The Economic Feasibility of Adopting Plastic Biodegradable Mulches in Pumpkin Production

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Preface

This publication aims to help vegetable producers understand the potential changes in expenses associated with transitioning from polyethylene (PE) mulches to biodegradable mulches (BDMs), as well as the factors influencing the economic feasibility of adopting BDMs in vegetable production, specifically pie pumpkin production.

This publication is not intended to be a definitive guide to production practices but helps estimate the physical and financial requirements of comparable plantings. Specific budget assumptions were adopted for this study, but these assumptions may not fit every situation since production costs and revenue vary 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 closely examine the assumptions made in this study and then adjust the expenses, revenues or both, as appropriate for their operation.

Mulch Use in Vegetable Production

Plastic mulches provide several benefits for vegetable production, including weed control, soil moisture conservation and crop yield improvement (Brodhagen et al., 2017; Ghimire and Miles, 2016). Polyethylene mulches are the most common type of mulches used in agriculture, and although they provide these benefits, their use is not considered environmentally sustainable because of the disposal methods for PE mulches. Traditionally, PE mulches are disposed of in landfills, field burned or stockpiled on the farm.

Plastic BDMs are a viable alternative to PE mulches, as they offer the same benefits as PE mulches with the additional benefit of being biodegradable, breaking down into carbon dioxide, water and microbes. BDMs do not have to be removed, but rather they are tilled into the soil or composted at the end of the season.

Sources of Information

The data used in this publication include data collected from a field experiment conducted at the University of Tennessee East Tennessee AgResearch and Education Center in 2015 and 2016 (Ghimire et al., 2018); three vegetable farms in Tennessee; a Tennessee fruit and vegetable farmer survey; input suppliers; and data from other secondary sources (i.e., U.S. Department of Labor and several Tennessee landfills) to evaluate the potential economic impact of adopting BDMs in pie pumpkin production at the farm level. These data were used to develop a baseline of costs associated with pie pumpkin production and to analyze changes in this budget component related to transitioning from PE mulches to plastic BDMs. The various data used in this analysis and their sources are presented in **Table 1**.

PE mulch prices were obtained from online vendors that publish prices for different dimensions and thickness of mulches, as well as local input suppliers. BDM prices were obtained from input suppliers posting prices online (**Table 1**). The quantity of mulch needed per acre, which can be estimated given the space between bed centers, was derived using a decision-aid tool entitled the Mulch Calculator[1] (Chen et al., 2018). For pie pumpkins, 1.4 4-by-4,000-foot rolls of mulch are required per acre, given an 8-foot spacing between bed centers. The hourly minimum wage rate for manual labor used in this publication is $11.63/hour, which is the 2019 Adverse Effect Wage Rate for Tennessee (U.S. Department of Labor, Employment and Training Administration, 2019). The Adverse Effect Wage Rate is the minimum wage rate established by the U.S. Department of Labor that an employer needs to offer and pay to H-2A workers and workers in

1 Available online at https://bit.ly/2UaqAYx.

corresponding employment so that wages of similarly employed U.S. workers will not be adversely affected. These base rates do not include workers' compensation insurance or social security contributions paid by farmers. Because these costs can vary depending on the location of the farm business, the subsequent analysis only accounts for the wage rates.

