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Agricultural Plastics as Solid Waste: What are the Options for Disposal?

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Summary. Agricultural plastics are a significant contributor to solid waste disposal problems, particularly in areas with heavy use of plastic-covered greenhouses or mulch films. Field-burning and landfilling are no longer viable options for disposal in many areas. Reuse and reduced weight of films are two methods to reduce the amount of material requiring disposal. Recycling, incineration, and on-site degradation appear to be the most-promising technologies for disposal. Each technology has its drawbacks. These include dirt and pesticide residues on mulch films, the presence of stabilizers and photoactivators, possible limitations to recycling mixtures of types of plastics, and high costs for recycling and incineration facilities. This is an active area of research for many members of the American Society for Plasticulture.

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Although agricultural plastics represent only a small fraction of the more than 22 billion lb (10 billion kg) of plastics used annually in North America, the impact is great in those areas with substantial use of plastic mulch and greenhouse films. Use of plastic mulch for vegetables, strawberries, and other row and orchard crops exceeds 110 million lb (50 million kg) annually in the United States (Ennis, 1987). If the definition of agricultural plastics is expanded to include food packaging, agricultural chemical containers, and shipping sacks for agricultural products and inputs, the United States used 3.4 billion lb of agricultural plastics in 1987 (Cornwell, 1989).

Other reports in this issue of *HortTechnology* establish the value and extent of use of plastics and polymers in horticulture. Indeed, some authors (Lament et al., 1991) have stated that agricultural plastics are appropriate components of reduced-input horticultural systems, as agricultural plastics may reduce the need for pesticides, water, and nitrogen fertilizers while increasing crop yield. Plastics seem destined to play an ever-greater role in horticulture. Disposal of waste plastics may, however, limit their use (Brown and Splittstoesser, 1991). How, then, are we to deal with the environmental and economic impact of the disposal of agricultural plastic waste?

Landfilling has been the primary disposal option for all plastic. Restrictions placed on disposal of agricultural plastics in landfills and the difficulties in finding sites for new landfills are forcing the development of alternative disposal technology. Other disposal options include disking mulches into the soil, on-site burning, on-site storage (Fig. 1), reuse, recycling, and incineration. Other solutions include

photo- and biodegradability and the production of thinner films that require a smaller mass and volume per unit area. Options such as controlled incineration and recycling are complicated by the diversity of types of plastics used in agriculture and, in many areas, by the geographically dispersed nature of agricultural plastics use. Types of polymers used in agricultural plastics include low-density polyethylene (PE), linear low-density PE, high-density PE, polyester, polypropylene, PE terephthalate, polyvinyl chloride, polystyrene, nylon, and biopolymers such as starch and cellulose. These sometimes are commingled in the same product. Plastics also contain stabilizers and dyes, including heavy metals, which may limit the types of products produced from recycled materials.

Uses of plastics and polymers in agriculture include mulch films, greenhouse covering, floating and hoop-supported crop covers, netting for turfgrass production and bird screens, netting and sprayed materials for erosion control, pots and trays, stakes and labels, irrigation systems, soil amendments, antitranspirants, cordage, and balewraps or silage bags. In addition, many products purchased for use on the farm, including pesticides and fertilizers, come in plastic containers. The greatest use nationally and the greatest geographical concentrations occur with the polyethylene-based mulch and greenhouse films. This article focuses on three disposal options for these films. The American Society for Plasticulture (ASP) has formed a plastics disposal committee composed primarily of representatives of manufacturers and retailers of mulch and greenhouse films. Some information in this article is drawn from the minutes of this committee.

Incineration

Plastics can be incinerated to produce usable heat and electricity, either as relatively pure plastics or as part of a mixed waste stream. Burning pure plastic produces up to 20,000 BTU/lb (4.64×10^7 J kg⁻¹) (ASP, 1991), about equal to the energy content of fuel oil. This compares to an average of 4500 BTU/lb for municipal solid waste. Incineration of all the greenhouse film used yearly in the United States would produce the energy equivalent of 300,000 gal (1,135,000 liters) of fuel oil (Bartok, 1989). This high energy

Fig. 1. A typical on-site storage of agricultural plastic waste that will be disposed by landfilling or burning. This small nursery site included mulch film, greenhouse film, rowcovers, pots, and trays, as well as discarded rooting medium

value offers the opportunity to solve a portion of the disposal problem through power and cogeneration facilities. Many incinerator/power plants, however, are not engineered to convert to usable power the extra heat generated by burning high-energy materials. Incinerators usually generate income through tipping fees on garbage disposal. If plastics replaced municipal wastes, the incinerator would lose these fees.

