Considerations for the Mechanical Harvest of Edamame

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Introduction

Vegetable soybean [*Glycine max* (L.) Merr.] is a popular component of Asian cuisine in the United States of America (USA). Vegetable soybean is better known by its Japanese name, "edamame," where it has been cultivated and consumed for centuries, with the first written account of the word in 1275 AD (Shurtleff & Aoyagi, 2021). Japan still consumes the majority of the world's edamame, importing much of its supply from Taiwan (Wang, 2018). In the USA, domestic market demands for edamame increased around the turn of the 21st century (Mentreddy et al., 2002), growing annually 12-15% by 2010 (UAEX, 2012). Today, edamame is the second most popular direct-consumption soy product in the USA (Soyfoods, 2014). Despite increased market demands triggering interest in domestic production, upwards of 70% of the USA's edamame consumption is still imported from China (Barlow, 2018). Increased financial, production, legal, labor, and market risks as a specialty vegetable crop, lack of processing infrastructure, labor expenses, market distribution, and challenges with mechanical harvesting have caused domestic production to lag behind market demand increases (Neill & Morgan, 2021).

While avenues to provide consumers with USA-grown edamame are being examined, nutrient management practices and mechanical harvesting technology need to be investigated. Most recent edamame research focused on varietal development (Carneiro et al., 2021; Carneiro et al., 2020; Moseley et al., 2021; Zhang et al., 2022a). Few studies focused on the role mechanical harvesting plays in scaling production and maximizing producer profitability. Historically and currently, most fresh market edamame is hand-harvested. Labor prices in the USA make hand-harvesting an unrealistic venture for large production systems and suppliers. Garber et al. (2019) determined labor costs for hand-harvested edamame in Virginia, USA, could account for as much as 62% of total production expenses, and the breakeven price for hand harvested edamame would be nearly double that of mechanical harvest costs ($1.03 and $0.53 per pound, respectively). Lord et al. (2021) reported that the breakeven price for hand-harvested edamame in Virginia exceeded the market price in 2019. Meanwhile, Neill & Morgan (2021) concluded that mechanical harvest, despite increased product damage, was profitable by reducing production costs by nearly half. Our goal was to quantify mechanical harvest efficiency to optimize edamame varieties best suited for commercial production.

Materials and Methods

Variety Selection and Planting

Field trials were conducted at the Virginia Tech Eastern Shore Agricultural Research and Extension Center (AREC) in Painter, VA (37.586917°, -75.823861°). Each plot consisted of four 40-foot rows with 36-inch row spacing. Our fields were conventionally tilled and planted at a 100,000 seed per hectare rate with 80% germination. In 2021, Tohya (Johnny's Selected Seeds, Winslow, ME, USA) 78-day maturing and MFL2P59 (Montague Farms, Center Cross, VA, USA) 115-day maturing edamame were planted (Fig. 1).

Figure 1. Comparison of MFL-2P59 (left) and Tohya (right) edamame on sandy loam soils in 2021.

Mechanical Harvest

Between August and October, pods from one row per plot were mechanically harvested using an ASA-LIFT GB-1000 (Sorø, Denmark) (Fig. 2), while another row in each plot was hand-harvested. Assuming 100% of marketable pods were collected by hand-harvesting, we calculated mechanical harvest efficiency by comparing the mechanical harvest yield to the hand-harvested yield.

Figure 2. ASA-LIFT GB-1000 mechanical snap bean picker harvesting edamame.

Results and Discussion

At harvest, the 12-inch Tohya plants were significantly shorter than the 29-inch MFL-2P59 plants on average (Table 1; Fig. 1). With respect to harvest efficiency, the mechanical harvester recovered 89.3% of marketable Tohya pods compared to just 61.8% of marketable MFL-2P59 pods (Table 1), which is consistent with the results of Zandonadi et al. (2010) who reported 62.0 to 84.5% efficiency across multiple varieties.

Anecdotally, researchers noted a reduction in maintenance delays from plant material wrapping into the harvester's drum when harvesting shorter plants. The shorter plants had less biomass on fewer, shorter branches. Larger plants in the study would have branches break from the main stem and sometimes the entire plant would break at ground level, causing mechanical jams. Additionally, fewer leaves and stems needed to be removed and cleaned from the final product when harvesting the short variety (Tohya). Harvested MFL-2P59 plots required more labor to remove plant biomass from the final product and to remove pods from stem sections due to taller plants. Our results were consistent with

Table 1. Mean edamame plant height, hand harvest yield, mechanical harvest yield, and harvest efficiency by variety in 2021.

Variety	Plant Height (inches)	Hand Harvest Yield (lbs ac-1)	Mechanical Harvest Yield (lbs ac-1)	Harvest Efficiency (%)
Tohya	12[b]	6971	6078[a]	89.3[a]
MFL- 2P59	29[a]	6221	3703[b]	61.8[b]
p-Value	<0.001	0.307	<0.001	0.002

Note: All significance tests conducted at $\alpha = 0.05$.
[a] Indicates a significantly larger value within the column.
[b] Indicates significantly smaller value within column.

those of Mebrahtu & Mullins (2007) who studied the mechanical harvest efficiencies of four edamame varieties ranging in height from 22 to 39 inches and found that shorter varieties were more efficient in mechanical harvestability. Additionally, Mebrahtu & Mullins (2007) observed the taller varieties intertwined with the harvesting drum and that tall varieties often had pods attached to branches. Likewise, determinant soybean varieties with less branching would also optimize mechanical harvesting and commercial production through uniform flowering and ripening.

Several studies speculated that transitioning from labor-intensive, hand-harvested edamame to mechanical harvesting could be pivotal for the successful adoption of the crop by American producers (Garber et al., 2019; Neill & Morgan, 2021). Local growers expressed interest in short-statured edamame varieties that would be better suited for mechanical harvesting. Growers also sought plants with shorter growing seasons to integrate seamlessly into their snap bean [(*Phaseolus vulgaris*) L.] production systems and crop rotations. Improved harvest efficiency of our short-statured edamame varieties validated the recommendations and requests of our local producers.

Conclusions

Results from this study indicated that short-statured, short-season edamame varieties are optimal for mechanical harvest and large-scale market production. Large plants showed reduced mechanical harvest efficiency (61.8%) and increased equipment maintenance. Short plants featured an 89.3% harvest efficiency and were easier to harvest. Overall, edamame production can move towards mechanical harvest in our domestic market to facilitate local supplies and reduce dependence on manual labor when optimal variety characteristics are used.

Acknowledgements

Funding for this work was provided in part by the Virginia Agricultural Experiment Station and the Hatch program of the National Institute of Food and Agriculture (NIFA), U.S. Department of Agriculture. Funding was also provided by NIFA through the Specialty Crop Research Initiative (SCRI) (Grant No. 2018-51181-28384; Accession No. 1016465).

Disclaimer

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2025 SPES-719NP