Research Updates

Degradation of Plastic Compost Bags Used for Yard Waste

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Summary. **Three trials, beginning June, July, and September 1991, examined the breakdown of photodegradable plastic bags. The plastic contained a light-sensitive compound dis - solved in the polymer to hasten degradation. The bags were placed in east west rows on bare ground. Other factors studied included turning the bags over either every 3 or 7 days and either filling the bags with fresh grass clippings or leaving them empty. Strength loss was determined with a hand-held puncture tester. Strength increased initially by 36%, 32%, and 63% in the three trials, respectively. The bags took 33, 35, and 64 days to reach brittleness (puncture strength of 180 g) in the three trials, respectively. Once degradation began, all trials showed similar rates of decline. However, the degradation began 7 days after exposure in the first two trials, but not until 14 days after exposure in the September trial. The addition of grass clippings to the bags increased the initial strength and delayed the onset of degradation. Turning the bags every 3 days rather than every 7 did not affect degradation.**

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The use of photodegradable plastic film has existed as one alternative for agricultural mulch for several years (Taber, 1991; Wolfe, 1989). Recently, trash bags for yard wastes have incorporated the same photodegradable technology. The photodegradation results from exposure to light in the ultraviolet (UV) portion of the spectrum (290 to 360 nm) or erythemal radiation, which also causes sunburn of the skin (Basher, 1989; Keller, 1965). Solar UV radiation is of particular interest because photon energy increases inversely with wavelength and is high enough to rupture weak molecular bonds and provide excitation energy for further chemical reactions (Basher, 1989).

The strength of plastic films depends on very long carbon chain molecules. Ultraviolet radiation breaks down these chains, particularly when oxygen is present, causing brittleness in the film. Manufacturers introduce oxygen into the carbon chains through carbonyl groups that absorb UV energy in the 270- to 360-nm range (Johnson, 1987). Photodegradable plastics are based on various patented technologies, such as ketone carbonyl systems, ethylene/carbon monoxide, antioxidant/photoactivated additive systems (Francis, 1989; Johnson, 1987; Statz and Dorris, 1987). British and Israeli researchers (Gilead, 1991) developed a method using two additives called an antioxidant/photoactivated system. By varying the relative amounts of two additives the life of the plastic can be controlled, provided the amount of UV exposure is known. A transition metal complex absorbs UV energy between 295 and 315 nm, releasing the metal ions that act as catalysts to break the polymer chains (Gilead, 1991). Once the chains are broken, the process continues in the absence of sunlight or oxygen. Thus, it becomes a chemical reaction that is highly dependent on temperature (Johnson, 1987).

Environmental variation in UV intensity is due to latitude and local conditions such as cloudiness, haze, smoke, dust, fog, and humidity (Keller, 1965). Light clouds and fog decrease direct solar radiation, but increase the scattered or sky light radiation. The absorption of *W* by water vapor in the atmosphere is small compared with the absorption of infrared wavelengths. Thus, on a bright, cloudy day, there still will be considerable ultraviolet radiation. The highest *W* radiance occurs near the equator, at high elevations, at midday, and during the summer and fall because of the incident angle of incoming solar radiation, air mass, and specific absorption by ozone (Keller, 1965).

The objectives of this research centered on the physical degradation of photodegradable compost bags marketed as Plastigone (Plastigone Technologies, Inc., Miami, Fla.). The bags contained the antioxidant/photoactivated system developed by Scott and Gilead (Gilead, 1991). We examined the effects of three factors on bag degradation: 1) season, with June, July, and September as starting dates; 2) presence and absence of clippings in the bags; and 3) turning the bags once every 3 days or once every 7 days.

Procedures

The studies were conducted at a farm site near Ames, Iowa (lat.42°N) on three dates in 1991. On 18 June (early summer), 19 July (mid-summer), and 5 Sept. (early fall), Plastigone photodegradable, gray-colored, 1-mil-thick compost bags, either empty or filled with grass clippings, were tied shut with baler twine and arranged in east west rows with the tied end facing north. A power mower with bag attachment served to collect the clippings. The June trial consisted of four bags full of grass clippings turned every 7 days. The July trial consisted of four blocks, each block containing an empty bag turned every 7 days, a fill bag turned every 7 days, and a full bag turned every 3 days. The September trial consisted of four blocks, each block containing a fill and empty bag turned every 7 days. The bags were placed on top of air-dried clippings over the soil. The bags did not touch each other.

