Alternatives to Synthetic Herbicides for Weed Management in Container Nurseries [1]

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Weed management is one of the most critical and costly aspects of container nursery production. High irrigation and fertilization rates create a favorable environment for weed growth in addition to crop growth. Weeds can quickly out-compete the crop for light and other resources, reducing the rate and amount of crop growth as well as salability (Berchielli-Robertson, Gilliam, and Fare 1990; Norcini and Stamps 1994). Weed management in nursery production is most effectively achieved through preventative practices, primarily with preemergent herbicides (Gallitano and Skroch 1993; Gilliam et al. 1990).

However, there are valid reasons for managing weeds with alternatives to synthetic herbicides:

- If the crop or site is not labeled for use with synthetic herbicides.
- If the crop is damaged by synthetic herbicides.
- If synthetic herbicides are not effective on the target weeds (because of tolerance or resistance).
- If the grower desires to employ sustainable alternatives to synthetic chemical herbicides.
- If there are concerns about synthetic herbicide leaching and runoff.

Ornamental crops encompass a wide array of species, and herbicide products need to be tested on each to ensure crop safety and for specific ornamentals to be added to herbicide product labels. Even when a product is labeled for a crop, it may not be sufficiently effective for the weeds present or may induce crop damage under certain circumstances. Alternatives are also needed for nursery growers who produce blueberries, fruit trees, and other edible crops that cannot be treated with preemergence herbicides once they begin bearing fruit. Finally, product labels often prohibit the use of synthetic herbicides in greenhouses and other enclosed structures.

Increased emphasis on sustainability also results in growers choosing alternatives to synthetic herbicides. The Floriculture Sustainability Research Coalition (http://sustainablegreenhouse.wordpress.com) defines sustainable production as one that aims to reduce environmental degradation, maintain agricultural productivity, promote economic viability, conserve resources and energy, and maintain stable communities and quality of life (Dennis et al. 2010; Hall et al. 2010). Social, economic, and regulatory issues might influence nursery producers to adopt sustainable production methods. By adopting more sustainable practices, producers should also be able to reduce input costs related to fertilizers and chemicals as well as reduce potential point source nutrient and chemical pollution. In addition,

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sustainable production of nursery plants could foster the development of new specialty nurseries, creating a market niche for "locally grown using sustainable methods."

Weed management alternatives to synthetic herbicides include sanitation, exclusion, prevention, hand weeding, mulching, and the use of cover crops, heat, and nonsynthetic herbicides. Only some of these alternative methods can be used to control weeds in containers, but all can be used to manage weeds around containers and in noncrop areas. Also, most alternatives are not used alone because they cannot individually achieve weed control comparable to synthetic herbicides. Two or more alternatives are usually used simultaneously in order to achieve acceptable levels of weed control.

Sanitation–Exclusion–Prevention

One of the most effective and economical means of avoiding weed problems is preventing their presence through exclusion and sanitation (Chappell, Williams-Woodward, and Knox 2012; Diver, Greer, and Adam 2008; Wilen 2010).

- Use containers, potting substrates, and fertilizers that do not contain weed seeds.
- Use weed-free plant/seed sources. Inspect all incoming liners for presence of weeds prior to potting.
- Use clean equipment.
- Manage a weed-free zone around and under containers.
- Manage weeds growing along the perimeter of the nursery and around a surface irrigation source.

These practices prevent or reduce the number of weed seeds and other propagules (bulbs, corms, rhizomes, and stolons) that can grow and reproduce, compounding weed management efforts.

The first critical step in reducing weed infestations is to follow adequate sanitation measures during propagation and liner production. Liners are often the initial source for introducing new weed species into production areas (Chappell, Williams-Woodward, and Knox 2012; Wilen 2010). Few if any herbicides may be used in this phase of production, necessitating reliance on sanitation and hand weeding. When receiving liners from an outside source, it is critical to monitor containers for weed emergence and to remove weeds before they reproduce and spread. If possible, visit liner and seed vendors to check out their sanitation practices before doing business with them. Additionally, equipment, containers, substrates, and fertilizers used in production should not contain weed seeds or propagules (Case, Mathers, and Senesac 2005; Chappell, Williams-Woodward, and Knox 2012; Wilen 2010). Simply washing equipment and containers and covering substrate storage areas can significantly reduce weed pressure.

