Compost as an Alternative Weed Control Method

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Weeds, which reduce crop quality and yield by competing for light, water, and nutrients, and increase harvesting costs, reduce U.S. crop production an estimated 13% (Dusky et al., 1988). Herbicides are the pesticide most utilized in any crop production system. Their popularity reflects cost savings in farm labor, species selectivity, their ability to increase yields, and reduction in production cost (Altieri and Liebman, 1988). The costs of the herbicides and the labor to apply them are lower than the cost of mechanical weed control; therefore, growers have become dependent on chemical control. Nevertheless, long-term herbicide usage can have a potential negative impact on the environment. In the last decade, environmental concerns associated with pesticide usage in agriculture have increased. For example, in Florida, the Environmental Protection Agency (EPA) has restricted usage of several common herbicides because of ground water contamination and negative effects on wildlife and humans (Crnko et al., 1992). Major pathways for herbicide removal from croplands are leaching, surface runoff water, and sediment carried in the water (Schneider et al., 1988).

Weed growth suppression is one of the most important effects of mulches (Food and Agricultural Organization, 1987; Grantzau, 1987), and composted and noncomposted organic mulches were an important method of weed control prior to the development of herbicides (Altieri and Liebman, 1988). Suppression effects are due to the physical presence of the materials on the soil surface, and/or the action of phytotoxic compounds generated by microbes in the composting process (Niggli et al., 1990; Ozores-Hampton et al., 1996, 1997). The phytotoxins in extracts from immature municipal solid waste (MSW) composts include acetic, propionic, and butyric acids (DeVleeschauwer et al., 1981). The concentration of acetic acid in immature MSW is between 6,000 and 28,000 mg·kg^{-1} (Keeling et al., 1994). Combining immature MSW with N did not improve the percent germination of several vegetable crops, suggesting that phytotoxicity, rather than C:N ratio, was primarily responsible for poor seed germination and growth inhibition (Keeling et al., 1994).

Organic mulches may improve soil physical and biological properties as they decompose; this reduces soil erosion, minimizes soil compaction, increases water-holding capacity, slows the release of nutrients, increases microbial activity, and controls soil temperature (Food and Agricultural Organization, 1987; Foshee et al., 1996). The objective of this publication is to present information on the effects of composted and noncomposted organic mulches as an alternative weed control method.

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PHYSICAL EFFECTS OF ORGANIC MULCHES

Organic mulches can sometimes control weed growth as effectively as herbicides. For example, more weeds grew under nonmulched and nonherbicide-treated flower crops than under those mulched with 3, 5, or 7 cm of bark (Grantzau, 1987). Cultivation costs were decreased by 40% and 20% when bark mulch or straw, respectively, were compared with nonmulched and nonherbicide-treated controls in ornamental shrubs (Kolb, 1983).

Mulching tomatoes (*Lycopersicon esculentum* Mill.) with rice (*Oryza sativa* L.) straw increased fruit yields, prevented soil erosion, slowed weed growth, minimized soil compaction, and prevented contact between soil and fruit (Villareal, 1980). Applying wheat (*Triticum aestivum* L.) straw at 3.4 and 5.1 t·ha^{-1}, or applying metalachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1 methylethyl)acetamide] herbicide, increased corn yields by 15% over nonmulched corn [*Zea mays* L. (Wicks et al., 1994)]. Organic mulches applied at 5 t·ha^{-1} in herb production–controlled weeds as effectively and at lower cost than did simazine (6-chloro-*N*-*N*′-diethyl-1,3,5-triazine-2,4-diamine), diuron [*N*′-(3,4-dichlorophhenyl)-*N*,*N*-dimethylurea], and oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene] herbicides (Singh et al., 1985).

Weed control usually improves as the thickness of the organic mulch layer increases. However, the degree of weed control is dependent on compost mulch type, weed species, and environmental conditions. Generally, to suppress weeds most effectively, a 10- to 15-cm-thick layer of mulch is needed (Food and Agricultural Organization, 1987; Marshall and Ellis, 1992). Sawdust, straw, and bark improved weed control in kiwi fruit (*Actinidia chinensis* Planch.) with thicker layers providing greater weed control than did simazine herbicide (Ingle and Bussell, 1988). In general, germination of weed seed declines as burial depth increases (Table 1). With *Erodium cicutarium* L. and *Agropyron psammophilum*, both the percent germination of buried seed and seedling emergence were negatively correlated with burial depth (Blackshaw, 1992; Zhang and Maun, 1990). Germination inhibition at greater depths has been attributed to several factors, including light, temperature, and moisture (Baskin and Baskin, 1989). However, phytotoxic compounds (e.g., acetaldehyde, ethanol, acetone, ethylene, and allelopathic compounds) and high levels of CO_2 resulting from biological activity may also be involved (Reisman-Berman and Kigel, 1991).

PHYTOTOXIC EFFECTS OF COMPOSTED ORGANIC MULCHES

Composting is a biological decomposition process in which microorganisms convert organic materials into a relatively stable humus-like material. During decomposition, microorganisms assimilate complex organic substances and release inorganic nutrients (Metting, 1993). An adequate composting process should kill pathogens and stabilize organic carbon before the material is used as a mulch (Chaney, 1991).

