Interim Report for Southern Region Small Fruit Consortium Grant for SRSFC Project 2023-R-01

Title: Blueberry Detachment Force and Mechanical Harvest Performance

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Public Abstract:

In the dynamic world of blueberry farming, transitioning to machine harvesting (MH) for fresh market blueberries is increasingly popular. This shift is driven by the development of new harvesters and blueberry varieties designed for modern agriculture. A key factor in MH success is the Pull Force (PF) - the force needed to detach ripe and unripe berries from the bush. Our research focuses on understanding PF and its impact on MH yields. We aim to create guidelines for selecting cultivars suitable for MH early in their development, aiding growers and researchers in evaluating current commercial varieties for MH. Our work lays the groundwork for future genetic research and harvester optimization, enhancing blueberry farming's efficiency and sustainability.

Description of Work:

Our project focuses on investigating the PF in blueberries and its relationship with MH yields. We conducted two experiments:

1) Machine harvesting known cultivars with historical data on PF of green and blue berries at various speeds.
2) Comparing hand and machine harvesting in advanced selections at two speeds, preceded by PF evaluations.

Challenges such as cultivar availability and field accessibility were encountered, necessitating adjustments in our initial cultivar selection. Cultivars Pinnacle, Farthing, Legacy, and New Hanover were harvested for experiment 1. For experiment 2, 15 advanced selections and 3 checks were harvested. For both experiments, on the day of harvest, 20 unripe and ripe fruit were sampled from each plot for PF using a 50 N generic digital force gauge (Hojila Model: AMF-50). A paperclip was modified to create an immobile hook as it was easier to manipulate than the rotating hook supplied by the manufacturer. On occasion green fruit would detach in clusters, so additional notes were taken if any clusters were removed during testing. Additionally, 1-2 plants from between each plot were fully picked clean of green and blue fruit to allow for harvester clean out. This fruit was also used as a baseline for yield and fruit quality to compare to harvester yield and fruit quality. Plots were then machine harvested (MH) using the “Little Blue” tractor-pull harvester; this sway arm harvester was modified to be able to be open the sway arms as needed, enabling it to harvest individual plots within a row (BEI 05666, BEI Incorporated, South Heaven MI). A digital photo sensor tachometer was used to measure the rotations

per minute (RPM) of the fly wheel as it drove the sway arm drive shaft assembly. Low force were deemed anything between 107 and 114 RPM, Medium between 142 and 177 RPM, High between 209 and 215 RPM. MH fruit was weighed then sorted using a WECO soft & color blueberry sorter (Woodside Electronics Corporation, Woodland, CA). Sorted and rejected fruit was weighed to account for any debris and give estimates for green/red fruit. Blue/sorted fruit was subjected to firmness testing using a Firmtech 2 and storability testing, along with brix/acidity assays at each time point (1-day post-harvest and 14 days post-harvest). PF data was measured in kilograms and later converted to grams.

Data analysis was performed using JMP Pro 17.

Results and Discussion:

The first experiment, intended to define RPM thresholds for berry detachment relative to PF, faced issues due to lack of variability between cultivars with regards to PF of unripe and ripe fruit, the exception being Pinnacle and New Hanover unripe fruit, which is likely due to the % ripeness at the time of harvest (Tables 1 and 2).

Level				Least Sq Mean
[Green]Pinnacle	A			186.52000
[Green]Legacy	A	B		153.33333
[Green]Farthing	A	B		152.58621
[Green]NewHanover		B		143.22222
[Green]Star		B		137.56667
[Blue]Pinnacle			C	83.72414
[Blue]Farthing			C	65.03333
[Blue]NewHanover			C	64.13793
[Blue]Star			C	62.96667
[Blue]Legacy			C	59.00000

Levels not connected by same letter are significantly different.

Table 1: Tukey HSD LSMeans Differences-green unripe fruit and blue ripe fruit by cultivar. Note Star was not machine harvested.