In addition, there are other drawbacks to incineration of agricultural films. Although plastics can be incinerated safely, the public may perceive that combustion of plastics produces toxic gases. Indeed, the effect of residual pesticides on the safety of burning mulch films has not been determined fully. The plasticizers and stabilizers used in films do not appear to be a major concern. The U.S. Environmental Protection Agency classifies agricultural plastic films as approved for incineration since their content of heavy metals is far below levels of concern. Films also must be shredded or pelletized and transported to the incinerator. This is not likely to be a viable option in areas with low volumes of plastics use or if the distance to an incinerator is great.

Mulch films present a greater problem as they typically carry a substantial residue of soil particles that will increase the ash production of the incinerator. Incineration can also be

thought of as the waste of a non-renewable resource-fossil hydrocarbons. Recycling may represent a more environmentally desirable solution. However, oxidation to carbon dioxide and water is the ultimate fate of all plastics. At least incineration, if used to produce power and usable heat, results in reduced direct burning of fossil fuels for energy.

Recycling

As recently as 1989, a survey of plastic mulch use in the United States indicated a dearth of successful recycling programs (Schales, 1989). Nevertheless, many producers and users of agricultural plastics have advocated recycling as the most desirable alternative for disposal. Cornwell (1989) presents an excellent review of the possibilities for recycling. He reports that, in Finland, the major commercial producer of agricultural and construction plastics goes into communities to collect used film. It is then separated by type of raw material and by color, washed, dried, and re-pelletized for feeding back into extruders. Cornwell acknowledges that reprocessed resin is not equal in quality to virgin resin. Up to 15% of recycled film material can be included with virgin material and still produce acceptable agricultural films.

Injection-molded plastics can contain up to 50% recycled material (Cornwell, 1989). Plastic containers from the nursery industry are being recycled

by the J.M. McConkey, Co. (Sumner, Wash.) and the Plastics Recycling Service (Parkersburg, W.Va.).

Among the practical impediments to recycling are the more than 1 billion lb (450 million kg) per year of clean scrap leftover from plastic manufacturing; the necessity to sort different types of plastic; and the dirt, chemical residues, and plant material content of agricultural plastic, particularly mulch film (T. Kallus, personal communication). These problems are not insurmountable for certain end uses: National Waste Technologies, Inc., is commingling plastics containing up to 50% films, without washing, then heating and densifying to make plastic wood. The FBM company of Italy manufactures equipment for recycling mulch films into resins usable for injection molding. This equipment has been tested by members of the Plastics Disposal Committee of ASP (V. Myers, personal communication). Low-density PE films are usually embossed (a diamond-shaped pattern stamped onto the film) to increase strength. These films appear to hold more dirt and may pose difficulties in recycling.

Some companies report that exposed greenhouse covering film cannot be recycled. However, Denton Plastics, Inc. (Portland, Ore.) and Environmental Plastics, Inc. (Oregon City, Ore.) will take clean greenhouse film. Recyclers generally concentrate on clean, high-quality plastics such as high-density PE milk jugs and PE terephthalate soft drink bottles. Few recyclers are currently accepting agricultural films. Recycling probably will not be a viable alternative to landfilling for most end-users for the foreseeable future. However, in areas such as southern Florida, where large volumes are used, recycling of mulch films using the FBM technology soon may be a reality.

Degradability

The performance of a new generation of photodegradable and biodegradable mulches has been a major research focus for many members of ASP. The concept seems simple: produce a mulch that will disintegrate a certain number of days after planting and rapidly break down to carbon dioxide and water, or at least to particles so small that they can be incorporated easily into the soil. Earlier attempts to produce commercially viable degrad-

able mulches were largely unsuccessful as the rate of degradation was unpredictable.

