Improved hydraulic-powered plastic mulch removal implement for MSU Student Organic Farm

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Background

Weed suppression and removal is one of the most labor intensive and expensive components of organic farming (Drost & Maughan, 2016). Many growers, including Student Organic Farm (SOF) at Michigan State University (MSU), have come to rely on plastic mulch to control weeds in place of herbicides.

Plastic mulch is a polyethylene film about 1/32 in thick that helps to retain soil moisture, moderate soil temperature, and suppress weed growth (Ngouajio, 2018). The SOF gets their embossed black and white plastic mulch from TRICKL-EEZ Irrigation Inc (Trickl-eez, n.d.). An implement pulled behind a tractor is used to stretch the plastic over a raised crop bed and bury the edges beneath 2.75 in of soil. One of the main drawbacks to using plastic mulch is the difficulty of removal. The plastic mulch is thin, weakens over the growing season and tears easily near the buried edges; thus, it causes the accumulation of small plastic debris in the soil over time (Huang, et al. 2020.)

Figure 1. Previously used SOF implement

Figure 2. Plastic Mulch Mound Sideview

Objectives

Design a plastic mulch lifting system that meets the following performance criteria.

- A production rate of 12 beds/hour, each bed 5 ft by 150 ft
- The implement should roll the plastic into a compact bundle for easy removal
- The implement must exert a greater force on the plastic than the material strength (i.e., no mulch tearing)

Constraints

Constraints for the project include
- Any solution must comply with organic farming standards (Legal Information Institute, n.d.)
- Removal early/mid fall after harvest
- No removal shortly after rain, as the soil becomes too heavy increasing tearing
- Implement sized to a plastic width of 4ft
- Remove 2 ac / season
- Available tractor 60 hp

Figure 3. Row of plastic mulch and drip tape

Figure 4. L-shaped blade with dimensions

Selected Design

The selected design is a hydraulically-driven, single-sided plastic collection reel that uses an L-Shaped blade to undercut the soil. This configuration was chosen based on its weighted rankings of safety, reliability, ease of use, cost and manufacturability.

Figure 5. Hydraulic system schematic

Soil loosening implement : L-shaped blade

Figure 6. Hydraulic motor and controls

Collection: Single reel winding mechanism

Utilizing a single reel to collect the plastic exceeds the minimum speed of collection and keeps the design within budget.

Figure 7. Final manufactured prototype

Design Parameters

The implement is designed to be mounted on a toolbar from the SOF and attached to a tractor via a 3-point hitch. A frame made of 2” square steel tubing with 3/16” thick walls was constructed to hold the hydraulic motor and winding reel. The height of the reel is 4.5 feet off the ground for easy removal of the plastic and to ensure that debris can fall off as winding occurs. Gauge wheels are mounted to the ends of the toolbar for smooth travel and L-shaped blade depth control.

Figure 8. Row of plastic mulch installed for testing purposes

Economics

Current practice yearly cost:

\[
\left( \frac{100 \text{ beds}}{20 \text{ minutes/bed}} \times \frac{1 \text{ hour}}{60 \text{ minutes}} \times \frac{7 \text{ workers}}{12 \text{ per hour}} \right) = $2,797
\]

Projected cost with implement:

\[
\left( \frac{2 \text{ hours}}{25 \text{ bed/s}} \times 100 \text{ bed/s} \right) + \left( \frac{2 \text{ workers}}{1 \text{ hour}} \times \frac{12 \text{ per hour}}{3.50 \text{ gallons}} \times \frac{3.50 \text{ gallons}}{1 \text{ hour}} \right) = $328
\]

Manufacturing Cost: $989.70

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\frac{$2797 - $328}{989} = 2.5
\]

Return on investment of 2.5 over a one-year period

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References


