

Title: Blueberry Detachment Force, Fruit Quality Traits and Mechanical Harvest Performance

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Public Abstract:

Mechanical harvesting of blueberries is becoming increasingly essential for growers as labor cost and availability fluctuate. Breeders need reliable tools to predict how new cultivars will perform under machine harvest. This project integrates field-based pull-force measurements, weekly mechanical harvesting, and AI-driven fruit classification to evaluate traits related to fruit detachment, ripening behavior, and postharvest performance. The goal is to build practical, technology-supported metrics that help breeders identify genotypes with improved mechanical harvestability.

Analysis of the 2025 dataset is still ongoing, but preliminary findings show that detached fruit clusters are a major source of green fruit ending up in machine-harvested fruit. This highlights the importance of evaluating both pedicel (fruit stem) and peduncle (fruit cluster) level attachment strength when selecting for machine-harvest suitability. A refined AI model capable of accurately distinguishing individual berries from intact clusters will be applied to this year's data, enabling more precise estimates of green-fruit loss and improving identification of advanced selections that are poorly suited for mechanical harvest.

By combining physiological measurements with machine-harvest testing and improved image-based classification, this project establishes a framework to guide development of future cultivars optimized for mechanized production and consistent fruit quality.

Introduction:

The rapid expansion of machine harvesting (MH) in blueberries has increased the need for cultivars with predictable mechanical harvestability. While fruit firmness is a known driver of MH performance, traits such as fruit detachment force, cluster structure and plant architecture remain poorly quantified. To address this gap, our program has begun building a framework to evaluate fruit detachment or pull force (PF) as predictors of MH efficiency and postharvest quality.

In 2023–2024, we conducted a series of experiments to explore the relationships among PF, harvester RPM, fruit retention, and berry quality. The protocol in these two years differed only slightly, with both harvesting at 50-60% ripe, and gleaning all fruit, ripe and unripe, from a selection of bushes within the plot. The 2023 study used a set of known cultivars and early-stage selections that revealed that ripe and unripe PF are moderately correlated within genotypes and PF in both blue and green fruit decreases over time as bushes ripen. Follow-up work in 2024 expanded the study to 42 new accessions. Both trials showed that higher harvester speeds increase fruit rejection and reduce firmness. While hand-harvested fruit consistently outperformed machine-harvested fruit in storage, immediate post-harvest chemistry (Brix, pH, acidity) did not differ across methods. The shelf-life penalties associated with MH appear driven more by bruising and disease spread during the harvesting and sorting process than by inherent fruit composition.

The 2024 trial exposed additional challenges that influence PF reliability and MH outcomes. Because of the single mid-stage harvest, ripeness variability within plots and the use of older mechanical sorting equipment all contributed to inconsistent yield and quality measurements. In 2025, we implemented a protocol to machine harvest and glean ripe fruit each week to minimize overripe fruit, and to use an AI model to estimate green fruit percentage in samples of MH fruit; the aim being to obtain a truer insight into fruit detachment force and the role it plays in machine harvestability.

Materials and Methods:

Each week, plots were monitored and flagged in the GridScore Next app (James Hutton Institute, Scotland) once approximately 10% of fruit had reached ripeness, indicating the start of weekly harvest. Using GridScore, two workers collected pull-force measurements on 10 green and 10 blue berries per plot each week using modified 50 N digital force gauges. Pull-force sampling continued until a plot was designated “complete,” defined as insufficient remaining green fruit for further measurement. Due to a concurrent collaborative study with Auburn University and the need to obtain data for selection

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advancement and potential cultivar release, only one replicated plot per genotype was harvested in most cases. In total, 45 genotypes across 51 plots were harvested.

