ECONOMIC FEASIBILITY OF USING ALTERNATIVE PLASTIC MULCHES: A PUMPKIN CASE STUDY IN WESTERN WA

Preface

The results presented in this WSU publication serve as a general guide for evaluating the feasibility of using plastic soil-biodegradable mulches (hereafter referred to as BDMs) as an alternative to conventional plastic polyethylene (PE) mulch in the production of pie pumpkin in western Washington. This publication is not intended to be a definitive guide to production practices but is helpful in estimating the physical and financial requirements of comparable plantings. Specific budget assumptions were adopted for this study, but these will vary as production costs and returns can be different across farm operations depending on the following factors:

- Capital, labor, and natural resources
- Crop yield
- Cultural practices
- Input prices
- Output prices
- Management skills
- Size of the operation

To avoid unwarranted conclusions for any particular operation, readers must carefully examine the assumptions made in this study and then adjust the costs, returns, or both as appropriate for their operation.

Mulch Use in Crop Production

Mulch is typically laid in the field before seeding or planting. It is primarily used for weed control, soil moisture conservation, warming the soil, and improvement of crop yield, among other benefits. PE mulch is the most common mulch type used for crop production. Disposal of PE mulch includes landfilling, field burning, or stockpiling in the farm, which are not considered environmentally sustainable. It is difficult to clean agricultural plastic mulch given the amount of soil and other crop debris that remain even after the mulch is lifted and rolled. Kasirajan and Ngouajio (2012) indicated that residues can weigh up to 50% of the total weight of the mulch at the end of the growing season. Thus, PE mulches are not readily recyclable as only 5% residues by weight is acceptable for recycling.

BDMs are environmentally friendly alternatives to conventional PE mulch. They come in two basic forms: paper and biodegradable plastic. Several studies have shown that BDMs perform the same and offer similar benefits to crop productivity as PE mulch (e.g., Cowan et al. 2014; DeVetter et al. 2017; Ghimire et al. 2018; Miles et al. 2012; Moore and Wszelaki 2019). The additional benefit of using BDM is that, at the end of the season, they do not need to be removed since they are tilled into the soil; only the drip tape needs to be removed (Chen et al. 2018).

Plastic BDMs and PE mulch have similar attributes, particularly color, texture, thickness, elasticity, and installation time (Chen et al. 2018). This publication enables growers to estimate the costs and benefits of transitioning from PE mulch to BDMs.

Data Sources

The data used in this publication are a composite of information gathered from two pumpkin growers in western Washington who use PE mulch and from a field study at the WSU Mount Vernon Northwest Research and Extension Center (NWREC). These data are used to develop a baseline of costs and returns, and to analyze changes involving the use of BDMs as an alternative to PE mulch. The various data used and their sources are presented in Table 1.

Table 1. Data used in the economic feasibility analysis.

Data	Definition	Source
PE mulch—dimension and price	4 ft × 4,000 ft; 1 mil; $111/roll	Average of online prices from two suppliers and prices from two local input suppliers
Plastic BDM—dimension and price	4 ft × 4,000 ft; 0.6 mil; $220/roll	Average online price from three suppliers
Required quantity of mulch per acre	Pumpkin: 1.4 rolls per acre	Calculation (Chen et al. 2018)
Marketable yield per acre	PE mulch: 50 bins (24 in. bin) Plastic BDM: 17–41 bins	Field study (Ghimire et al. 2018)
Output price	Pumpkin: $181.67 per 24 in. bin	Wholesale price (USDA AMS 2018)
Labor cost	Manual: $14.12/hour	2018 Adverse effect wage rate (U.S. DOL ETA 2018)
	Mechanical: $15.12/hour Harvest (manual): $15.12/hour	Wage rates for agricultural equipment workers and agricultural workers—all other (U.S. DOL BLS 2018)
PE mulch disposal	$90 per ton	Skagit County
Manual labor requirements (hours per acre)—PE mulch	11 hours/acre to lift, pull out, and roll up PE mulch and drip tape; 6 hours/acre to pick up fragments; 0.5 hours/acre to dispose	Mulch removal and disposal from two pumpkin growers; cleanup of fragments is from average of data gathered from growers in Washington and Tennessee
Manual labor requirements (hours per acre)—BDM	2 hours/acre to pull out drip tape; 1 hour/acre for tillage	Drip tape removal from two pumpkin growers; tillage from field study

Mulch prices are obtained from online vendors that publish prices for different dimensions and thicknesses of mulches. As shown in Table 1, PE mulch is less expensive than BDM. As with most agricultural inputs, there is variability in the prices of mulch products. Also, growers may be able to buy mulches more economically with a large volume discount; therefore, actual cost may be lower than the values presented in Table 1. There may be additional shipping costs that local input suppliers may pass on to growers because many do not carry BDM. An input supplier or a sales representative will be able to provide the grower the exact purchase price for BDM based on the specifications provided by the grower (e.g., width, length, thickness, number of rolls).

