Lettuce production using plastic mulch and an update on the status of biodegradable plastic mulch for organic systems

Comparing two baby-leaf lettuce production systems

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Over the last two decades, annual supermarket sales of ready-to-eat salad mix have increased more than five-fold in the U.S., from $197 million in 1993 to $2.7 billion in 2012. While baby-leaf salad mixes are composed of lettuce, spinach, arugula, pac choi, kale, Asian and Indian mustards, and raddichio, consumer demand is especially high for baby-leaf lettuce. The primary barrier to baby-leaf salad production for organic growers is weed pressure because the crop is produced in densely seeded beds and the only practical post-emergence weed management method is hand weeding before harvest, and manual removal of weeds from the crop after harvest. Both of these practices are very labor and time-intensive and greatly increase production costs.

One method to produce baby-leaf lettuce while minimizing weeds is to use plastic mulch to grow head lettuce varieties that are designed for salad mix production, such as Salanova™ from Johnny's Selected Seeds. At the mature head stage, the individual leaves of these cultivars remain short (approximately 3 in.) and the head will develop an average of 200 leaves as opposed to the 60 leaves that are typical of conventional head lettuce. One drawback to growing Salanova™ lettuce is substantially higher cost per seed. Additionally, little information is available on yield.

Two separate but adjacent studies were conducted in Spring 2014 at the Washington State University Northwest Washington Research and Extension Center in Mount Vernon, WA in a field that was in its third year of transition to organic. One trial was of traditional baby-leaf lettuce with the romaine cultivar Flashy Trout's Back planted twice, two weeks apart. The crop was seeded in six rows spaced 4 in. apart within the bed, and spacing within each row was 1/2 in. The second trial was of Salanova™ lettuce with eight cultivars, Red and Green Oakleaf, Red and Green Butterhead, Red and Green Sweet Crisp, and Red and Green Incised. Transplants were spaced 8 in. center-to-center with three rows per bed, and beds were covered with 1 mil black embossed plastic mulch. Both studies were drip irrigated at a rate of 1 in. per week accounting for precipitation.

The traditional baby-leaf lettuce planting was harvested when leaves were 4-in. length, which was 48 days after seeding. In this study the planting was only harvested once, and yield was multiplied to estimate the yield for one and two reharvests. The second and third harvest would have been 10 days apart such that the third harvest would be 68 days after seeding. Salanova™ cultivars were harvested when heads reached 8 in. diameter, 75 days after seeding and 52 days after transplanting.

Mean yield of traditional baby-leaf lettuce did not differ due to planting date. For Salanova™, yield was measured for cored heads and there was no significant difference among cultivars, but green Salanova^{TM} cultivars (2.7 lb per bed-foot) had a higher yield than red cultivars (1.7 lb per bed-foot). For a 100-ft bed of baby-leaf lettuce from the traditional planting the yield was 32.6 lb. for a single harvest with a value of $67 wholesale ($2.04 per lb.) and $268 retail ($8.22 per lb.), 65.0 lb. for a double harvest with a value of $145 wholesale and $539 retail, and 97.7 for a triple harvest with a value of $199 wholesale and $801 retail. Yield of Salanova^{TM} lettuce was 155 lb. per 100-foot bed, with a value of $317 wholesale and $1275 retail. Yield of Salanova^{TM} lettuce was 1.6 to 4.7 greater and value was 0.6 to 3.8 times greater than for traditional baby-leaf lettuce.

A 100-ft bed of traditional baby-leaf lettuce requires approximately 14,400 seeds at an average cost of $0.0006 per seed and a total cost of $8.64. A 100-ft bed of Salanova^{TM} lettuce with three rows requires 300 seeds at an average cost of $0.064 per seed and a total cost of $19.20. The cost per seed is 100 times greater for a Salanova^{TM} cultivar than for a common leaf lettuce cultivar, while the cost of seeding a 100-foot bed is two times greater for Salanova^{TM} than for a common leaf lettuce. The difference in cost of seed for Salanova^{TM} lettuce was insignificant considering its increased yield.

The yield advantage of salad mix head lettuce combined with the weed management advantages of growing such varieties on plastic-covered beds shows promise for baby-leaf lettuce production. Thus a complete economic comparison of the two production systems is warranted.

Biodegradable mulch films: their constituents and suitability for organic agriculture

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Today there are many agricultural mulches that are marketed as "biodegradable." The goal for a biodegradable mulch is that it will retain a relatively high level of intactness during the growing season, so that it meets the functionality expectations of growers (e.g., weed control, moisture retention), and at the end of the growing season it can then be incorporated into the field where it will biodegrade fully over a relatively short period of time (i.e., within 2 years). Being able to till the mulch into the soil after the crop harvest eliminates removal and disposal costs for growers and reduces landfill waste for communities.