When a plot was designated as harvestable, fruit was mechanically harvested weekly using a modified “Little Blue” tractor-pulled sway-arm harvester (BEI 05666, BEI Inc., South Haven, MI). The sway arm was operated at the lowest functional setting, approximately 116 flywheel rotations per minute (RPM), verified using a digital photo-sensor tachometer. The tractor was driven at a constant speed of 0.7 miles per hour. After mechanical harvest, all remaining ripe fruit was hand-gleaned from the plot.

Mechanical-harvest and gleaned yields were recorded. Three pints of mechanically harvested fruit and one pint of gleaned fruit were collected in one-pint clamshells for imaging, texture evaluation, and postharvest storage assessments. Each clamshell was spread in a tray and photographed to support both AI-based and human estimation of percent green fruit. Ten berries from each clamshell were evaluated using an Agrosta Angele Texture Analyzer. An additional 25 berries per treatment were weighed and stored at room temperature for 10 days to assess weight loss and disease incidence. The remaining fruit was frozen for later analysis of soluble solids content (°Brix), titratable acidity, and pH.

Results and Discussion:

Analyses are ongoing. To date, 242 clamshell images have been processed by the AI model to quantify green and total berry numbers; an additional 92 pictures were misclassified and will need to be run as well. Initial analysis revealed a weak positive correlation between green fruit pull force and percent green fruit harvested ($R^2 = 0.124$), a direction opposite of what was expected. However, image review showed that most green fruit present in harvested samples were still attached in clusters via the peduncle. During pull-force collection, detached clusters were counted among the 10 sampled berries, but cluster detachment was not linked to individual pull-force measurements, limiting interpretability. This disconnect likely inflated the apparent “green fruit” counts in the harvested samples and contributed to the observed positive correlation. Much of the green fruit loss occurred during the first harvest, when the highest proportion of unripe berries remained on the plant, indicating that even low-intensity harvester settings can remove entire clusters early in the season (Figure 1). This suggests that machine parameters alone cannot prevent green fruit removal when cluster architecture is weak, highlighting the importance of evaluating peduncle-level attachment traits.

An expected negative relationship was observed between blue fruit pull force and percent ripe fruit harvested, but the correlation was weak ($R^2 = 0.135$). This likely reflects multiple interacting factors. Variation in berry distribution within the canopy and cluster architecture

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may have further obscured the expected pattern, as sheltered ripe berries with low detachment force can remain attached, while more exposed berries with slightly higher detachment force may be removed. Pull-force sampling was also limited to ten berries per week and did not capture positional effects. Together, these factors indicate that ripe-fruit detachment force alone is insufficient to predict machine harvestability without considering canopy distribution, cluster architecture, and harvester intensity.

The unexpectedly high frequency of cluster detachment also exposed limitations in the current AI pipeline. The model is unable to distinguish cluster-attached fruit from individual berries, resulting in misclassification and artificially elevated counts of “green fruit” in mechanically harvested samples. Improving the AI model to classify clusters independently will be critical for generating meaningful relationships between detachment forces and harvest outcomes. Once the mislabeled images are corrected and cluster counts are isolated, more accurate and meaningful correlations should emerge.

Weekly mechanical harvesting followed by complete gleaning provided more reliable estimates of machine-harvest efficiency and fruit loss than a single harvest, but the approach was substantially more labor-intensive. Adding machine sorting would have further increased the burden. These logistical constraints should be considered in future trial design, particularly for studies aiming to refine detachment-force thresholds or develop predictive models of mechanical harvestability.

Overall, this study highlights the importance of distinguishing between berry-level and cluster-level detachment processes and underscores the need to measure forces at both the berry–stem and peduncle–cluster interfaces. For breeding programs targeting improved mechanical harvestability, these results point to key architectural traits—cluster strength, peduncle attachment, and canopy distribution—that must be evaluated alongside traditional firmness and detachment-force metrics.

