was no statistical difference in picking loss for the field conditions tested, except for Plot 2. The overall mean picking loss for Plots 1, 3, and 4 was 9.3% compared to 16.2% for Plot 2. Since Plot 2 had heavy weed conditions, the significantly higher picking loss found was to be expected. Even so, the harvester performed quite well in the weedy conditions. These results are an improvement over the Bragg harvester which has capacity issues in heavy crop conditions, and cannot pick at all in weedy conditions.

Conclusions and Recommendation

Based upon the results of the field testing, the following conclusions and recommendation were made.

1. The mean picking loss for the harvester in Plot 1 was determined to be 9.9%, and the hand-raking crew had a loss of 13%, but there was no statistical difference between these means. This is an improvement over the reported hand raking comparisons for the Bragg harvester where general usage picking efficiency is in the range of 60 to 65% of what hand rakers harvest.

2. There was no statistical difference in picking loss for the field conditions tested, except for Plot 2. The overall mean picking loss for Plots 1, 3, and 4 was 9.3% compared to 16.2% for Plot 2. Since Plot 2 had heavy weed conditions, the significantly higher picking loss found is to be expected. Even so, the harvester performed quite well in the weedy conditions. These results are an improvement over the Bragg harvester which has capacity issues in heavy crop conditions, and cannot pick at all in weedy conditions.

3. The pre-production WMi harvester performed well in the field, thus advancing the technological state-of-the-art of wild blueberry harvesting. Its development should continue to commercial manufacture.

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Súhrn

Voľne rastúce čučoriedky v prírode (divé čučoriedky) sú komerčne obhospodarovaná plodina v Severovýchodnej oblasti Spojených Štátoch Amerických a v Kanade od Onatria smerom na východ. Je to jedna z najdôležitejších plodín tejto oblasti, ktorá ročne vynáša takmer 250 miliónov dolárov. Tento projekt zahŕňa rozvoj a testovanie prototypu zberača, ktorý umožní rýchli zber čučoriedok s minimálnymi stratami a zdokonalí súčasnú technológiu. Výkonnosť kombajnu bola odskúšavaná v roku 1996 v rôznych poľných podmienkach (polička od 1 do 4)vo Wood Islands a v oblasti Souris ostrova Princa Eduarda v Atlantickom oceáne . Výkonnosť zberača sa tiež porovnávala s ručným zberom. Pri mechanizovanom zbere priemerne straty na poličku č.1 boli 9.9 % a pri ručnom zbere 13%. Na poličku 1, 3 a 4 celkové priemerné straty pri použití kombajnu boli 9.3 % ale na poličku č. 2 priemerné straty dosiahli 16.2 %. Políčko č.2 bolo veľmi zaburinené a vyššie straty sa predpokladali. Napriek množstvu burín kombajn podal dobrý výkon. Prototyp WMi kombajnu pracoval dobre v poľných podmienkach a preto je potrebné pracovať na jeho zdokonalení čo umožní jeho komerčnú výrobu.

Kľúčové slová: kombajn na zber čučoriedok, počítačom podporovaná funkčná analýza, poľné skúšky.