Improve Soil Quality, Decrease Costs, or Reduce the Weed Seedbank?

Insights from a Systems Comparison of Prominent Organic Weed Management Strategies

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Introduction

Weed competition has its greatest impact during the adolescent crop stage; consequently, many farmers will focus weeding efforts in that "critical period" (Hewson & Roberts 1971). But considering that lax weed control can increase the weed seedbank fifteen-fold (Bond et al. 1998), more extensive cultivation may be desired to keep weeds from "raining" seed, which may provide labor savings in the long-term (Norris 1999). As an alternative to cultivation-based management, some crops are amenable to mulching which can prevent weed growth and benefit soil quality (Schonbeck & Evanylo 1998). Given that each of these weed management strategies can be successful, our **objective** was to quantify the economic and ecological benefits and drawbacks of each strategy to help farmers decide which one is best for their farm. More detail on the strategies:

Critical Period Weed Control
Cultivate only when the crop is in its sensitive adolescent stage. For onions this period is the first eight weeks after transplanting (Grundy et al. 2003).

Zero Seed Rain
Cultivate frequently so weeds do not set seed. This reduces weed abundance in subsequent years.

Black Plastic Mulch
Suppresses weeds and warms soil with a layer of plastic film. Paths are cultivated to control weeds.

Hay Mulch
Suppresses weeds in beds and paths. Keeps soil moist and builds soil organic matter. A rate of 20 Mg ha^{-1} is necessary for weed suppression (Schonbeck 1998).

Materials and Methods

To pursue our objective of quantifying the benefits and drawbacks of each strategy, we implemented each strategy in a side-by-side systems comparison in Old Town, ME, USA. Yellow onion was used as a test crop since it is commonly used in each strategy and is sensitive to changes in weed management. Plots were 7 m long by 2 m wide separated by buffer beds in a randomized complete block design with four replicates. Onions were grown on separate fields in 2014 and 2015. Onions were transplanted in mid-May with two plants per hole every 15 cm and three rows per bed. Aside from tillage and application of plastic mulch, all activities were done by hand. Hoeing occurred about every 10 days for Critical Period plots through the end of July, all season for Zero Seed Rain and Black Plastic paths, and twice pre-mulching for Hay Mulch. Hay was applied in late June since warm soil and sufficiently large onions are required for mulching. Black Plastic was handweeded three times and Hay Mulch once. Drip irrigation was used to maintain optimal soil moisture for each treatment. Harvest occurred in September. All labor and materials costs were recorded as well as measures of weeds, pests, soil quality, and yield. Net profit was calculated by estimating sales at \$1.10 kg^{-1} and subtracting material costs and labor costs at \$10 hr^{-1}. In 2015, sweet corn followed the 2014 onions and was managed uniformly with weed control achieved be one harrowing, three row cultivations, and two hillings. All statistical analyses were completed using Fisher's Protected LSD.

Results and Discussion

The experiment was successful in characterizing multiple aspects of each strategy (Figure 1). Yield was affected by weeds more strongly in 2014 than 2015. Greater earthworm populations in Hay Mulch may have been due to the food source (Schonbeck & Evanylo 1998). Carabid results may be explained by the habitat (Birthisel et al. 2014) offered by weeds. As expected, end of season aboveground weed biomass was greatest in Critical Period plots. Black Plastic plots had greatest NO3-N, likely due to reduced leaching (Schonbeck & Evanylo 1998) but decreased microbial biomass. Mulched plots had less compacted soil, likely due to decreased foot traffic and rainfall impact. Workload over the season was most uneven for Hay Mulch (consistent with Schonbeck 1998) and most even for Zero Seed Rain. Greater disease damage in Critical Period plots may have been due to reduced humidity levels caused by the weeds (McDonald et al. 2013). Zero Seed Rain and Hay Mulch required more labor but were more profitable than Critical Period Weed Control (Figure 2) due to higher yields. Consistent with previous study (Bond et al. 1998), one season of Critical Period Weed Control increased the weed germination 10x that of the other strategies the following year (Figure 3), and was the likely cause of the yield loss of Sweet Corn grown in these plots.