Harvest Date	Name	Est. % ripe	Average % Blue*
Wednesday, May 17, 2023	Pinnacle	25	33.3%
Wednesday, May 17, 2023	Farthing	70	72.6%
Monday, June 12, 2023	Legacy	70	76.0%
Monday, June 12, 2023	NewHanover	90	93.1%
	*when green weight multiplied by 2		

Table 2: Harvest dates and Estimated and Calculated percent ripe of Experiment 1 cultivars

However, the first experiment did allow us to analyze a few other parameters, such as the change of firmness due to harvester speed and sorting machine(Figures 1 & Table 3, & Table 4). We also saw an increase in rejection at higher machine speeds, which is likely due to both green and soft fruit (Figure 2 and Table 4). Unfortunately, we did not measure these two parameters separately after sorting.

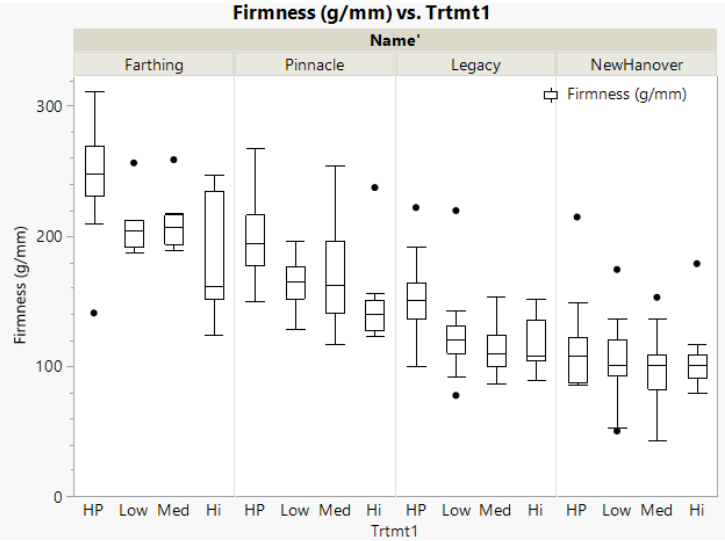

Figure 1: Changes in Firmness by treatment of Machine Harvest at 3 different speeds and Hand Picked (HP)

Level		Least Sq Mean
HP	A	179.48759
Low	B	149.76023
Med	B C	147.70355
Hi	C	137.13002

Levels not connected by same letter are significantly different.

Table 3: Tukey HSD LSMeans Differences of Firmness at 3 different speeds and Hand Picked (HP)

Level		Least Sq Mean
PreSort	A	116.09226
PostSort	B	104.60702

Levels not connected by same letter are significantly different.

Table 4: Tukey HSD LSMeans Differences in Firmness before and after machine sorting.

Level			Least Sq Mean
Hi	A		0.44059364
Med	A	B	0.39795256
Low		B	0.35564014

Levels not connected by same letter are significantly different.

Table 5: Tukey HSD LSMeans Differences in % Rejected fruit between MH speeds.

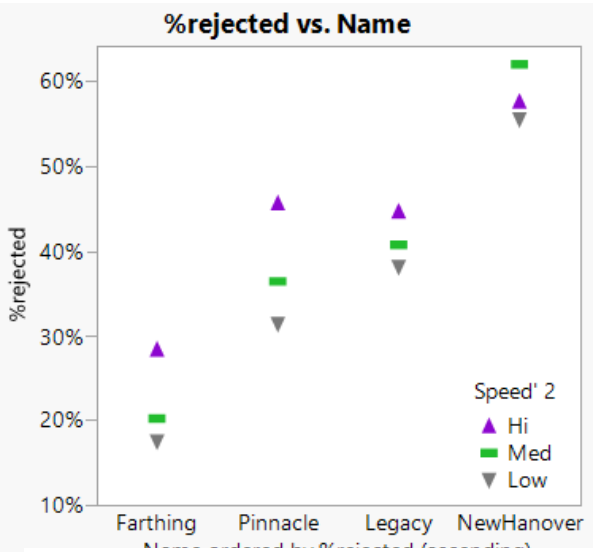

Figure 2: %Rejected by cultivar and harvester speed.

