# MECHANICAL HARVESTING OF EDAMAME

Project Final Report

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***Abstract***: Edamame (green vegetable soybean) is a relatively new crop to Kentucky agriculture that has exciting potential. One of the major hindrances to development of edamame production is that currently the crop must be harvested using hand labor. The goal of this project was to develop a scale-appropriate mechanical harvesting system for vegetable soybean production in Kentucky. The harvesting machine used in the study was a Pixall® BH-100 (Oxbo Corp., Byron NY) single row bean harvester. This machine is primarily intended for use in edible green bean harvest; however, the nature of its design allows it to be used in a variety of vegetable crops. Edamame were grown and harvested with this machine over 3 seasons, and harvest efficiencies were measured. The harvest efficiency was found to vary from 54 to 85% and was dependent heavily on plant spacing and height, which affected pod location on the plants.

## Material and Methods

Harvest efficiency data were collected over 3 growing seasons (2007 – 2009) at the Horticulture Research Farm of University of Kentucky.

During the 2007 harvesting, ground and fan speed were varied to understand how the machine would work in the edamame (Table 1). Each configuration was tested three times and a comparison of means was used to compare the configurations.

Table 1: Harvesting configuration tested on 2007 harvesting.

| Configuration | Speed (mph) | Fan speed |
|---|---|---|
| 1 | 1.1 | High |
| 2 | 2.1 | High |
| 3 | 1.1 | Low |
| 4 | 2.1 | Low |

During the 2008 harvest, only the ground speed was varied (1.1 and 2.1 mph) during two different harvests resulting from two different planting dates. The first planting was harvested on 08/14/08 and the second plating was harvested two weeks later on 08/28/08. Each speed was repeated five times during each harvest. A comparison of means was conducted for different ground speed and harvest group.

During the 2009 harvesting, the machine configuration was fixed (2.1 mph and high fan speed), and six varieties of Edamame were evaluated with two different row spacing (18 and 30 inches). The varieties were classified in three height categories and planted on two different dates (Table2). Data analyses were carried out through a split-plot design where the varieties (parcel) with its respective row spacing (sub-parcel) were repeated in three different blocks.

Table 2: Varieties of Edamame evaluated in 2009 harvesting.

| Reference | Variety | Height | Planting | Harvest date |
|---|---|---|---|---|
| 1 | BeSweet 292 | Short | 1 | 08/25/09 |
| 2 | KY06-E-1023 | Tall | 2 | 09/09/09 |
| 3 | KY06-E-1035 | Mid | 1 | 08/25/09 |
| 4 | KY06-E-2039 | Tall | 2 | 09/09/09 |
| 5 | Gardensoy 12 | Mid | 1 | 08/25/09 |
| 6 | Gardensoy 22 | Short | 1 | 08/25/09 |

All the data were collected from row sections 40 to 50ft long isolated by removing plants beyond the test section. The material collected by the harvester during each run was sorted by clean pods, pods still attached to plant fragments, and trash. The three fractions were weighed separately. The total weight of the clean and attached pods was considered as the harvested material. The pods left in the row after the harvester passed were collected by hand and weighed. This was the un-harvested material and it included the pods left on the plant stem as well as pods dropped on the ground during harvest. The harvest efficiency was computed by dividing the weight of the harvested material by the total of the harvested and unharvested material.

## Results and Discussion

The results from the 2007 harvest showed that the harvest efficiency varied from 71 to 82% (Table 3). The analyses of variance (Table 4) indicated that there was no significant difference between the mean harvest efficiencies at a 10% level of significance, so the different ground or fan speeds did not have a tremendous influence on the harvest efficiency.

Table 3: 2007 Harvest efficiency results.

| Configuration | Speed (mph) | Fan speed | Mean Harvest Efficiency (%) |
|---|---|---|---|
| 1 | 1.1 | High | 70.85 |
| 2 | 2.1 | High | 72.41 |
| 3 | 1.1 | Low | 82.37 |
| 4 | 2.1 | Low | 74.31 |

Table 4: Anova from 2007 harvest efficiency evaluation.

| | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 236.38 | 78.79 | 2.85 | 0.1051 |
| Error | 8 | 221.28 | 27.66 | | |
| Corrected Total | 11 | 457.66 | | | |

The results of the harvest efficiency for 2008 are summarized on Table 5 and Figure 2.

Table 5: 2008 Harvest efficiency results.

| Planting | Speed (mph) | Mean Harvest Efficiency (%) |
|---|---|---|
| First | 1.1 | 62.0 |
| First | 2.1 | 64.7 |
| Second | 1.1 | 84.5 |
| Second | 2.1 | 83.5 |

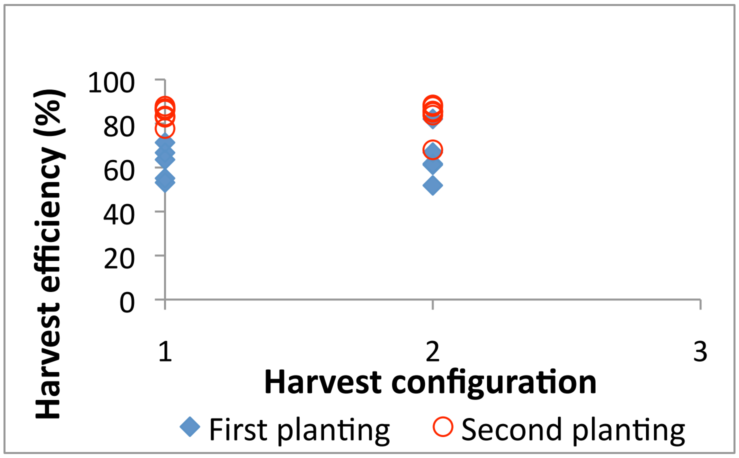


Figure 3: Harvest efficiency according to ground speed.