A hand-held Chatillon puncture tested (Model DFG2, John Chatillon & Sons, Inc., Kew Gardens, N.Y.) with a 3.2-mm rounded tip measured the rupture strength of the bags in grams per roil. Four or six readings from the center of the top and the center of the bottom of each bag gave an average strength measure for analysis. Previous research with plastic mulch films indicated a high correlation (r= +0.9) between the puncture test and the traditional Instron measurement (Taber, 1991).

Environmental conditions were monitored by sensors attached to a Campbell 21X Datalogger (Campbell Scientific, Logan, Utah) with a scan rate of 5 rein, averaged hourly. The sensors were located in a standard U.S. Weather Shelter adjacent to the plot area. Solar radiation data were obtained by use of a LI-COR 200S pyranometer (LI-COR, Lincoln, Neb.), and air temperatures by Model 107 thermistor probe. Thermocouples (type T40) attached to the inside of each bag determined bag temperature in the September trial.

Summarization of the results used analysis of variance for a randomized complete block design with time trends summarized by lines fit by simple linear regression.

Results

Date of application. Figure 1 shows the rate of degradation or strength loss of bags filled with fresh grass clippings in each trial. A puncture-strength reading of 180 g was associated with brittleness (visual observation), or no strength left in the plastic bag. At this point, the plastic behaved like paper tore easily and wind and rain caused it to break into small particles (Francis, 1989).

The initial strength of the bags, based on 128 punches over all three trials, averaged 363 g with a standard deviation of 45 g. In each trial, the strength increased from day O to day 7 for reasons not now understood. In the June and July trials, the strength declined after day 7 at a rate of 12 g/day. In the September trial, the strength continued to increase to day 14 and then declined at a rate similar to that observed in the first two trials. No statistically significant deviations from simple linear decline occurred in any trial; the equations for these lines show the similarity of their slopes:

June: Strength = 505 g -12.5 g/day for days 7 to 30
July: Strength = 493 g -11.3 g/day for days 7 to 28
September: Strength = 705 g -10.5 g/day for days 14 to 42

The days to reach brittleness (180 g) based on these equations compute to 33, 35, and 64 days for the three trials, respectively. The difference between the June and July trials does not come close to conventional statistical significance (P= O .05), but the longer time evident in the September trial cannot have arisen simply due to chance alone ($P < 0.05$). In addition, the bags in the September trial gained more strength initially than the bags in the June and July trials (63% vs. 36% and 32%, respectively, $P < 0.05$). The reasons for the delayed degradation in September remain unknown, but less daily UV radiation and cooler temperatures seem reasonable possibilities. The temperature during the first 14 days of the trial averaged 3.4C cooler in September compared to July, and the total solar radiation for the two periods calculated as 206 mJ m^{-2} and 243 mJ m^{-2}, respectively. However, UV radiation declines faster than total solar radiation in the fall (Johnson et al., 1976; Keller, 1965). Using calculations from Johnson et al. (1976), the solar UV radiation could potentially decline by 38% from July to September at the latitude of these trials.

Effect of grass clippings. Bags not filled with grass clippings degraded more rapidly than those filled with grass (see Figs. 2 and 3). In both the July and September trials that included both filled and empty bags, the full bags had higher strengths than empty bags, with the average difference being 119 g.

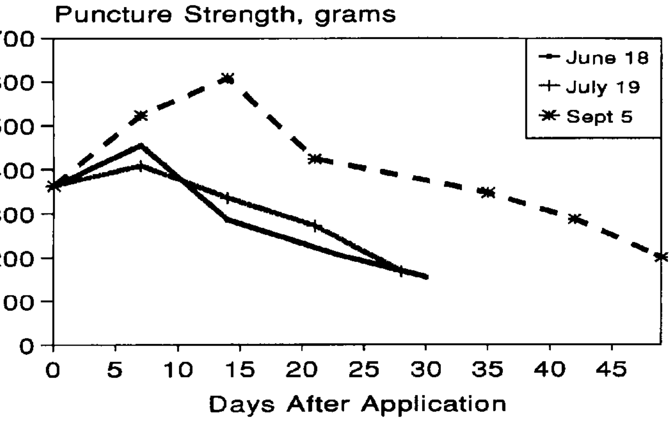

Fig. 1. ***Strength loss of photodegradable compost plastic bags filled with grass during the 1991 season, Ames, Iowa (lat.42°N).***