Experiment 2 contained bushes with a much wider range of pull forces between cultivars (Figure 3). This is promising for future experiments once the protocols are corrected.

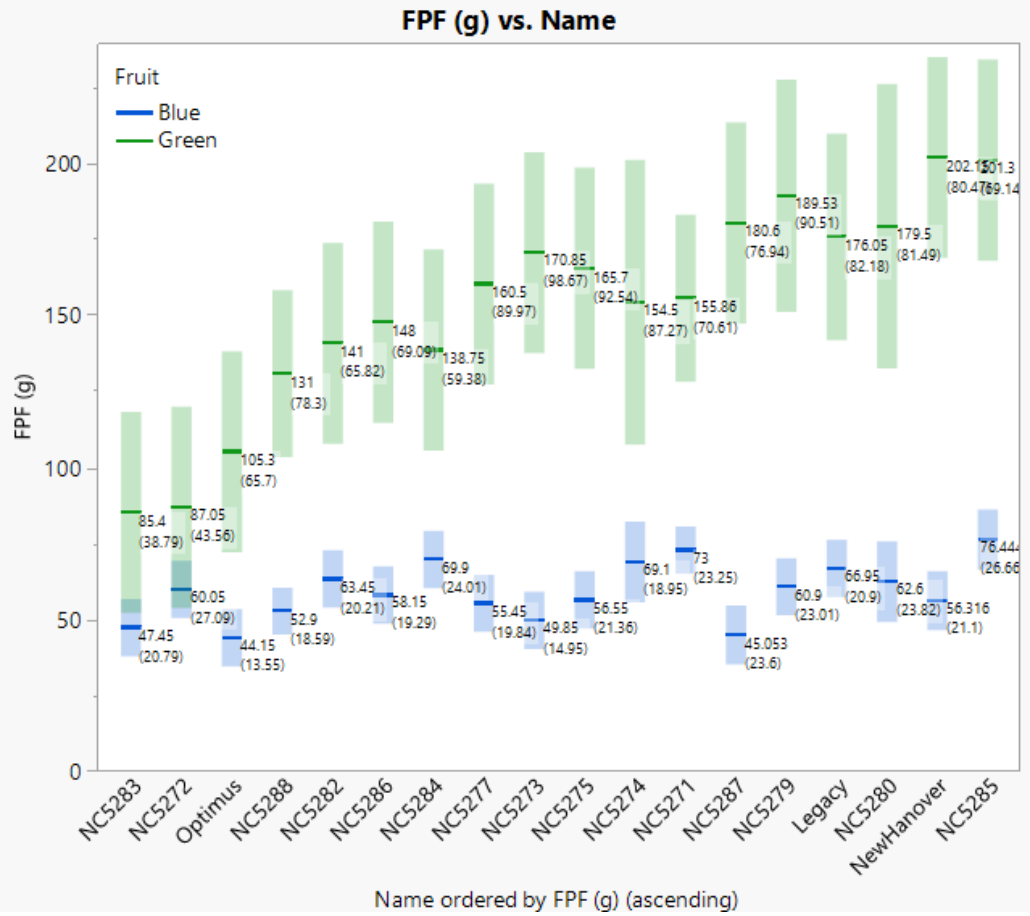

Figure 3: Fruit Pull Forces of Green unripe and ripe Blue berries in Experiment 2.

Additionally, the correlation matrix below found promising correlations between several parameters.

There is a moderate positive correlation (0.3596) between the detachment force of green and blue berries. This suggests that bushes with higher detachment forces for green berries tend to also have higher forces for blue berries. Consistent with ripening profiles, the negative correlation between Blue PF and estimated % ripe(-0.565) as well as the Green unripe berry PF and estimated % ripe (-0.5214), reiterates that as berries ripen the less force is needed to detach berries from the bush. However, there are still significant differences between cultivars.

There is a moderate positive correlation (0.3581), which could imply that higher rpm settings on the harvester are associated with a higher percentage of rejected berries, which is consistent with both previous findings that harvester speed decreases fruit firmness, leading to rejection, and the hypothesis that higher speeds increase the amount of green fruit harvested.