Table 1. Data Used in the Partial Budgeting Analysis

Data	Definition	Source
PE mulch – dimension and price	4 ft x 4,000 ft; 1 mil; $106/roll - $115/roll; Average price of $111/roll	Average of two prices found online and two prices gathered directly from local input suppliers
BDMs – dimension and price	4 ft x 4,000 ft; 0.6 mil; $204/roll - $245/roll; average price of $220/roll	Average online price from three suppliers
The required quantity of mulch (PE or BDM) per acre (based on space between bed centers of 8 ft)	Pie pumpkin: 1.4 rolls/acre	Chen et al., 2018
Disposal cost Disposal fee/ton	$35/ton	Three TN landfills and three TN farms
Labor cost FY 2019 adverse effect wage rate	$11.63/hour	U.S. Department of Labor, Employment and Training Administration
May 2017 Tennessee wage estimates for agricultural equipment operators	$13.26/hour	U.S. Department of Labor, Bureau of Labor Statistics
Labor hours for removal and disposal of PE mulch Removal (including manual and operator labor)	3 to 40 labor hours/acre Average of 15 labor hours/acre	Data collected from three TN farms and a 2019 Tennessee fruit and vegetable survey (n = 41 responses)
Disposal (including labor for cleaning, binding, truck driving)	0.1 to 20 labor hours/acre Average of 3.3 labor hours/acre	Data collected through a 2019 Tennessee fruit and vegetable survey (n = 46 responses)
Labor hours for removal of drip tape and tilling BDMs into the soil Removal of drip tape only	Average 1.5 labor hours/acre	Data from one on-farm trial
Tilling BDMs into the soil	0.75 labor hours/acre	Data from field trials (Ghimire et al., 2018)

Partial Budgeting Analysis

Evaluating the economic feasibility of adopting BDMs in pie pumpkin production entails evaluating potential economic benefits and costs associated with transitioning from PE mulches to BDMs. In this publication, we used partial budgeting to evaluate the changes in costs associated with this transition.

In this publication, we assume no changes in revenue due to the adoption of BDMs. Revenue could be affected when transitioning from PE mulches to BDMs if there are changes in yields and/or prices. Statistically, results from field trials suggest that for the Knoxville region, pie pumpkin (pie pumpkin cv. Cinnamon Girl [Johnny's Selected Seed, Winslow, ME]) yields were not significantly different for PE mulch when compared to BDM treatments (Ghimire et al., 2018). Therefore, we assume no changes in yield when

transitioning from PE mulches to BDMs. It is important to acknowledge that although field trial results showed no statistically significant difference in yields across mulch treatments, mulch adhesion on some fruits was observed. Based on data from field trials, 6 percent of the total yield associated with BDM treatments had mulch fragments adhere to the fruit (Ghimire et al., 2018). The risk of mulch adhesion is possible for any fruit and vegetable that comes in contact with BDMs at any point during the growing season. The mulch fragments could be easily wiped off when harvesting the crop during the early morning hours when fruits are dewy, but it is more difficult to wipe these mulch fragments off the fruit as the temperature warms up and mulch fragments dry on the pumpkins (Ghimire et al., 2018). Further research should explore questions such as: Will consumers react negatively to mulch adhesion? Will farmers have to sell produce with mulch adhesion at a discounted price? Will mulch adhesion affect the grade and, therefore, the price received for pumpkins? We also assume no changes in pie pumpkin prices due to the adoption of BDMs. A preliminary study suggests consumers may be willing to pay a price premium for strawberries grown using BDMs (Chen et al., 2019). Nonetheless, for this study, we took a conservative approach, assuming no changes in vegetable prices received by farmers due to the adoption of BDMs.

Partial budgeting is a decision-making framework that allows a market manager to compare the costs and benefits of an alternative faced by a farm business or the financial effect of a change in a farm business (Lessley, Johnson, and Hanson, 1991; Tigner, 2018). Adopting BDMs is a small change, as it only entails changing one input in the production systems, as well as those activities associated with this particular input (e.g., eliminating removal of mulches, adding tilling of the mulch into the soil).

The partial budgeting framework focuses on changes in revenue and expenses and, therefore, net changes in profit resulting from the adoption of BDMs. The partial budget evaluates four components that could change in a farm budget when adopting BDMs (see **Figure 1**): additional revenue, reduced expenses, reduced revenue and additional expenses (Lessley, Johnson, and Hanson, 1991).