Seeds are the primary source of weeds in production environments (Wilen 2010). Considering that the immediate nursery environment is the source of most weeds (Cross and Skroch 1992), the elimination of seed-bearing weeds within and adjacent to production areas can greatly reduce weed incidence and severity. This may entail working with neighboring property owners. Surface irrigation water also may be a source of weed seed if not sufficiently filtered before application (Kelley and Bruns 1975). To reduce weed introduction via irrigation water, weeds from the periphery of surface water supplies should be controlled prior to seed set. Irrigation intake pipes should be placed below the water surface but high enough to avoid suction of sediment from the bottom of the water source. This is often accomplished using a floating dock system to suspend the intake pipe in the water column.

Hand Weeding

Regardless of prevention efforts, wind, equipment, birds, and other animals (including humans) will eventually introduce weeds (Wilen 2010). Nonchemical weed control is done on a very limited basis in the nursery industry; however, it is critical to scout *regularly* for invading weeds and deal with them before they mature and spread. Hand weeding is extremely labor intensive and thus an expensive control option (Mathers 2003; Neal 2003). In addition, it may be difficult to find laborers willing to work for wages typical of the geographic area where the nursery is located, particularly near urban areas.

Nonetheless, hand weeding is an integral part of any successful weed control program since even preemergent herbicides are not 100% effective in eliminating weeds. Field nurseries practice mechanical cultivation, but typically as a supplement to an herbicide regime. Therefore, weed management should include regular scouting and hand weeding or mechanical control to prevent emerging weeds from maturing and dispersing seed. More frequent hand weeding will reduce overall hand weeding costs. Research has shown that weeding every 2 weeks versus every 8 weeks can reduce hand weeding costs by an average of 37% (Barker and Neal, 2016). Nurseries should strive to create a culture where "no weeds" is everyone's mantra.

Mulch

Mulch is applied to the substrate surface to create a physical barrier that inhibits weed seed germination and suppresses weed growth (Ferguson, Rathinasabapathi, and Warren 2008). Mulch is a traditional means of weed management in field nurseries and landscapes and may be adapted to container production (Billeaud and Zajicek 1989; Case, Mathers, and Senesac 2005).

Two general types of mulch have been adapted to container production: disk barriers and loose-fill products. Disk barriers are permeable or impermeable products in the shape of a disk with a slit for placing the disk around a stem and on the substrate surface. Disk barriers include impermeable, disk-shaped, solid plastic or cardboard lids, and permeable barriers composed of woven or particle-based products held together by resins or other binders (Chong 2003; Frangi et al. 2010; Mathers 2003) (Figure 1). Disk-type mulches are made from the following materials:

Impermeable

- Solid plastic lid or bags
- Cardboard

Permeable

- Geotextile fabric
- Coconut fiber
- Hair
- Peat

Disks can be useful for weed control, may reduce water loss from container plants, and have been shown to neither positively nor negatively affect plant growth (Ruter 1997; 1999).

However, disks have issues of cost, handling, irrigation, and fertilization, as well as problems with fitting containers adequately to prevent weeds, especially with multistem plants or when two or three liners are planted into the same pot (Chong 2003; Mathers 2003; Ruter 1999). If using impermeable disks, plants must be irrigated below the disk via drip irrigation to maintain adequate soil moisture. Additionally, fertilizer must be placed under the disk to maximize plant growth (Ruter 1999).

Disks must be installed by hand, which increases labor costs. Disks must fit the container exactly or there will be gaps between the disk edge and container rim where weeds can grow (Figure 2). Even with exact container fit, there will be gaps along the disk installation slit and around the plant stem where weeds can grow. In addition, the disk system is limited to plants with a central leader because disks are not designed to fit around multiple stems. Finally, some disk products may be blown away or displaced by wind, resulting in exposed substrate where weeds can grow. Disks are usually removed before sale and often may be reused several times; however, removing and reusing disks involves additional labor.

Figure 1. Permeable disk-type mulches composed of coconut fiber (upper left and lower right) and hair (upper right and lower left).
Credits: James H. Aldrich

Loose-fill mulches can be applied as a topdressing to the container substrate (Case, Mathers, and Senesac 2005; Chong 2003; Cochran et al. 2009; Ferguson, Rathinasabapathi, and Warren 2008; Mathers 2003; Mervosh and Abbey 1999; Smith et al. 1997). Many loose-fill mulches are locally available and inexpensive agricultural/forestry by-products. They include the following:

- Hulls and shells (almond, cocoa, hazelnut, pecan, peanut, rice, etc.)
- Starch/straw combination product
- Sawdust
- Wood chips
- Bark
- Chipped yard waste

Figure 2. Gaps between the disk edge and container rim, along the installation slit, and around the plant stem allow weeds to grow.
Credits: Gary W. Knox

- Shredded tires
- Shredded, crumbled, or pelletized recycled newspaper (Figures 3 and 4)

The ideal loose-fill mulch provides little or no nutrients, dries quickly after irrigation, resists decomposition, applies easily, and is cost effective, nontoxic to humans and crops, readily available, and acceptable to customers. Few products have many of these characteristics.