The overall ripeness of blueberries on the bush was originally estimated by eye. Afterwards, percent ripeness was calculated by dividing blue berry weight by green berry weight multiplied by 2 and added to the blue berry weight. A positive correlation (0.5931) between the calculated and estimated

percentages of ripe berries suggests that these two measures generally agree.

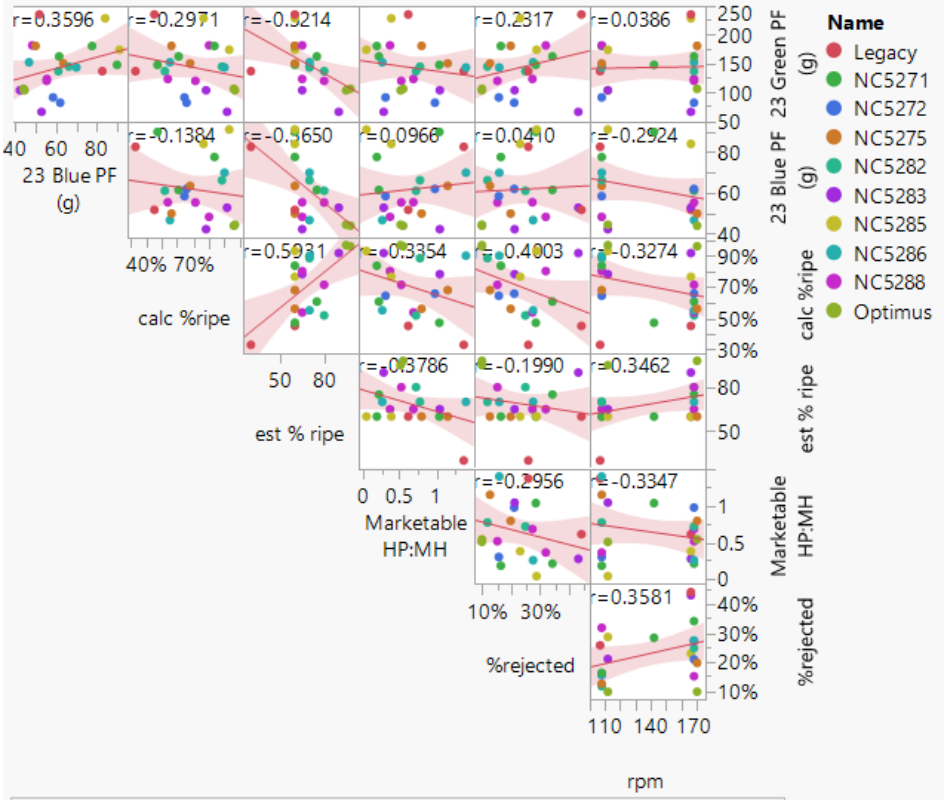

Table 6: Correlation matrix of Experiment 2 parameters.

Data for the effects of machine harvest on shelf life, brix, acidity, and flavor are to be analyzed.

Lessons and Future Directions:

It was initially thought that the handpicked berries would be sufficient to estimate how much fruit was left on the bush, and so it was deemed unnecessary to glean leftover fruit from the bushes after machine harvest. However, we did not account for the amount of fruit missed by the harvester catch plates. Our machine, being an older model, is particularly poor at catching fruit, and a large discrepancy was seen between handpicked and machine harvested yields. This led to a poor estimation of blue and green fruit left on the bush, a discrepancy that was not realized until data analysis. This discrepancy was compounded when we weighed green/red rejected and soft rejected fruit together instead of separately. We plan to update our protocols for next year to include gleaning leftover berries from a subset of bushes from each plot after machine harvest, and to weigh unripe and soft sorted berries separately.

Additionally, data suggests that to define RPM thresholds, a better methodology may be to harvest cultivars at multiple ripeness points, so to capture a wider range of berry detachment forces that can then be correlated to RPMs. The data also suggests that the wide range of deviation from the mean on green berry PF necessitates refining our protocols with regards to which berries are selected for green fruit pull force measurements.