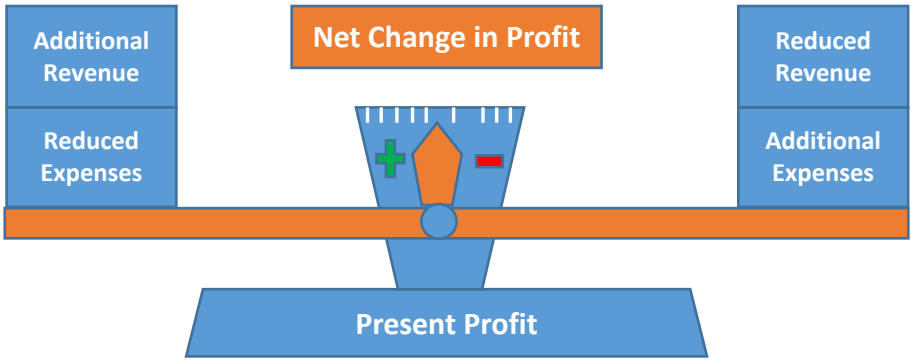

Figure 1. Illustration for the Partial Budgeting Approach (taken from Lessley, Johnson, and Hanson, 1991).

Given the assumptions described above, we will only evaluate the impact of BDM adoption on expenses. In general, BDMs are more expensive than PE mulches (see **Table 1**). Additionally, when adopting BDMs, there are potential savings related to the reduction of end-of-season activities, as BDMs do not have to be removed, but rather they can be tilled into the soil at the end of the season. There could be other long-term benefits associated with the use of BDMs, such as the elimination of the potential negative impact on yields of removing topsoil when removing PE mulches. In this publication, we will only focus on the short-term economic impacts of adopting BDMs at the farm level.

Assumptions for the Partial Budgeting Analysis

The assumptions made for this partial budgeting analysis include:

1. A farmer growing multiple vegetables in 5 acres decides to adopt BDMs in 1 acre of pie pumpkins;
2. Space between bed centers is 8 feet;

3. Although only 1.4 4-by-4,000-foot rolls are required to cover one acre, assuming an 8-foot space between bed centers, a grower will purchase two 4-by-4,000-foot rolls, as it is unlikely that an input supplier will sell 0.4 4-by-4,000-foot rolls;
4. The price of a 4-by-4,000-foot roll of PE with a thickness of 1 mil was estimated at $111 (see **Table 1**);
5. The price of a 4-by-4,000-foot roll of BDM with a thickness of 0.6 mil was estimated at $220/roll (see **Table 1**);
6. The hourly wage rate for manual labor is $11.63, and the hourly wage rate for agricultural equipment operators is $13.26;
7. The PE mulch disposal cost is $35/ton (based on data collected from farms located in counties where disposal cost is different than zero);
8. The mulch weight is going to increase by 50 percent (Kaisrajan and Ngouajio, 2012) during the growing season. This information will help us determine the cost of disposal at the end of the season;
9. Labor hours required (including both operator and manual labor) for removing and disposing of PE mulches (see **Table 1**), as well as labor associated with removing drip tape and tilling BDMs into the soil at the end of the season, are based on labor data collected directly from farms, data from a 2019 Tennessee fruit and vegetable survey, as well as data collected from field trials; and
10. There are no changes in machinery cost (e.g., gas, repairs and maintenance). Although a plastic lifter will not have to be used when transitioning from PE mulches to BDMs, a rototiller will have to be used to till BDMs into the soil. Depending on soil type and equipment conditions, these two activities may take about the same time to be completed, and both — lifting plastic and tilling BDMs into the soil — require the use of a tractor. Labor data collected from UT's East Tennessee AgResearch and Education Center field trials suggest that tilling BDMs into the soil could take anywhere between 45 minutes to one hour per acre. Labor data collected from three vegetable farms in Tennessee suggest lifting plastic with a plastic lifter could take anywhere between 35 minutes to one hour per acre. As mentioned above, these estimates will vary depending on soil, environmental and equipment conditions.

Expense Changes

Expense changes due to the adoption of BDMs are associated with two factors: 1) differences in the price of PE mulches and BDMs; and 2) differences in end-of-season activities when using PE mulches and BDMs.

In general, BDMs are more expensive than PE mulches. Using information from four suppliers, we estimated an average price for a 4-by-4,000-foot with a thickness of 1.0 mil mulch roll at $111. We acknowledge that some producers may be able to buy PE mulches at a discounted price by directly negotiating with input suppliers, but in this study, we used prices as reported by input suppliers.