The quantity of mulch needed per acre can be estimated given the between-row spacing of plants by using the Mulch Calculator developed by Chen et al. (2018). The calculator has two parts—requirement and cost. The requirement calculator determines the quantity of mulch that needs to be purchased based on the distance between bed centers and the length of a roll of mulch. The cost calculator enables the user to compare the costs of PE mulch and BDM use.

Using the mulch requirement calculator for pie pumpkin, 1.4 rolls of 4 × 4,000 ft mulch are required per acre given an 8-foot spacing between rows.

Marketable yield data were gathered from the field study at the WSU Mount Vernon NWREC. For pie pumpkin, the number of fruit harvested were collected for 2015 and 2016, and the two-year average is about 7,676 pumpkins per acre for the PE mulch treatment (Ghimire et al. 2018). There are approximately 110–200 pie pumpkins in a 24 in. bin (Lyon n.d.; Barr Evergreens of North Carolina, LLC 2016) or, on average, 155 pie pumpkins per 24 in. bin. Therefore, an average marketable yield of 50 bins per acre is used in the analysis. For BDM, the marketable yields ranged from 17 to 41 bins per acre, depending on the BDM treatment (Ghimire et al. 2018). These yields were lower due to mulch adhesion, in which pieces or fragments of BDMs stick to the bottom of the pumpkin fruit where it contacts the mulch, whereas there was no mulch adhesion in the PE mulch treatment.

Output price is based on the terminal market prices (wholesale) for pie pumpkins that are gathered daily at terminal markets in selected U.S. cities (USDA AMS 2018). Between October 1, 2017 and October 29, 2018 the terminal market weekly average price for non-organic pie pumpkins in all markets was $181.67 per 24-inch bin.

The hourly minimum wage rate for manual labor used in the analysis is $14.12/hour, which is based on the prevailing wage rate in Washington as of January 2018 (U.S. DOL ETA 2018). Mechanical labor and harvest (manual) labor rates are assumed at $15.12/hour. The one dollar difference between manual and mechanical labor rates is supported by the median wage data of agricultural workers and agricultural equipment operators in Washington (U.S. DOL BLS 2018). These rates do not include the overhead (i.e., taxes and benefits) that employers also pay. Because the overhead can vary depending on the location of the farm business, the subsequent analysis only accounts for the wage rates.

The disposal cost in Table 1 is based on the rates for general solid waste in Skagit County as of 2018, where the participating growers are located.

The labor requirements to remove and dispose of PE mulch, to remove drip tape, and to till BDM into the soil at the end of the growing season are based on labor data collected directly from farms and the field study. In farms that utilize PE mulch, they may: (1) cut the mulch down the center of the bed using a disk and then remove/pull from the sides by hand, (2) use a mulch lifter then manually pull the mulch, or (3) use a shovel to dig out the sides and pull out the mulch by hand (Chen et al. 2018; DeVetter, personal communication, 2019; McMoran, personal communication, 2019; Ryan, personal communication, 2019). The chosen method depends on the production area where mulch is used. The labor requirements for PE mulch in Table 1 assume the use of a mulch lifter.

In western Washington, the use of PE mulch is not widespread due to the cost and time spent laying and removing (DeVetter, personal communication, 2019; Ryan, personal communication, 2019). However, it must be noted that for those who use PE mulch, they specify that removal is time consuming and requires a lot of manual labor (DeVetter, personal communication, 2019; McMoran, personal communication, 2019; Ryan, personal communication, 2019).

Partial Budget Analysis

A full enterprise budget provides estimates of potential revenue, costs, and profit for the production of a specific crop. Some decisions on the farm only lead to adjustments in certain existing activities, leaving all other activities and expenses the same. Using a different type of mulch is only one of several activities on the farm. Hence, we use a partial budget method to calculate the net change in profit that can be expected from a specific change in production, which in this case is the use of plastic BDM.

