Alternatives to pesticides in controlling pests and diseases©

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Abstract

Many California consumers and government agency regulators increasingly demand agricultural products produced with less, or without, use of synthetic chemical pesticides. As a prime example, soil fumigation with synthetic chemical toxicants now is seen as having decreasing compatibility with public safety and environmental quality. Alternatives are being developed and such methods must be shown to be effective, predictable, and economically viable. Active heat-based treatments are attractive options for soil disinfestation and certain elements of the biogeochemical environment, such as accumulation of passive solar energy and knowledge-based utilization of organic materials and byproducts, may be harnessed to provide economic pest management. Recent research and implementation projects on alternatives including biosolarization, biofumigation, and anaerobic soil disinfestation (ASD) will be discussed.

OVERVIEW

The movement in California agriculture away from use of synthetic chemical soil fumigants is well-known and documented. Over the past 30 years, materials including ethylene dibromide (EDB), dibromochloropropane (DBCP), methyl bromide, and others, have been taken from the marketplace by regulatory action (Stapleton et al., 2000). In addition, newly developed fumigant products touted as useful replacement materials, such as methyl iodide, have yet to pass regulatory scrutiny. At the same time, consumer sentiment toward certified organic agricultural products has skyrocketed. Most large supermarket chains in California now feature sections of certified organic products, both fresh and processed. Rightly or wrongly, synthetic pesticides are seen by large segments of society as being undesirable or harmful and having decreasing compatibility with public safety and environmental quality. As anti-soil fumigant sentiments have grown, interest and economic stimulus in developing alternatives to synthetic soil fumigants has increased accordingly. The arena of soilborne pest management (and in this discussion we will consider disease-causing organisms as pests) has expanded to include not only implementation of fumigant alternatives, but the broader and integrated concept of agricultural soil health stewardship. Apart from soilborne pest management, the integrated concept of soil health requires a focus on optimizing fertility and soil biotic community factors (Simmons et al., 2014).

SYNTHETIC CHEMICAL SOIL FUMIGANT ALTERNATIVES

Planning for soil fumigant alternatives

In considering use of fumigant alternatives, asking a few preliminary questions can assist in the planning process. Obviously, knowledge of field and cropping history is very important. A follow-up question relates to the choice of broad-spectrum or narrow-range strategies. Is elimination of a few specific pests (e.g., weeds) the objective, versus a range of problematic weeds, nematodes, and soil fungi? Or, perhaps even control of unknown/unidentified soilborne pest agents is desired, in order to maximize crop yield? Once these questions are answered, all possible soil treatment options can be evaluated.

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Soil fumigant alternative options

For certain pest problems, specific biological and/or cultural approaches may be sufficient. Such approaches are favored by some agriculturists, and may include inoculation of soil, seeds, or plants with various amendments, inoculants, or competitors. If available, use of crop cultivars with genetic resistance may be used. However, if organic certification is desired, genetically engineered propagative material currently will not be allowed. Some soilborne pests can be effectively controlled by cultural adjustments, such as proper water/nutrient management (e.g., *Phytophthora* diseases), modifying planting date to optimize soil temperature (e.g., certain nematodes), tillage modifications, crop rotation, and/or cover cropping.

Example: sweet potato hot beds, Merced Country, California

In terms of replacing soil fumigant usage, perhaps the least radical option, for non-organic producers, is simply using the above-mentioned questions to replace fumigation with a "softer" synthetic pesticide. One example is that of Stoddard et al. (2011) in Merced County, California. They found that production of sweet potato slips in hotbeds, which were traditionally fumigated with methyl bromide, could be safely done with only an herbicide application. The unique production conditions of early-spring slips, sprouting from healthy mother tubers in cool soil, were seen as prohibitive to activity and development of prevalent nematode and fungal pests.

Another non-pesticide approach to soil disinfestation, which also contributes to overall soil health, is the use of cover crops, green manures, teas, composts, biofumigants (e.g., *Brassica* spp.) and other soil amendments (Stapleton et al., 2000). Depending on the agroecological conditions (e.g. physical, chemical, biological) present in the treated area, as well as the attributes of targeted pest organisms, these practices may or may not provide rapid and effective control of soilborne pests.

Physical soil disinfestation

For fumigant-like biocidal activity in soil, the physical methods of disinfestation may be most useful. Active soil heating, such as with steam, can provide drastic reductions of soil biota; however, this approach is both difficult and expensive to conduct and is used only in very small areas. More recently, two physical methods, passive solar heating of soil by solarization (Stapleton et al. 2000; Dahlquist et al., 2007; Marshall et al., 2013) and deliberate causation of anaerobic conditions in soil by anaerobic soil disinfestation (ASD) (Butler et al., 2011), have received considerable attention for fumigant-like activity. Both of these methods also have some limitations.

"Double-tent" solarization — small soil volumes

The State of California (CDFA) allows a specific protocol of solarization of soil, using a "double-tent" tarping setup (Stapleton et al., 2002), to disinfest soil for containerized nursery production (CDFA, 2009). However, this method is mainly useful for small and/or seasonal operations since solarization is dependent upon atmospheric conditions and high air temperatures. According to CDFA regulations, the "double-tent" protocol dictates treatment "until temperature of all soil reaches a minimum of 158°F (70°C) that is maintained for at least 30 continuous min, or a minimum of 140°F (60°C) that is maintained for at least 60 continuous min. Soil must be either in polyethylene planting bags or in piles not more than 12 in. high. Soil in piles must be placed on a layer of polyethylene film, concrete pad, or other material, that will not allow reinfestation of soil and covered by a sheet of clear polyethylene film. An additional layer of clear polyethylene film must be suspended over the first layer to create a still air chamber over the soil to be treated. Soil moisture content must be near field capacity. Soil temperature at the bottom center of the pile or bag must be monitored" (CDFA, 2009).

Biosolarization and anaerobic soil disinfestation (ASD)

Recent developments in deploying various combinations of plastic film-covered soil, organic materials, moisture, and heat have provided some promising directions in the future of soil disinfestation. These integrated soil treatments can provide more effective and predictable pest management options for operations not wishing to use synthetic chemical products. Although research and implementation efforts are well-underway, the precise effects and modes of action of biosolarization and ASD have yet to be fully elucidated (Butler et al., 2011; Simmons et al., 2013, 2014). Both approaches use various tarped applications of organic residues and/or composts to produce naturally-occurring, biocidal conditions in soil. The ASD process emphasizes reductive and fermentative conditions to inactivate pests, while biosolarization efforts are focused on aerobic processes leading to effective soil disinfestation (Simmons et al., 2013). Further clarification of pesticidal activity mechanisms may be expected in the near future.

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