Depending on the thickness of BDMs, prices can vary greatly. Based on the products used in our field experiments, BDM prices could be anywhere between $204/roll and $245/roll for a 4-by-4,000-foot roll with a thickness of 0.6 mil. For this analysis, we used an average price of $220/roll. It is important to note that price information of BDMs is publicly available.[2] Farmers could request a different thickness of the BDMs to the manufacturer, but this change will likely represent an increase in price. In field trials, the performance of plastic BDMs with a thickness of about 0.6 mil was comparable to the performance of PE mulches with a thickness of 1.0 mil, and the thinner BDM assures that it begins to breakdown by the end of the field season.

One of the benefits of transitioning from PE mulches to BDMs is savings from the reduction of removal and disposal activities at the end of the season. BDMs will not have to be removed, but rather they will be tilled into the soil (Ghimire and Miles, 2016), eliminating almost all labor related to removal and disposal (drip tape will still have to be removed and disposed of). PE mulch removal includes two major activities: 1) lifting plastic with plastic lifter and 2) manually removing plastic and drip tape.

For this study, we assume drip tape disposal cost is zero. As based on farmer interviews, this cost will be very small, although, in reality, this cost will be greater than zero. In Tennessee, disposal cost varies by location. There are some counties where the disposal cost will only include the transportation cost associated with moving PE plastic mulches from the farm to the landfill. In contrast, other counties have a disposal fee of anywhere between $20 and $50 per ton. Some landfills may not even accept PE mulch for disposal. In this study, we assumed an average disposal cost of $35/ton.

2 https://ag.tennessee.edu/biodegradablemulch/Pages/biomulchprojects.aspx

Potential Savings/Additional Cost Associated With Transitioning from PE Mulches to BDMs

Based on the assumptions presented above, we estimated net changes in profit when transitioning from PE mulches to BDMs. As depicted in **Table 2**, for this particular example, additional expenses are larger than reduced expenses, and, therefore, a producer transitioning from PE mulches to BDMs will lose about $28/acre. As you can see in this table, the greatest additional expenses are associated with the price of BDMs when compared to PE mulches. In this scenario, two rolls of BDMs cost $218 more than two rolls of PE mulch. Additionally, the greatest reduction in expenses when transitioning from PE mulches to BDMs is labor savings. The labor savings associated with transitioning from PE mulch to BDMs are $214.46/acre.

Table 2. Net Changes in Profit Associated With the Adoption of BDMs

Additional Expenses (AE) =	**$245.39**	**Additional Revenue (AR) =**	**$0.00**
BDMs =	$218.00	No changes in prices and yield	
BDM tillage =	$9.95		
Labor for pulling = drip tape	$17.45		
Reduced Revenue (RR) =	**$0.00**	**Reduced Expenses (RE) =**	**$217.61**
No changes in prices and yield		Labor savings =	$214.46
		Disposal savings =	$3.15
A. Total AE and RR =	**$245.39**	**B. Total AR and RE =**	**$217.61**
Net Change in Profit (B-A) = (-$27.78)			

Sensitivity Analysis

From the results presented in **Table 2**, we can infer that labor costs and the price of BDMs are the most important factors influencing the economic feasibility of adopting BDMs. Therefore, we wanted to evaluate how potential net changes in profit when transitioning from PE mulches to BDMs vary when BDM price and labor costs change.

In **Figure 2**, the horizontal axis shows the price of a 4-by-4,000-foot roll of BDM with a thickness of 0.6 mil, and the vertical axis shows net changes in profit associated with transitioning from PE mulches to BDMs. As the price of a BDM roll gets closer to the price of a roll of PE mulch, the more likely a producer is to experience a positive impact on profit when transitioning from PE mulches to BDMs, due to labor savings. For example, if the price of a 4-by-4,000-foot roll of BDM with a thickness of 0.6 mil is $126 (i.e., $15 more expensive than a roll of PE mulch), then the profit per acre when using BDMs is going to be about $160 higher than the profit when using PE mulches. Given the assumptions presented in this study, the breakeven price for BDM is going to be $206/roll. At $206/roll, the profit associated with BDM use is going to be the same as the profit associated with PE mulch use.