A new generation of degradable mulches debuted in the mid-1980s and incorporates two basic approaches to degradability. The first relies on photodegradation. All plastics are degraded by solar radiation; agricultural plastics must be stabilized to inhibit this process. But stabilization produces a product that is insoluble and may last dozens of years. The new generation of photodegradables is stabilized in a way that allows for timed self-destruction. Gilead (1985) lists specifications for a photodegradable mulch film: 1) the film must retain its physical properties until the end of the crop cycle and then break down rapidly and completely; 2) the stabilizers must not leave a toxic residue; 3) the degradative system must not cause instability during manufacture; and 4) degradation must not ensue until the film is exposed to sunlight.

Breakdown of agricultural films is caused by absorption of ultraviolet (W) light. Pure polyethylene does not absorb in the W range (Gilead, 1985), but, during polymerization and film manufacture, heat causes chemical reactions that increase sensitivity to UV radiation. Hydroperoxides are produced; these functional groups are stable at room temperature but act as absorbers of UV (Albertsson and Karlsson, 1988). Transition metal chelates, most often nickel cobalt dithiocarbamates, are added to the films and act as heat stabilizers, trappers of free radicals, and decomposes of hydroperoxides. In contrast to nickel and cobalt compounds, iron and copper chelates become active radiation sensitizers after an induction period. Free metal ions catalyze nonreversible and self-accelerating chain reactions that degrade the polymers. The selection and concentration of photoactivators controls the length of the induction period (Gilead, 1985; Upton, 1990).

Another approach to timed break down is biodegradability. Plastics can be made from biopolymers, or starch can be incorporated into polyolefin-based films. Bonsignore et al. (1990) have described a process for converting food wastes, such as corn and potato starch, into polylactic acid polymers. Plastics of this type already are used widely in medical applications such as sutures, since they degrade to

a harmless product lactic acid. Use of this material in agricultural films offers the promise of a product that is rapidly and totally biodegradable. At present, high cost limits its wide use in agriculture.

Research experience with degradable plastic mulches has been decidedly mixed. One problem is that the buried edges are slow to degrade and often must be brought to the soil surface for exposure to light before they will degrade. Nevertheless, degradable plastic mulches have become popular in Florida, at least for growers who do not intend to double-crop the mulch over two seasons (Hochmuth, 1990). Johnson (1989) reported satisfactory results in the use of degradable mulches for production of strawberries, bell peppers, and melons in southern California. Degradable plastic mulches also performed acceptably for melons under northern Florida conditions (Kostewicz and Stall, 1989) and in Kansas (Lament and Marr, 1990). However, several authors have pointed out that the rate of degradation of a given product differs with intensity of solar radiation, temperature, latitude, season of application, and the crop (Clough and Reed, 1989; Hemphill and Clough, 1990; Sanders et al., 1989; Taber, 1991; Wolfe, 1989). This creates problems for users because a product may degrade too rapidly or too slowly, depending on location, season, and cropping system.

Aside from variability in rate of degradation, other problems encountered include longitudinal tearing between transplant holes or directly above surface drip irrigation tubing. The latter was attributed to excessive heating or stress where the film contacted the tubing (Hemphill and Clough, 1990). Another problem is litter: some degradable films breakup into small pieces that are easily scattered by wind.

Degradable plastics have not been perfected yet for all locations and applications and represent a waste of a resource that might be recycled or used for production of power. However, I believe that degradable will play an important role in many production areas, particularly those in which the quantities of films used are not large enough to make recycling or energy-production facilities economical. The plastics industry tends to favor the six Rs of waste reduction: reduce, reuse, recycle, recover energy,

retain landfills, and research. Degradability often is dismissed since most degradable plastics for consumer use are landfilled anyway. For agricultural films, however, the exposure to light during use will continue to make degradation a possible alternative for disposal of agricultural plastics.

In conclusion, field-burning and landfilling of agricultural plastic waste will not continue to be viable options for disposal. The plastics industry, user groups, and private and public sector researchers must continue to seek environmentally acceptable alternatives. Recycling, incineration, and degradability appear to be the most-promising alternatives.

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