Traditional compostable organics include animal manures, leaves, paper, wood chips, straw, textiles, etc. Composts made from other waste material, such as biosolids, MSW, yard trimmings (YT), and food waste have recently become available on a commercial scale. The largest potential user of these compost materials is the agricultural industry (McConnell et al., 1993; Parr and Hornick, 1992). Compost incorporated into soils has increased yields of corn, cucumber (*Cucumis sativus* L.), cabbage [*Brassica oleracea* (L.) capitata], lettuce (*Lactuca sativa* L.), snap beans (*Phaseolus vulgaris* L.), peas (*Pisum sativum* L.), carrot (*Daucus carota* L.), tomato, squash (*Cucurbita pepo* L.), pepper (*Capsicum annuum* L.), and watermelon (*Citrullus vulgaris* Schrad.) (Gallardo-Lara and Nogales, 1987; Obreza and Reeder, 1994; Ozores-Hampton et al., 1994; Roe et al., 1993; Smith, 1993).

Table 1. Depth of burial in soil required to prevent weed seed germination.

Species	Soil depth (cm)	Reference
Datura ferox	10	Reisman-Berman and Kigel, 1991
Datura stramonium	10	Reisman-Berman and Kigel, 1991
Agropyron psammophilum	8	Zhang and Maun, 1990
Erodium cicutarium	9	Blackshaw, 1992
Cyperus esculentus	0.5	Lapham and Drennan, 1990
Setaria faberi	6	Mester and Buhler, 1991
Solanum mauritianum	15	Campbell and Staden, 1994
Malva pusilla	8	Blackshaw, 1990

Phytotoxic chemical compounds in composted waste materials can injure plants (Table 2). The type and degree of injury are directly related to compost maturity or stability. Compost maturity is the degree to which the material is free of phytotoxic substances, and stability is the degree to which it consumes N and CO_2 in significant quantities to support biological activity, and generates heat, CO_2, and water vapor that can cause plant stunting and yellowing of the leaves (Florida Dept. of Agriculture and Consumer Services, 1994). Toxic substances obtained from water extracts of composted waste materials inhibited germination and growth of seedlings and also induced darkening and necrosis of root cells (Patrick and Kock, 1958). Organic acids, such as acetic, propionic, and butyric acids, can accumulate in compost with a high C:N ratio, and high concentrations of ammonia in compost with low C:N ratio (Hadar et al., 1985; Jimenez and Garcia, 1989). Crop injury has been linked to use of immature compost (Zucconi et al., 1981b). Toxicity also has been related to composting method; phytotoxins disappeared faster in static piles than windrows (Zucconi et al., 1981a).

Compost extracts from fresh and 5-month-old MSW contained high concentrations of acetic, propionic, isobutyric, and isovaleric acids (DeVleeschauwer et al., 1981). The most phytotoxic organic acid is acetic, which can inhibit cress (*Lipidium sativum* L.) seed growth at concentrations >300 $mg \cdot kg^{-1}$ (DeVleeschauwer et al., 1981). Shiralipour et al. (1997) demonstrated that the inhibitory effects of acetic acids on seed germination of cucumber *(Cucumis sativus)* 'Poinset' was a metabolic phenomenon, rather than an effect of high ionic strength or pH imbalance. Additionally, application of immature compost can reduce soil oxygen concentration, leading to anaerobic conditions in the root system, increase soil temperature to levels that are incompatible with normal root function, and cause N immobilization by the soil microbial population because of high C:N ratio (Jimenez and Garcia, 1989).

Water extracts from 3-week-old YT compost inhibited germination of several perennial and annual weeds at temperatures >60 °C (Shiralipour et al., 1991). In another study, extracts from 8-week-old MSW compost inhibited seed germination and growth of 14 important economic weed species, but not of yellow nutsedge (*Cyperus esculentus* L.). Inhibition of weed germination and growth were attributed to the presence of phytotoxic compounds in the immature compost (Ozores-Hampton et al., 1996). Field application of immature 4-week-old MSW compost at depths of 7.5, 11.3, and 15 cm in alleyways of raised vegetable beds completely inhibited the germination and growth of weeds for 8 months (Ozores-Hampton et al., 1997). Inhibition was attributed to both the physical effect of the mulch and the presence of phytotoxic compound in the immature compost. Acetic, propionic, and butyric acids were present at concentrations of 1221, 34, and 33 $mg \cdot kg^{-1}$, respectively (Ozores-Hampton et al., 1997). Mature MSW compost applied at 224 $t \cdot ha^{-1}$ reduced weed growth in alleyways of bell pepper, but herbicides were more effective than mature compost (Roe et al., 1993). Application of newsprint and broiler litter mulch decreased the number of large crab grass (*Digitaria sanguinalis* L.) seedlings by 65%, and also the number of henbit (*Lamium amplexicaule* L.), cutleaf evening primrose (*Oenothera laciniata* Hill), and cress seedlings in cotton (*Gossypium hirsutum* L.) (Edwards et al., 1994). Utilization of fresh oak bark in an apple (*Malus* ×*domestica* Borkh.) orchard improved annual weed control under the trees more than did mature bark (Niggli et al., 1990). Inhibition of weed seed germination was both chemical and physical.