The primary differences in using the two types of mulches are the cost of materials and end-of-season activities. With PE mulch, mulch removal and disposal are both carried out at the end of the growing season. On the other hand, with BDM, both end-of-season activities associated with PE mulch are eliminated since BDM is tilled into the soil. All other activities, like removing drip tape, are the same.

Therefore, the additional cost associated with BDM is the cost of the material. Reduced costs are represented by labor savings from pulling out plastic mulch, rolling up plastic mulch, and picking up leftover mulch fragments in the field; and disposal costs (including labor cost for disposal and landfill fee). Additional or reduced revenue will occur depending on the marketable yield relative to using PE mulch.

Figure 1 illustrates how the partial budget analysis is done. The change in an input in the production system can have one or more of the following effects: (1) new or additional expenses, (2) reduced or eliminated expenses, (3) new or additional revenue, or (4) lost or reduced revenue (Kay et al. 2012). The partial budget will evaluate changes in expenses and revenue when transitioning from PE mulch use (i.e., the baseline scenario) to BDM use. The left side represents changes generating a positive impact on profit, and the right side represents changes that will imply a negative impact on profit. Whichever side is larger will tip the scale to that direction, and inform us if using BDM will yield a gain or loss with respect to the current level of profit.

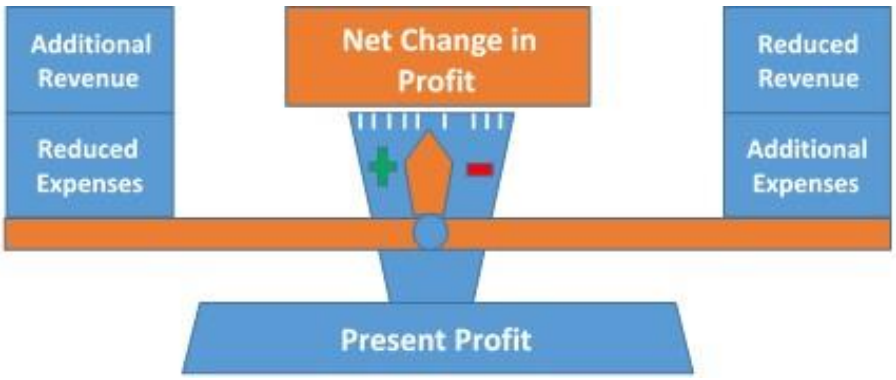

Figure 1. Illustration of the partial budgeting approach (Lessley et al. 1991).

Assumptions for the Partial Budget Analysis

The data in Table 1 are utilized in the partial budget analysis as well as the assumptions listed below:

1. A 100-acre farm operation of mixed vegetable crops decides to adopt BDM on five acres of pie pumpkins;
2. 1.4 rolls of mulch (4 × 4,000 ft) are required to cover an acre given the 8 ft bed spacing; the grower will purchase 7 rolls for 5 acres (1.4 rolls per acre × 5 acres = 7 rolls). The cost is $111/roll for PE mulch and $220/roll for BDM (see Table 1);
3. PE mulch weight at the end of the growing season is 50% more than its original weight due to accumulated soil, water, and other debris. Total weight of contaminated PE mulch at the end of the season is 174.3 lb/acre;
4. As a baseline for the analysis, crop yield is the same when using either PE mulch or BDM; and
5. No changes are assumed regarding machinery cost (including fuel, maintenance and repair, and depreciation). Although a plastic lifter will not be required when using BDM, a rototiller or disc harrow will still have to be used to till BDM into the soil. Depending on soil type and equipment conditions, lifting PE mulch and tilling BDM may take about the same time to be completed, and both require the use of a tractor.

Study Results

Table 2 shows the results of the partial budget analysis. There is neither additional nor reduced revenue because the same output price and yield are assumed when using either type of mulch. Reduced costs are attributed to labor and disposal cost savings. In particular, labor savings include activities that are eliminated when using BDM, for example, mulch removal and disposal. Additional costs associated with BDM include the costs of the material and labor to till BDM into the soil after the growing season. Given these assumptions, there will be a gain of about $76/acre, mainly due to labor savings with BDM application relative to PE mulch.

The labor and disposal cost savings are more than the additional costs of transitioning from PE mulch to BDM. Assuming the revenue associated with the use of BDM is the same as in PE mulch, the main factors influencing the profitability of using BDM are the costs of labor and BDM material. Hence, as long as the cost savings in labor outweigh the cost of BDM, the likelihood of adopting BDM may increase.

Given that many factors affect crop production costs and revenue, individual producers are encouraged to estimate their own costs and revenues and examine the economic impact associated with the use of BDM. The Mulch Calculator (Chen et al. 2018) will be useful in comparing the costs of PE mulch and BDM use.