The analyses of variance for ground speed (Table 6) indicated that there was no significant difference between 1.1 and 2.1 mph. However, the analyses of variance for planting (Table 7) indicated that mean harvest efficiency of the second planting was significantly higher than the mean harvest efficiency of the first planting. This was primarily due to the fact that the stand count was much higher for the second planting. This denser spacing caused the pods to be dispersed higher on the plant making it easier for the machine to remove the pods from the plant.

Table 6: Anova from 2008 harvest efficiency evaluation considering harvesting ground speed.

| | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 1.93 | 1.93 | 0.01 | 0.9145 |
| Error | 22 | 3591.79 | 163.26 | | |
| Corrected Total | 23 | 3593.72 | | | |

Table 7: Anova from 2008 harvest efficiency evaluation considering planting.

| | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 2477.49 | 2477.49 | 48.83 | <.0001 |
| Error | 22 | 1116.21 | 50.74 | | |
| Corrected Total | 23 | 3593.72 | | | |

These findings prompted a further study in 2009 to explore the effects of plant height and row spacing on harvestability. Six different varieties (Table 2) were planted on two different row spacing (18” and 30”). The results (Table 9) showed that there was a strong difference in the mean harvest efficiency value between the varieties, but the row spacing did not have as strong an effect. In fact, the narrow spacing made it difficult for the operator to guide the machine along the harvested row without missing some of it or damaging plants in the next row.

Table 9: Analysis of variance table for the 2009 harvest efficiency experiment.

| | SS | Df | MS | F | P | Conclusion* |
|---|---|---|---|---|---|---|
| **Model** | 4137.20 | 23 | 179.88 | 7.341 | 0.0005 | S |
| **Main plots** | 3919.69 | 17 | | | | |
| **A (blocks)** | 121.17 | 2 | 60.58 | 1.085 | 0.3745 | NS |
| **Variety** | 3231.29 | 5 | 646.25 | 11.577 | 0.0007 | S |
| **E. Main plots (A*Var)** | 558.23 | 10 | 55.82 | | | |
| **Spacing** | 119.76 | 1 | 119.76 | 4.887 | 0.0472 | S |
| **Var*Spa** | 106.75 | 5 | 21.35 | 0.871 | 0.5282 | NS |
| **E. Sub-plots** | 294.05 | 12 | 24.50 | | | |
| **Total** | **4431.25** | **35** | | | | |

***Significance of: 0.05. According to the P-value, the source of variations could be significant (S) or not significant (NS).**

Also the P-value supported the non-significance of the means among the blocks, and the interaction of row spacing and varieties for the mean harvest efficiency. Therefore, the harvest efficiency between the varieties was evaluated using a Tukey test (Table 10). Note that varieties 1 and 5 had a shorter plant height, varieties 6 and 3 were medium height, and varieties 2 and 4 were the tallest. There is a clear tendency of shorter plants to present higher harvest efficiency. Practically, this was probably due to the fact that additional biomass material going through the machine made it more difficult for the stripping fingers to remove the pods from the stems and recover them onto the conveyor. In fact, the largest plants caused significant problems with plugging of the machine. To use this particular machine on larger plant varieties, it would be necessary make some modifications in the angle of attack of the stripping reel or the size of the passageway for plant material.

Table 10: Results of the Tukey test for grouping the mean value of the harvest efficiency.

| **Tukey Grouping** | | **Mean** | **N** | **var** |
|---|---|---|---|---|
| | A | 80.183 | 6 | 1 |
| | A | | | |
| | A | 74.895 | 6 | 5 |
| | A | | | |
| B | A | 74.440 | 6 | 6 |
| B | | | | |
| B | C | 61.547 | 6 | 3 |
| | C | | | |
| | C | 60.193 | 6 | 2 |
| | C | | | |

| | | | |
|---|---|---|---|
| C | 53.863 | 6 | 4 |

## Conclusions

These studies showed that it is feasible to use a mechanical harvester to harvest edamame. Harvest efficiencies as high as 85% were realized. The harvest efficiency can be greatly affected by plant condition. Very sparse plant spacing will cause pods to be formed lower on the plants making it more difficult for the stripping reel to reach the pods to remove them without introducing dirt into the product stream. Also, increased biomass of the plant can interfere with machine function. In some of these situations, harvest efficiencies below 55% were observed. Proper management of plant density will insure that pods are reachable by the machine without causing machine plugging because of too much biomass material.