INVESTIGATIONS INTO LIQUID COMPOST EXTRACTS ("TEAS") FOR THE CONTROL OF PLANT PATHOGENIC FUNGI

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Introduction

The potential disease suppressive characteristics of composts is well known and is the subject of increasing scientific efforts, dating from reports as early as 1973 (Hunt et al, 1973). New interest is seen with the use of liquid extracts for disease control. Compost seed-dips and plant and soil sprays based on compost and other plant materials have been reported from organic farming literature since from as early as 1924 (Koepf, 1992).

The presence of highly developed microbial communities in the rhizosphere (root-region) of plants has long been known, but a comparable flora on the leaf surfaces has only been more recently recognized. This area of research was first developed when Last (1955) and Ruinen (1956) coined the term *phyllosphere* for the leaf surface microbial habitat in analogy with rhizosphere. With the organization of the first symposium on this area by Preece and Dickinson (1971), the stage was set for new appreciation of the microbial population of the leaf surface with respect to host- pathogen interactions. Eventually, phyllospheric effects moved into the focal point of research on the biological control of leaf diseases and emphasis on antifungal properties of watery extracts of composts is evident from about 1986 to the present (Weltzien, 1986; Tränkner, 1993). Thus, about a 30-year "incubation" has been involved in getting to where we are presently with a basic understanding of compost teas to combat leaf disease. It is unfortunate that there has been so little scientific interest in this arena until quite recently. The uncertainty about formulating proprietary technologies based on compost is the most frequently cited reason for the slow development (Tränkner, 1993).

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Compost teas as herein intended should not be confused with use of "leachates" collected off compost sites, although the latter may also possess nutrient and potential fungicidal properties. It should also not be equated with compost humic extracts, compost microbial starters, and other similar preparations. Compost teas, also called watery-compost-extracts, refer to a more deliberate production of specific extracts and spraying undiluted based on composts of known properties and age (York and Brinton, 1995). Several different types of natural sprays have been compared with specific compost teas and compost teas do not necessarily always perform well (OFRF, 1994). This paper will discuss some of the potentials and pitfalls involved in this work.

The use of compost extracts differs significantly from the reported use of solid compost used in container-media to suppress damping off and root-fungal diseases (Spring et al.,1980; Hoitink, 1980). Watery compost extracts described in this paper are applied directly to plant surfaces via conventional high-pressure spraying apparatus. The extracts act directly in varying degrees to suppress both the germination and growth of plant pathogenic organisms and are efficacious for short periods of time (Ketterer, 1990; Tränkner, 1993).

The Needs and Obstacles to Implementing Compost Teas in Agriculture

A number of serious agricultural problems areas exist presently which are of immediate possible candidates for applications of compost extracts. These are chiefly where fungal diseases start and spread from leaf and stem surfaces. Examples are apple scab (*Venturia inaequalis*), downy and powdery mildew on grapes (*Plasmopara viticola, Uncinula necator*) and *Botrytis* infections of vegetables and small fruits. Crop damage by these fungal pests in the US alone is in the $-billions/year.

Of special concern is the worsening situation in potato culture with Late Blight causative *Phytopthphora infestans* showing new genotypes with increasing resistance to conventional fungicidal treatments (Dowley, 1981). While chemical spraying programs can still result in satisfactory control, it has become a substantially more complicated and costly undertaking. Successful research and implementation this area using biocontrols is likely to have extremely important agronomic and economic impacts. Despite this apparent fact, many agricultural officials remain unconvinced that compost based disease suppression is likely to prove economical in the near future and there is continued concern that spraying live cultures of "manure"-based extracts, which are likely to contain opportunistic pathogens, may be hygienically problematic (USDA, pers. comm.).

Mode of Effects of Compost Extracts

Compost teas exert influence in the so called phyllosphere (plant surface) through a coating with actual live bacteria (NOTE: see photo showing scanning electron microscopic view of leaf surface sprayed with compost tea). The principal agents in the composts extracts appear to be bacteria representing but not necessarily limited to the genera of *Bacillus, Pseudomonas, Serratia, Penicillium*, and *Trichoderma* (see photo). In examining normal composts, we have found that the majority of bacteria in moderately-mature materials are facultative anaerobes or aerobes. Species such as *Enterobacteria, Serratia, Nitrobacter, Pseudomonads, Bacillus, Staphylococcus* and various *Actinomycetes* are all present (Droffner et al. 1995). Thus, it seems likely that many composts possess potential disease suppressive traits.

There is no single mechanism explaining effects of compost extracts against pathogens. To date, the effects of compost extracts have been divided into several categories (Ketterer, 1990; Beicht, 1981;Budde & Weltzien, 1990):

- Inhibition of spore germination
- Antagonism and competition with pathogens:
- Induced resistance against pathogens:

The primary source of the effects observed with compost teas is apparently of a live, microbiological nature (see bioassay photos). Sterilized or micron filtered compost extracts usually exhibit significantly reduced activity against pathogens (Weltzien, 1986). This does not rule out that in some cases sterile extracts will possess suppressive effects. There is some evidence that chemicals called siderophores, pseudobactins and pseudomycins produced by *Pseudomonas* exert a powerful chemical suppressive effect of other organisms (Kloepper, 1980; Potera, 1994). Antibiotics have been observed to be formed by *B. subtilis* and inhibit the germination and/or growth of many fungi. Also, an emerging field of study is the area of induced or acquired resistance. Ample evidence is being seen that microbes whether pathogenic or not can cause the induction of plant internal defenses. For example, by inoculating cucumber leaves with the bacteria *Colletotrichum lagenarium*, the infected leaves not only became resistant toward *C. lagenarium*, but also toward all other pathogens of bacterial and viral nature. In fact, the concept of induced systemic resistance was coined for this phenomenon (Kuc et al., 1975). An overview of the use of microbial metabolites to induce resistance has recently been presented (Schönbeck and Dehne, 1986). It may or not be ironic that difficulties and hygienic concerns about using live extract compost sprays are avoided by using metabolites from compost cultures for stimulating plant resistance. However, this work is still in its infancy.