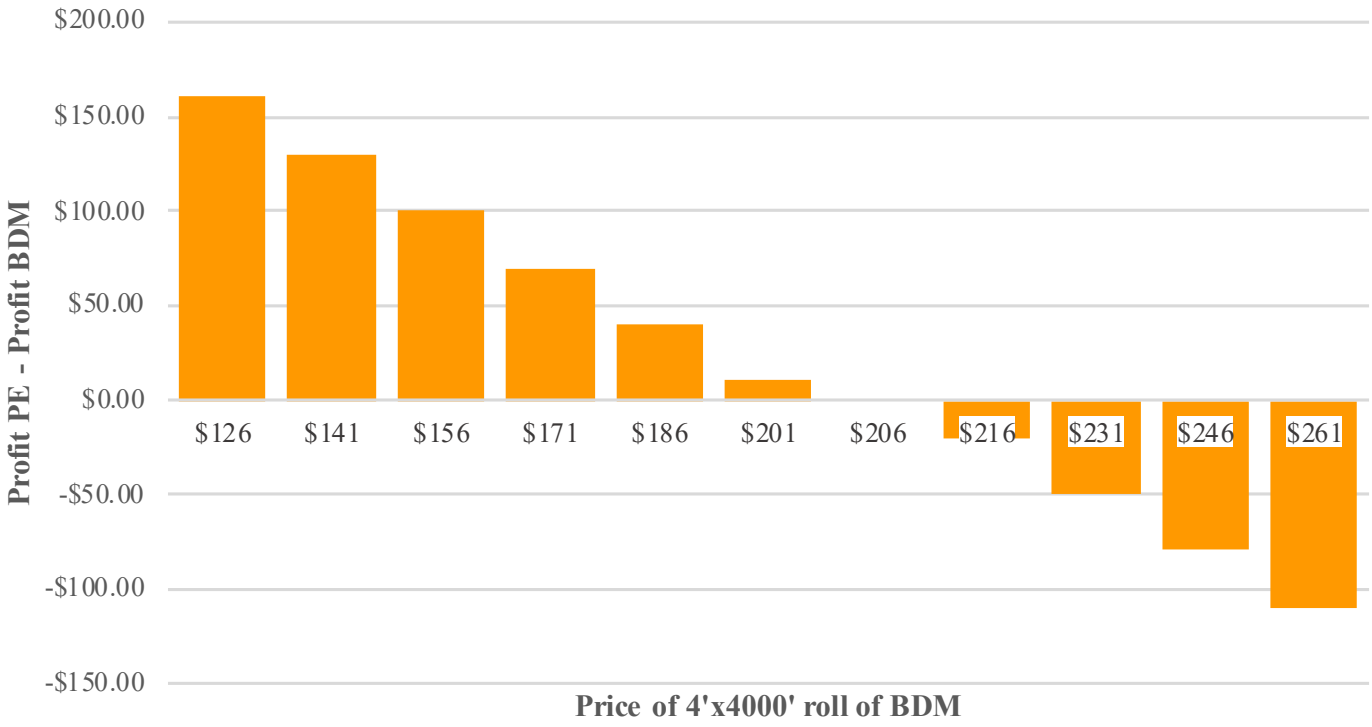

Figure 2. Net Changes in Profit Associated With the Adoption of BDMs for Different BDM Prices Per Roll.

Figure 3 shows the total number of labor hours associated with removal and disposal of PE mulches on the horizontal axis, and the vertical axis shows the net changes in profit associated with transitioning from PE mulches to BDMs. Preliminary survey results from a 2019 Tennessee fruit and vegetable survey and labor data collected from three vegetable farms in Tennessee suggest that labor hours associated with removal and disposal of PE mulches vary greatly, depending on worker characteristics performing end-of-season activities, soil conditions, and on whether producers pick up or leave the mulch fragments left behind after manually removing PE mulch from the field. As the number of labor hours per acre increases, the prospect of positive net changes in profit when transitioning from PE mulches to BDMs also increases. At 20.7 labor hours per acre, the profit associated with PE mulch use is the same as the profit associated with the use of BDMs (holding price of BDMs constant at $220/roll and PE mulches at $111/roll).