Sensitivity Analysis

To examine the sensitivity of the net change in profit by using BDM, certain parameters can be changed, particularly crop yield, price of plastic BDM, and labor cost.

In their field study, Ghimire et al. (2018) indicated that 48% of the total yield for four mulch treatments had mulch adhesion because most of the fruit rested on the mulch surface. Adhesion is an issue because it can reduce marketable yield as the fruit may be discarded due to quality concerns. In contrast, if the mulch is wiped off the fruit, marketable yield may not be affected negatively, but there will be an increase in labor costs, especially if it takes a long time to clean off the mulch that adhered to the fruit.

Figure 2 shows the sensitivity of profit given changes in marketable crop yield while holding all other variables constant. The base yield is 50 bins per acre. If 48% of the yield has mulch adhesion and is subsequently discarded, the grower's marketable yield will be 26 bins per acre and profit will be $4,284/acre lower than the profit associated with the use of PE mulch. Profits with BDM and PE mulch become equal when the marketable yield is 49.58 bins per acre.

Table 2. Net change in profit per acre by adopting BDM.

Additional Revenue	$0.00	Additional Costs	$142.61
Current assumption: No changes in prices and yields.		*Plastic BDM*	*$142.61*
Reduced Costs	$218.20	Reduced Revenue	$0.00
Labor to remove mulch—eliminated	*$204.74*	***Current assumption:*** No changes in prices and yields.	
Disposal cost—eliminated	*$8.10*		
Other (overhead, interest)	*$5.36*		
A. Total additional revenue and reduced costs =	***$218.20***	***B. Total additional costs and reduced revenue =***	***$142.61***
Net Change in Profit (A minus B) = $75.59			

The price of BDM varies depending on the type of material (plastic or paper) and thickness. For those plastic BDMs used in the field study at WSU Mount Vernon NWREC, their prices range from $204/roll to $245/roll given a dimension of 4 ft × 4,000 ft and thickness of 0.6 mil. Also, plastic BDMs were found to have comparable performance to PE mulches with a thickness of 1.0 mil. In this economic analysis, the average price of $220/roll is used. Figure 3 shows the sensitivity of profit given changes in the purchase price of BDMs while holding all else constant. Profit becomes equal to that of PE mulch when the BDM price is about $270/roll.

Figure 4 shows the impact of changes in labor cost on profit. The partial budget analysis showed that the primary benefits of using BDM are savings in labor cost. The profits when using BDM and PE mulch become equal when the labor rate is $9.30 per hour, which means that lower rates would result in a loss of profit when using BDM. Results in Figure 4 imply that the likelihood of BDM adoption increases when labor rates are high.

As of January 2018, the prevailing wage rate to be paid to H-2A workers in Washington was about $14 per hour. An H-2A employer must offer this rate not only to its H-2A workers but also to other workers in corresponding employment, thus ensuring equal-pay treatment. Washington's prevailing wage rate is the second-highest rate in the nation, tied with Oregon and following only Hawaii. Including benefits, taxes, and overhead, the wage rate could well be in the neighborhood of $15 per hour for manual labor. It is also possible that growers will pay more than this rate to attract laborers to work on their farm.

Discussion

Given this study's assumptions, the results of the partial budget analysis suggest that the production of pie pumpkins using BDM mulch can be more economically feasible than using PE mulch if one or more of the following conditions are met: (1) the marketable yield is 50 or more bins per acre, (2) the cost of BDM material is less than $270/roll, and (3) manual labor cost is higher than $9.30/hour.

There are three critical factors to consider when assessing whether or not the adoption of BDM is economically feasible—a grower has to know the costs of: (1) removing and disposing of PE mulch, (2) BDM material, and (3) BDM tillage. For crops that rest on the mulch surface, like pumpkin, growers also have to consider whether or not mulch adhesion is going to be an issue on their marketable yield.

The grower's choice of using BDM will primarily depend on whether or not the overall benefits outweigh the additional costs associated with this alternative mulch. It must also be noted that the results are formed by production-related assumptions established for the partial budget analysis. Production costs and revenue for growers can vary; thus, the results cannot be generalized to represent the population of growers.

Figure 2. Sensitivity analysis of profit given different marketable yields of pumpkin.

Figure 3. Sensitivity analysis of profit given changes in BDM cost.

Figure 4. Sensitivity analysis of profit given changes in labor cost.

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