PRECAUTIONS TO BE TAKEN WHEN USING COMPOSTED ORGANIC MULCHES

Application of organic mulches for weed control can have negative effects on crop plants. Merwin et al. (1995) compared natural mulches (hay, wood chips, and recycled paper pulp) with herbicides in an apple orchard for 4 years. Market value was higher with hay mulch than with herbicides, but serious trunk damage by meadow and pine voles (*Microtus* spp.) was observed in mulch treatments. Over a 6-year period, trunk diameter and fruit yield were higher in both hay-straw and herbicide treatments than in the nontreated control. Soil K, P, and B, and leaf K concentrations were higher with the hay-straw mulch, but serious *Phytophthora* root rot and meadow vole depredation were severe in hay-straw mulch plots (Merwin and Stiles, 1994).

Organic mulch application may provide less weed control than herbicides. Merwin et al. (1995) reported that managing weeds at the edges of the mulched strips and weeds around the bases of the tree was problematic. For commercial fruit production, an additional spot treatment with herbicides may be required for acceptable weed control.

Mulches are more expensive to establish and maintain than herbicides. As the material breaks down, more must be added to maintain the necessary thickness for optimum weed control. The benefits of compost utilization must compensate for the additional expense. Higher establishment and maintenance costs of certain organic and synthetic mulches were offset by their prolonged efficacy over successive years in apples (Merwin et al., 1995). Economic studies indicated that organic

Table 2. Phytotoxicity of several compounds found in compost.

Phytotoxic compound	Compost type/age	Species affected	Reference
Acetic acid	Wheat straw, 4 weeks	Barley (*Hordeum vulgare L.*)	Lynch, 1978
Acetic acid	MSW, immature	Cabbage	Keeling et al, 1994
		Cauliflower [*Brassica oleracea* (L.) *botrytis*]	
		Cress	
		Lettuce	
		Onion (*Allium cepa* L.)	
		Tomato	
Ammonia	Biosolids	*Brassica campestris* L.	Hirai et al., 1986
Ammonia and copper	Pig spent liter, < 24 weeks	Lettuce	Tam and Tiquia, 1994
		Snap beans	
		Tomato	
Ammonia, ethylene oxide	MSW, <16 wk	*Brassica parachinensis* L.	Wong, 1985
Organic acid	Cow manure, 12 weeks	Tomato	Hadar et al., 1985
Organic acid	MSW, <4 weeks	*Brassica campestris* L.	Hirai et al., 1986
Organic acids and other compounds	Yard trimming waste, <17 weeks	Australian pine (*Casuarina equisetifolia* J.R. & G. Forst.)	Shiralipour et al., 1991
		Bahiagrass (*Paspalum notatum* Flugge.)	
		Brazilian pepper (*Schinus terebinthifolius* Raddi.)	
		Ear tree (*Enterolobium cyclocarpum* Jacq.)	
		Punk tree (*Melaleuca leucadendron L.*)	
		Ragweed (*Ambrosia artemissifolia* L.)	
		Tomato	
		Yellow nutsedge	
Phenolic acids	Pig slurries, <24 weeks	Barley	Maureen et al., 1982
		Wheat	

mulches should only be used for sites or cultivars in which increased crop value justifies the greater costs (Merwin et al., 1995).

CONCLUSIONS

Herbicide use has increased substantially during the past three decades. These chemicals have increased horticultural crop yields and reduced production costs. However, long-term herbicide use can have negative impacts on the environment. The EPA has banned several because of ground water contamination and negative effects on wild habitat and human health.

Weed control methods utilizing waste materials, such as bark, straw, and sawdust, were used in commercial crop production prior to chemical weed control, and organic mulches are often as effective as conventional herbicides. Depending on the weed species and type of compost, a 10- to 15-cm-deep mulch layer is necessary to effectively discourage weed growth in these systems. In general, weed seed germination declines as depth increases, probably due to unfavorable conditions such as high or low temperature, absence of sufficient moisture, O_2, or light, and high CO_2 levels. Preliminary investigations indicate that mulch reduces weed growth because of high concentrations of phytotoxic substances, especially when the compost is immature. The phytotoxins include organic acids (acetic, propionic, and butyric acid in high concentration), ammonia, ethylene oxide, and phenolic acids.

The benefits of composted and noncomposted organic mulch must compensate for their greater expense relative to herbicides. The higher establishment and maintenance costs of organic mulches can be offset by their prolonged efficacy, but a cost analysis should be made before they are recommended as a weed control method. Some economic studies indicate the increase in crop value justifies the greater costs. Integrated pest management programs that incorporate alternative weed control methods, such as mulch, should be considered when possible, since they reduce herbicide use in vegetable and fruit production.

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