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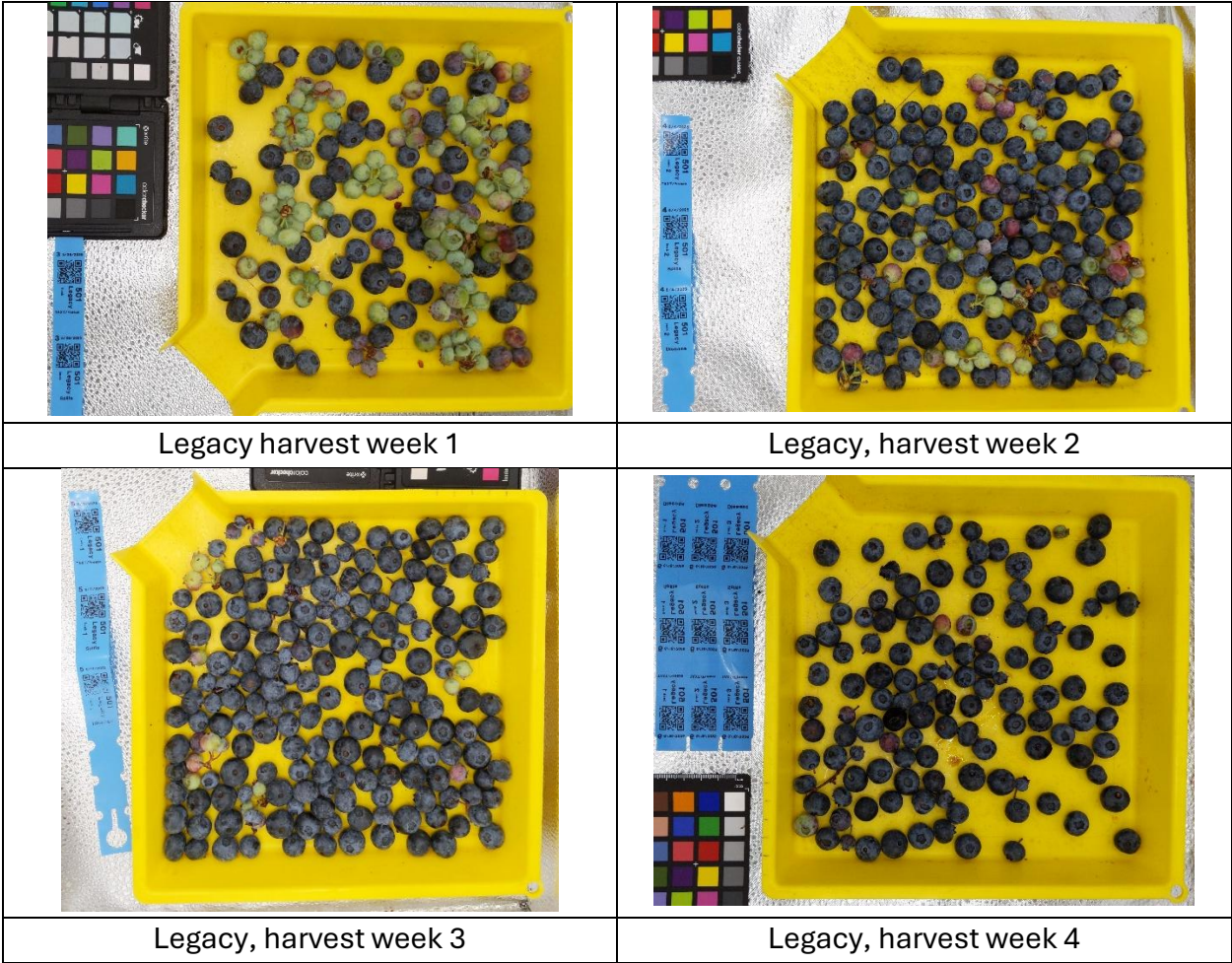


Figure 1 - Fruit clusters in cultivar "Legacy" by week.