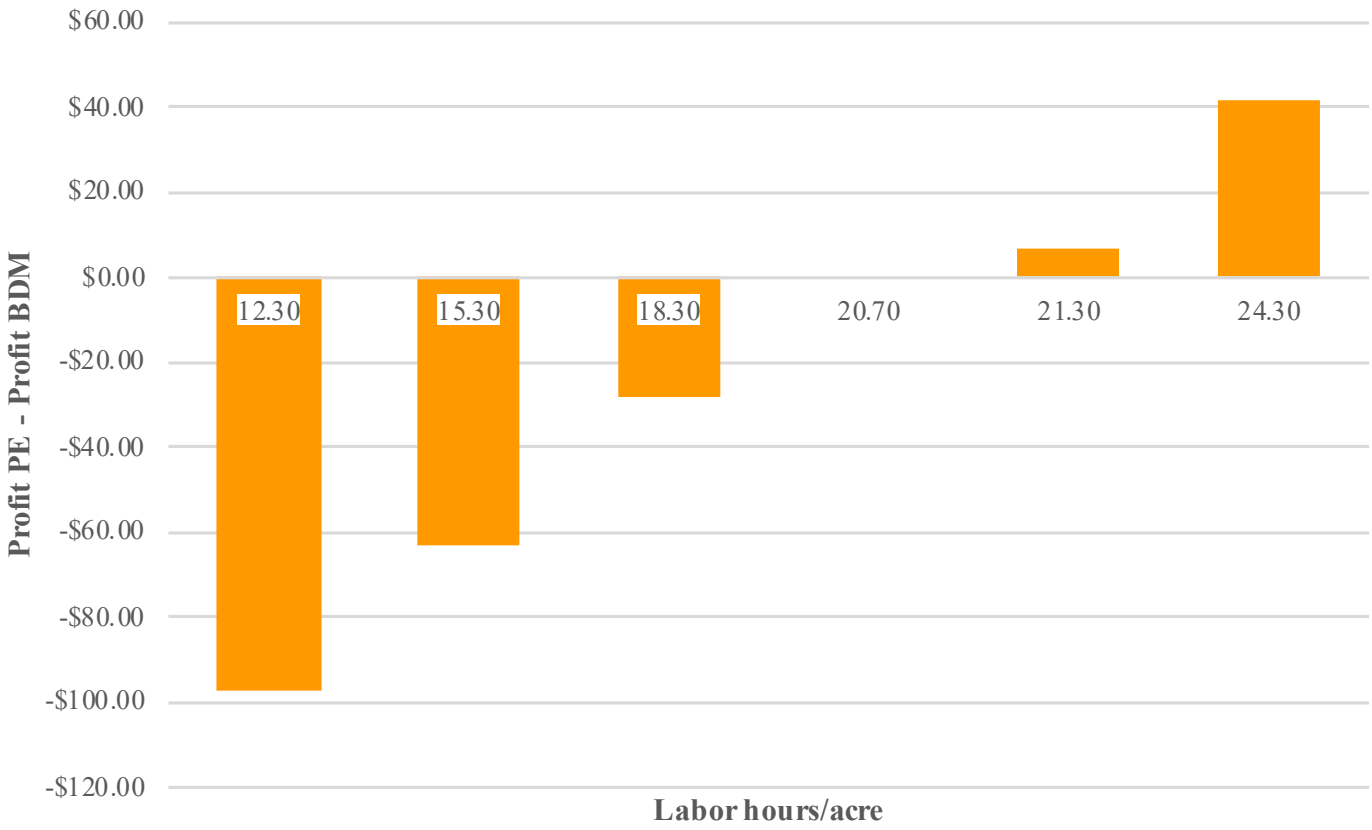

Figure 3. Net Changes in Profit From the Adoption of BDMs for Different Labor Hours Per Acre for Removal and Disposal of PE Mulches.

Finally, **Figure 4** shows net changes in profit for various hourly wage rate values. The horizontal axis shows hourly wage rates for manual labor, and the vertical axis shows net changes in profit associated with transitioning from PE mulches to BDMs. As the cost of manual labor increases, the prospect of the profit associated with the use of BDMs being higher than the profit associated with the use of PE mulches also increases. Given the assumptions mentioned in section 6, the breakeven hourly wage rate is about $13.39/hour. At $13.39/hour, the profit associated with BDM use is the same as the profit associated with PE mulch use.