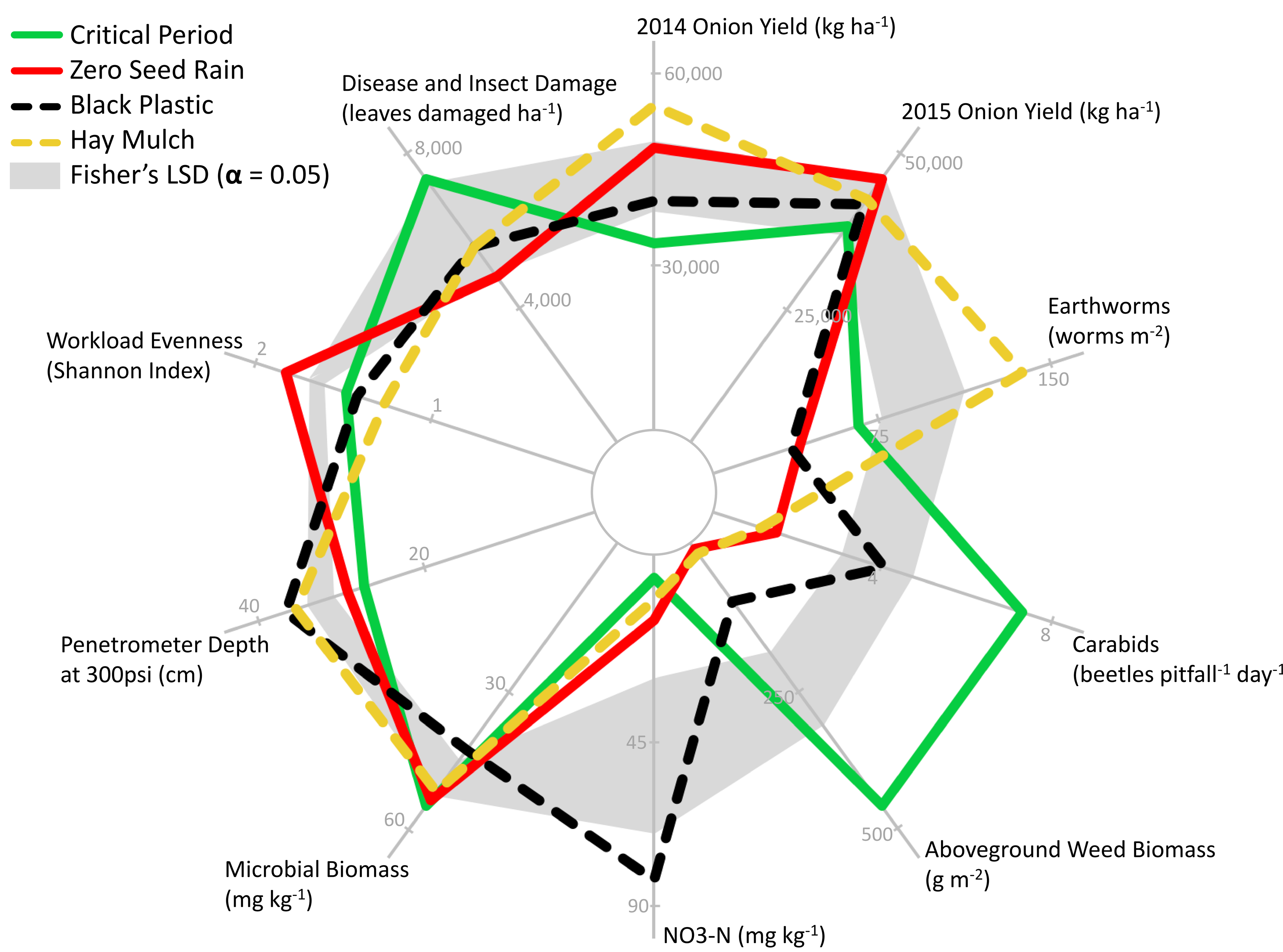

Figure 1. **Radar plot of late-season results of each strategy.**

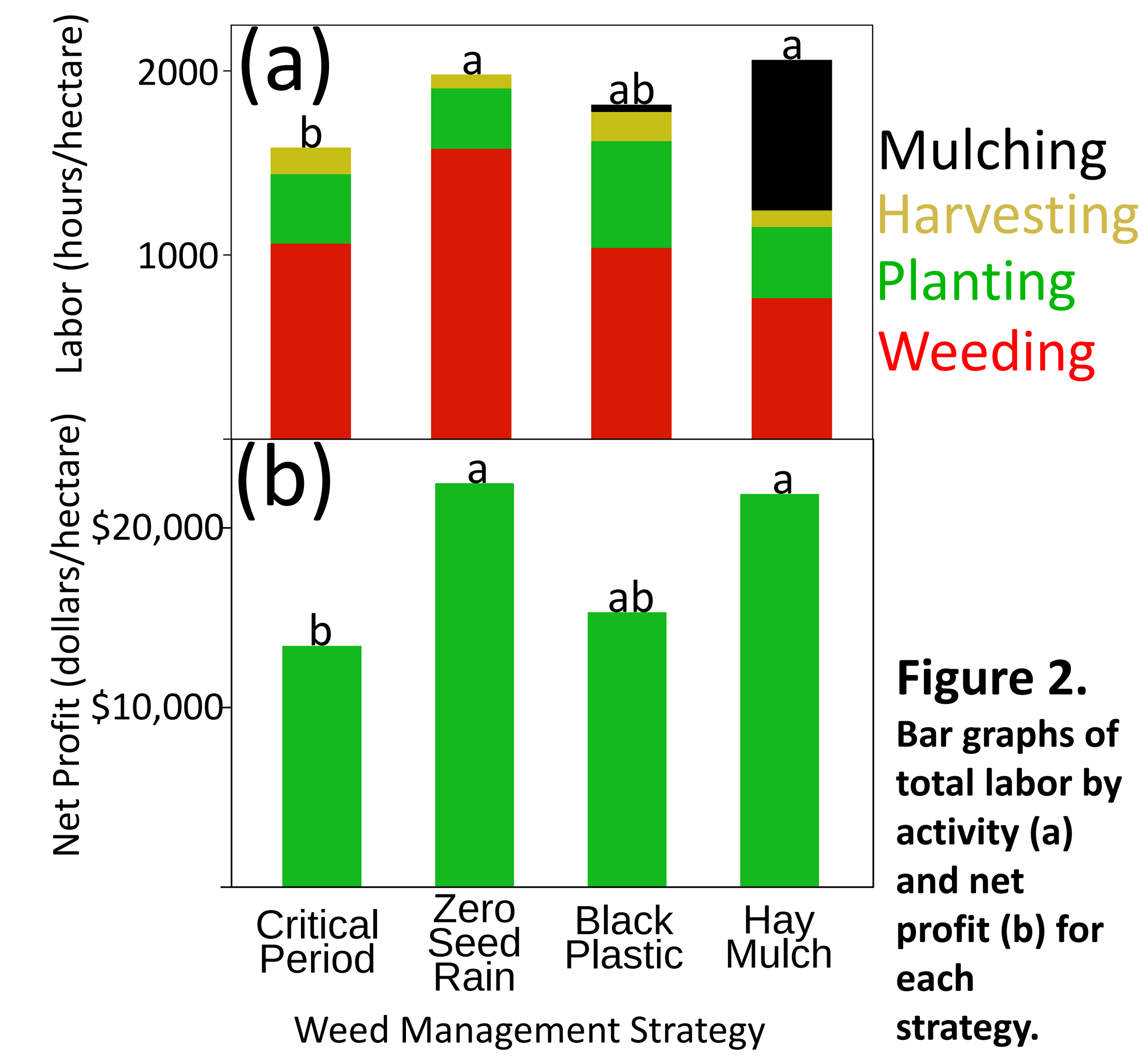

Figure 2. **Bar graphs of total labor by activity (a) and net profit (b) for each strategy.**

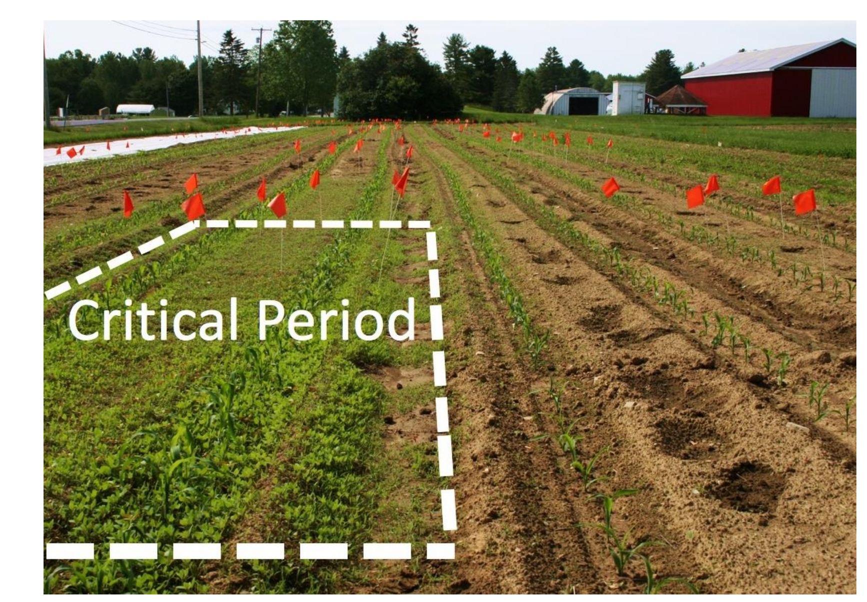

Figure 3. **Image of the high weed germination the year after Critical Period Weed Control was implemented.**

Conclusions

Zero Seed Rain and Hay Mulch were most profitable in the short-term, which was unexpected since they are thought of as investments that pay off over time with decreased weed seedbanks (Norris 1999) or boosted soil quality (Lalande et al. 1998), respectively. Therefore, we recommend that farmers implement Zero Seed Rain or Hay Mulch for weed sensitive crops like onions. Zero Seed Rain may be best for farmers that have a steady labor source and grow mostly short-season crops or crops that cannot be mulched. Farmers with access to inexpensive hay should consider mulching their long-season vegetables, especially if their soil organic matter is low and they have the labor (or mechanical spreader) to apply it in the early season. Critical Period Weed Control should only be used if reducing labor is the main goal and future weed competition is not important. Black Plastic can be used if soil warming or nitrate conservation is desired.

Future Research

Simulation modeling will be used to expand our results to other crops, scales, and durations of implementation. When results were presented to farmers, they asked how the quality of hay would affect yield, how the effectiveness of the strategies compared to cover cropping alone, and how long it would take to build soil organic matter using hay.

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