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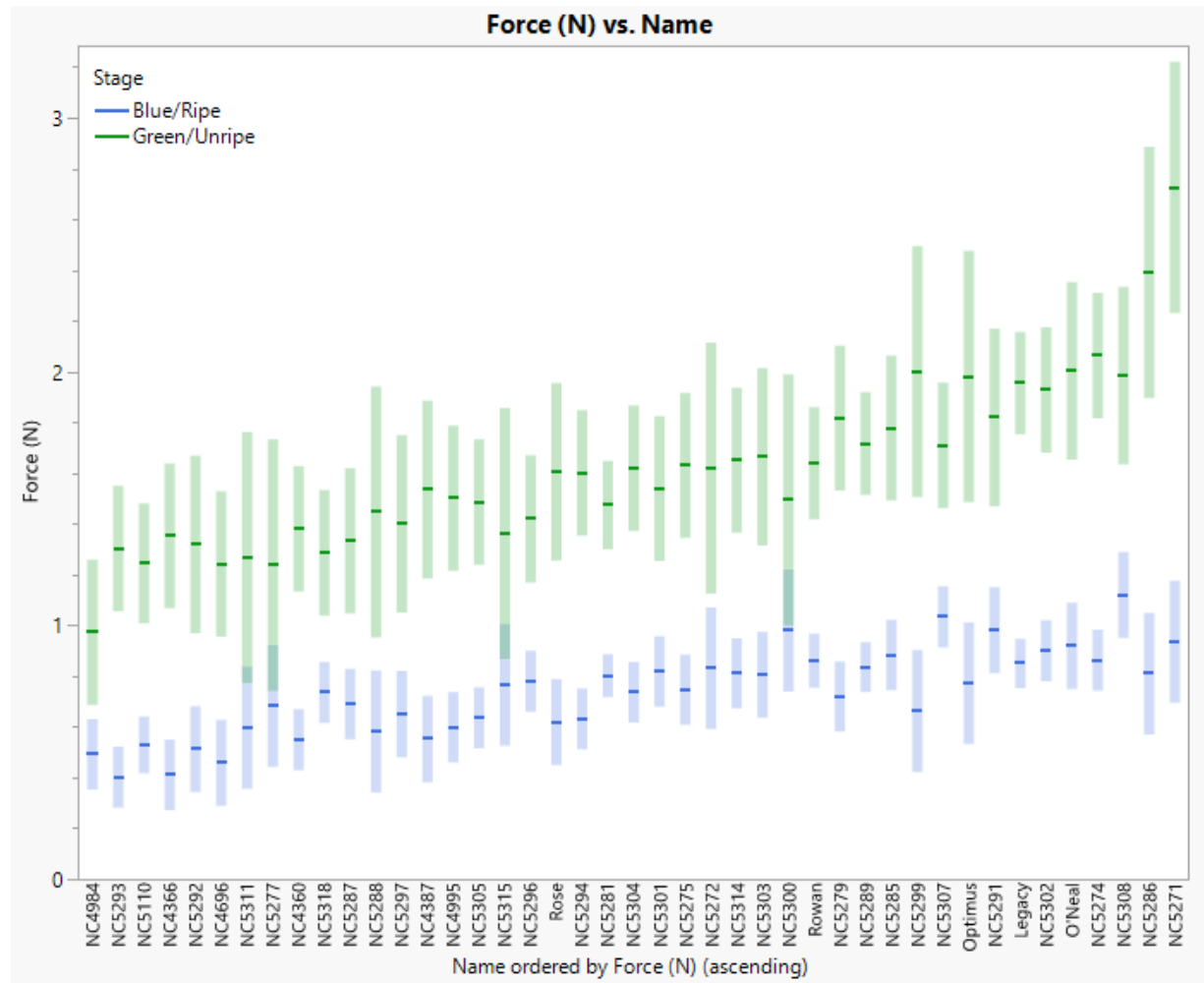


Figure 2- 2025 Pull Force in Newtons for green and blue fruit by genotype.