The USDA National Organic Standards Board (NOSB) passed a final rule on October 30, 2014 which added 'biodegradable biobased mulch film' to their list of allowed substances for organic crop production ["7 Code of Federal Regulations (CFR) section 205", available at http://www.regulations.gov/#!documentDetail;D=AMS-NOP-13-0011-0125]. To be considered biodegradable and biobased, a mulch film MUST:

- Achieve at least 90% biodegradation in the soil within two years, in accordance with the ISO 17556 or ASTM D5988 testing methods
- Be biobased, with biobased content measured using ASTM D6866

- Meet compostability specifications of one of the following standards: ASTM D6400, ASTM D6868, EN 13432, EN 14995, or ISO 17088 (*Section 205.2*)
- Be produced without organisms or feedstock derived from excluded methods [*Section 205.601(b)(2)(iii)*]
- Be produced without the use of synthetic (non-biobased) polymers; minor additives such as colorants and processing aids are not required to be biobased (*NOP Policy Memo 15-1*)

It is important to note that while biodegradable paper mulch is allowable in certified organic production systems, **currently, none of the biodegradable mulch films have been approved for use in the U.S. because, so far, none meet the requirement of using only biobased feedstock**. To be considered 'biobased' the feedstocks used to make the mulch must be derived from a renewable resource (plant and/or animal mass derived from carbon dioxide recently fixed via photosynthesis). The feedstock must be made using biological processes and may not be derived from, or using, GMO organisms. Biodegradable mulch films currently on the market contain only 10 – 20% biobased content and the remaining content includes polymers derived from fossil fuels (petroleum or natural gas) as well as dyes, minerals, and in some cases heavy metals (OMRI report to USDA-NOP, June 5 2015).

The most common biobased materials used to make biodegradable mulch films are starch, polylactic acid (PLA), and polyhydroxyalkanoate (PHA). Each of these three biopolymers is most commonly blended with non-biobased polymers and minerals, and then processed using synthetic procedures. Starch starts as a natural polysaccharide but is typically processed into a thermoplastic material by extruding with water and organic alcohols (usually glycerol, a biobased co-product from biodiesel manufacture), or it may be esterified chemically. Corn starch sourced from the U.S. is most likely derived from a genetically modified organism (GMO); however, there are no cost-effective assays for determining GMO status. PLA is derived from starch and oxidized by yeasts or other microorganisms to produce lactic acid, which is subsequently polymerized synthetically through a series of reaction steps. PHAs are biopolymers that are biosynthesized through fermentation by bacterial enzymes. PLA and PHA are most commonly produced using GMOs.

Under the NOP rule, the grower is responsible for ensuring that the mulch reaches 90% biodegradation within the 2 year period. All the biodegradable testing procedures cited by the NOP are laboratory procedures that utilize controlled conditions including temperature, moisture, and organic matter substrates; and the material being tested is ground into a fine powder. In the field, there is variability in environmental conditions: heat, UV light, wind, soil type, pH, microbes, irrigation, aeration of the soil, and other production practices. Environmental conditions during the period of time when the mulch is being used on the soil surface may also affect biodegradation. For example, PBAT (a constituent of several biodegradable mulch films) can undergo photochemical reactions that form cross-links, and the cross-links reduce the extent of biodegradation that can be achieved. If the mulch does not adequately biodegrade in the soil, the grower may be in non-compliance.

In 2009, the USDA-Specialty Crop Research Initiative (SCRI) funded project *Biodegradable Mulches for Specialty Crops Produced Under Protective Covers* (Ref. No: 2009-02484) followed four biodegradable mulches (BioAgri, BioTelo, PLA Experimental, WeedGuard) in the soil for 2 years at three locations in the U.S. (Knoxville TN, Lubbock TX, Mount Vernon WA) post-incorporation using a mesh-bag protocol. Results from this study showed that WeedGuard biodegraded at all locations, BioAgri and BioTelo (very similar products) biodegraded at different rates at each location, and the PLA mulch did not biodegrade at any location. A new 5-year field study initiated in 2015 (USDA-SCRI Ref. No. 2014-51181-22382) *Performance and Adoptability of Biodegradable Plastic Mulch for Sustainable Specialty Crop Production* at Washington State University Northwest Washington Research and Extension Center and the University of Tennessee–Knoxville is testing 5 biodegradable mulch products, WeedGuard, BioAgri, Naturecycle, Organix, and an experimental PLA/PHA-based mulch film. Evaluation includes mulch impacts on crop production and soil micro-organisms, and mulch biodegradation in the soil over 4 years of repeated applications. Soil sampling methods will be developed to enable growers, certifying agencies and scientists to determine how much mulch is remaining in the soil post-incorporation. For more information about this research project, see www.biodegradablemulch.org.

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