Weed control efficacy of loose-fill mulches generally increases the deeper the mulch is applied (Cochran et al. 2009; Penny and Neal 2003; Smith et al. 1997). Loose-fill mulch application may be mechanized (e.g., during potting) (Chong 2003). However, there are challenges associated with this option. Some mulches may contain weed seeds or phytotoxic components. Organic mulches may facilitate weed seedling development and may reduce available nitrogen near the substrate surface if not composted (Billeaud and Zajicek 1989). Spillage during handling and production is an issue. Most loose-fill mulching systems are considered more costly than an effective preemergence herbicide program, but an economic comparison of such systems has not been reported.

Living Mulch

Many field nursery crop producers use living mulches successfully (Diver, Greer, and Adam 2008). They can be adapted to container production, particularly with deciduous crops in winter (Figure 5). These living mulches

Figure 3. Crumpled newspaper may be used as mulch.
Credits: Gary W. Knox

Figure 4. Examples of pelletized and processed and colored recycled newspaper that can be used as mulch.
Credits: Robert H. Stamps

or cover crops may be used as a seasonal groundcover that suppresses weeds without competing with crop production. Such systems must be customized to local conditions to find the right combination of crop, living mulch species, and other compatible weed management practices.

Other Alternative Methods

Most other nontraditional alternatives to synthetic herbicides are not adapted to managing weeds in containers but may be applied around containers and in noncrop areas. For example, heat can be used to manage weeds in noncrop areas (Mathers 2011). Heat acts to kill weeds by denaturing proteins in cell membranes and breaking down the cellular structure of the weed. Alternatively, heat can induce water within cells to boil, thereby exploding cells and desiccating the plant. Application equipment has been developed to apply heat via propane-generated flame, infrared emitters, and direct application of boiling water or steam. Solarization, in which sunlight warms soil in a plastic-enclosed area, results in high temperatures that kill weeds, seeds, and disease and pest organisms (Stapleton, Wilen, and Molinar 2008).

Figure 5. Ryegrass seeded around a deciduous plant acts as a living mulch in winter, dying in spring and serving as a mulch.
Credits: Gary W. Knox

Alternatives to synthetic herbicides include natural chemicals, such as acids, soaps, oils, and salts that can act as contact herbicides (Diver, Greer, and Adam 2008). These nonsynthetic herbicides are best used as a targeted spray or in noncrop areas because contact can damage plants in production. It is important to note that these products do not kill roots, and repeated applications will be necessary for weeds that have the ability to regenerate from their roots.

For example, vinegar solutions can be sprayed to damage weeds (Diver, Greer, and Adam 2008; Fausey 2003). Vinegar is a product of fermentation containing about 5% acetic acid. It is more effective as a nonsynthetic herbicide when concentrated to levels of 15% and 30% acetic acid by distillation and freeze evaporation, respectively. Acid solutions are believed to cause changes in plant cell pH that result in loss of cell membrane integrity and eventual death.

Similarly, salts of fatty acids (soaps) act by penetrating cells and disrupting cell membranes, ultimately causing desiccation and death (Diver, Greer, and Adam 2008). Soaps include pelargonic acid (Scythe®), ammonium nonanoate (Axxe®), and potassium salts of fatty acids.

Plant-based oils, such as cinnamaldehyde (the primary component of cinnamon), are used as contact herbicides (Diver, Greer, and Adam 2008; Fausey 2003). Oils are believed to disrupt cell membranes. Plant-based oils include clove, eugenol, lemongrass, citrus, thyme, and oregano.

Salts, such as sodium chloride (table salt) (Mathers 2011) or ammonium chloride (Fausey 2003), can be used to kill plants. They cause plant tissues to dehydrate via osmosis. Some combination products mix acetic acid, salt, citrus oil, eugenol, and other natural chemicals. A current list of synthetic and alternative postemergence herbicides labeled for use in nurseries is available at http://edis.ifas.ufl.edu/wg059. `

Other alternative products include hydrogen dioxide (Fausey 2003) and plant by-products. Corn gluten meal, derived from processing corn, has not proven effective in containers (Mervosh and Abbey 1999; Wilen, Schuch, and Elmore 1999), particularly in high rainfall/irrigation areas. Mustard seed meal has shown promise for use with crops grown in the ground (Boydston et al. 2011; Handiseni et al. 2011) but has not been evaluated for use in containers. Finally, although there have been advances in biological control of arthropod pests and plant pathogens in nursery crops, no such strategies are currently available for weed control in nurseries.

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