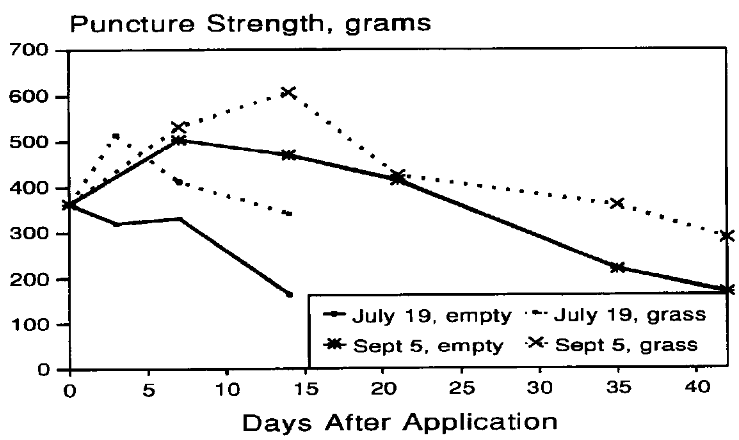

Fig. 2. ***Effect offilling photodegradable compost plastic bags with grass clippings on strength loss on two dates, Ames, Iowa.***

Fig. 3. *Grass-filled bag in center, flanked by empty bags held in place by bricks. All bags laid out on 19 July 1991, and turned every 7 days. Photograph taken on 5 Aug 1991.*

In the July trial, bags declined in strength by 15 g/day after an initial 7-day exposure. The rates of decline in empty and full bags did not differ significantly (15.5 and 15.0, respectively). In the September trial, the decline after the initial increase averaged 9.2 g/day, and, while the empty and full bags show different individual declines (10.3 and 8.1), the difference could easily have arisen by chance alone. Grass-filled bags increased more in strength during the first 3 to 7 days than empty bags. Grass-filled bags in the September trial had significantly lower temperatures than empty bags (a difference of 6C).

Frequency of turning the bags. Figure 4 shows that, in the July trial, increasing the frequency of turning the bags from 7 to 3 days did not significantly affect the rate of degradation. The average difference between the two treatments did not approach statistical significance, nor did the data provide any evidence that the change over time was different in the two treatments.

Discussion

Once the bag begins to degrade, it does not break uniformly throughout. The portion of the bag receiving the most sunlight reaches brittleness first. Measurements (data not shown) indicated that the south and middle portion of the bag broke down more rapidly than the north end near the tie.

These experiments show that photodegradable plastic bags containing the Scott-Gilead (Gilead, 1991) additive system degrade to a brittle state on exposure to sunlight provided that they are turned frequently. Interestingly, the bags initially increase in strength, especially when filled with grass; but, once breakdown begins, no difference in the rate occurs and the rate seems independent of season. Once the material begins to decline, there is no evidence that the rate of decline can be modified by environmental conditions.

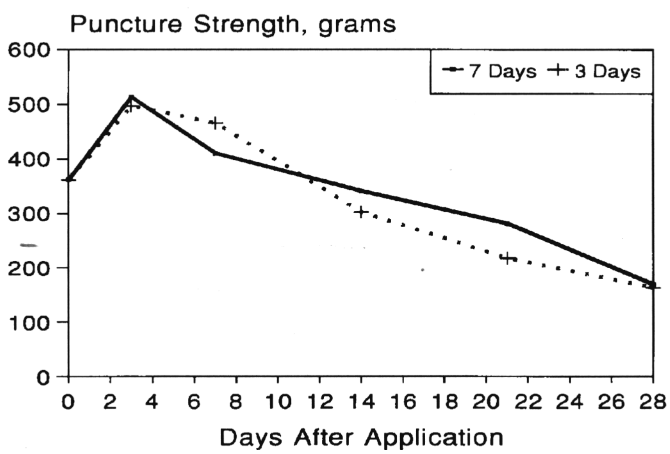

Fig. *4. The effect of turning grass-filled photodegradable plastic compost bags every 7 days or 3 days on the rate of plastic degradation, Ames,* Iowa.

The time from initial exposure to brittleness changes through differences in the extent of the initial strength increase, but not in changes in rate once degradation begins. In a typical windrow compost pile with many bags not exposed to sunlight, differential degradation almost certainly would occur. Thus, a new procedure will have to be devised to make photodegradable bags effective. In northern latitudes, the rate of degradation will be the greatest in summer and least in the winter, reflecting the amount of solar radiation (UV radiation) available.

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