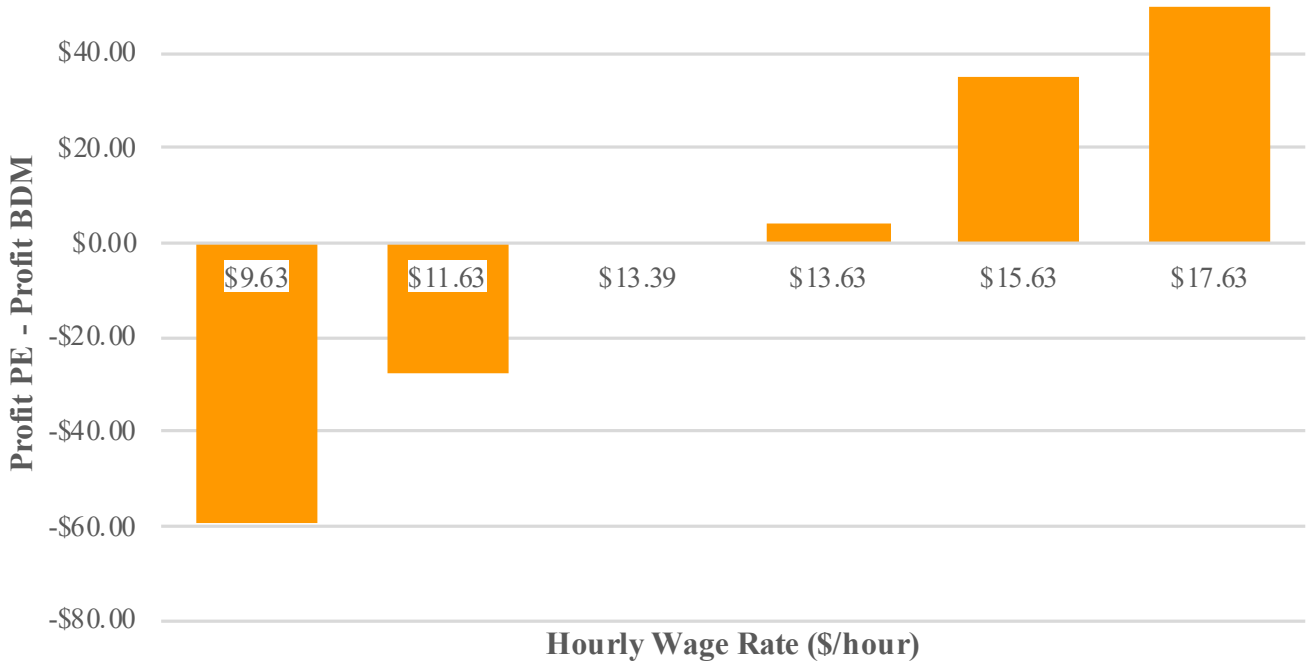

Figure 4. Net Changes In Profit Associated With the Adoption of BDMs for Different Hourly Wage Rates.

Discussion

The cost of labor and the price of BDMs are critical in assessing whether the adoption of BDMs is economically feasible for a farm or not. Farmers need to have accurate information about labor hours associated with removal and disposal of PE mulches, prices of BDMs, and cost of labor to assess if the adoption of BDMs is an economically feasible option for their farm businesses.

It is important to evaluate potential changes in labor costs and how these changes may affect net changes in profit when transitioning from PE mulches to BDMs. Under current conditions, H-2A labor costs can be fairly high after incorporating worker recruitment, housing and transportation costs (Roka, Farnsworth, and Simnitt, 2017).

It is also important to acknowledge that although changes in environmental regulations could eventually influence the cost of disposing of PE mulches, changes in disposal cost will not have as great of an impact on the economic feasibility of adopting BDMs compared to changes in BDM prices and labor costs, unless future environmental regulations limit the options farmers have to dispose of PE mulches.

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