Based on existing information, it is clear that successful use of compost extracts for disease control needs to be evaluated in relation to specific cultivars and specific fungal pathogens. In many reported cases pathogens have been controlled by compost teas to levels similar if not better than conventional fungicidal treatment (Ketterer, 1990; Tränkner, 1993)— (see Table 5). However, the findings also suggest that different modes of preparation of the watery compost extracts may be required to satisfactorily treat different diseases under varying field circumstances. It is conceivable that in the not-too-distant future on-farm laboratories will extract and prepare enrichment extracts and sterile metabolites from on-farm wastes and use them in pest bio-control programs. New development efforts by our group and others to work out field bioassay techniques such as in suppression of growth of Botrytis by compost extracts (see bioassay photo) may permit growers to screen for fungicidal activity prior to costly implementation; however, this work is far from complete.

"Four Step Approach" to Making Compost Extracts For Fungicide Sprays

There are four stages in the process of preparing compost teas: preparation, extraction, filtration and induction. Each stage has a few specific conditions. (See photo of spray tank and orchard spraying at Golden Hooves Farm, CA)

1. PREPARATION STAGE: Fresh compost is blended with tap water in a dilution ratio of 1 part: 5-10 parts (vol/vol). The ideal ratio must be experimentally derived. Wooden barrels or large tanks are preferred. To be avoided are pesticide/bio-cide tanks even if previously washed.
2. EXTRACTION: Allow to stand at 15-25^{o} C, over 3-8 days, stirring 2-3 times during this period. A highly aerobic mix is *NOT* required. Stirring is performed either with a rod or rotating bar, or any kind of pumping-agitation, for about 30 minutes at each event, during the life of the extract.
3. FILTRATION: The best approach is to decant from partway up fron the bottom of the tank and pass through a 200 mesh (75-micron) sieve. Determine in advance the operational spray rig nozzle sizing so that clogging does not occur. To avoid serious filtration problems, do not stir mixture within 8 hours of filtering.
4. INDUCTION: Apply the extract periodically at or prior to the times of fungal infection pressure using conventional plant protection spraying equipment. It is highly advisable to add a wetter/sticker agent, but it must be pre-screened for antimicrobial properties using a standard micobial challenge procedure.

Assuming all the proper steps are taken, the most significant factors influencing the effectiveness of watery compost extracts are considered to be the age of the compost itself and the nature of the source ingredients which go into it. It should be noted that some wetter-sticker (surfactant) agents commonly used with fungicides have been found to be microbially suppressive, spoiling the effects intended for of the compost teas. Woods End's Lab in Mt Vernon Maine and other microbial labs like BBC Laboratories in Tempe, Arizona offer a screening service to pre-test these agents.

Farm and Commercial Composts to Combat Fungal Disease

Both farm and commercial agricultural composts possess qualities that may lend themselves to disease suppression. Given the ability of many farmers to produce their own, and the likelihood that some of these composts may already possess fungicidal properties, then more widespread use for biological control is within sight. However, farms deprived of livestock may be the most in need of microbiologically rich composts. Biodiversity studies tabulating biocontrol potentials on varying farms are only recently getting underway.

This much being said, it is obvious that while the theory of compost tea disease control is easy to grasp, it is operationally more difficult. The heterogeneity of compost source materials and the lack of stability or relative immaturity of many commercial composts is likely to limit the usefulness of this approach (Tränkner, 1993). If compost leachate is substituted for prepared compost teas, there is no guarantee that it will possess the same properties as a prior batch. Even given a good compost, the improper handling or poor timing of applications could frustrate growers efforts to achieve success in the field. Thus, the need exists to define the qualities that make for high value composts and to determine the means of preparation and application needed to achieve consistent field effects. In Europe, emphasis is on the use of the Dewar Flask method (see Biocycle, Nov 1995) to determine relative age of the compost (compost not older than category IV is used). In one study, we determined the efficacy of differently aged horse manure compost against Fusarium wilt of clover seedlings (see Table 1) and found 8-week old product was significantly superior to 20 week product.

Table 1: Effects of extracts made from variously aged horse manure compost on infection rate of clover seedlings with Fusarium culmorum

Age of compost	Infection index [a]
8 weeks	0.53 a
12 weeks	0.61 a
20 weeks	0.78 b

a. treatments followed by the same letter are not significantly different at $P \leq 0.05$

Compost of varying organic materials such as leaves, yard debris and straw, can show varying disease suppressiveness, with a loss of the ability after as little as 3 months of aging. Composts containing manures (horse and dairy) have shown significant antifungal properties in some cases up to 9-12 months of age (Dittmer, 1990).

In another study we compare the efficacy of various extracts prepared from differing substrates (Table 2). Recently, some biosolids compost extracts have been found to possess some fungistatic potentials against the fungus *B. cinere*a that affects bedding plants (Warner, 1995).

Preservation of compost tea effects is problematic, since they must be used within one-week or less of the extraction. However, in one set of studies, the antipathogenic effectiveness was lengthened through drying the compost prior to storage and the natural fungicidal properties were elicited later after remoistening (Dittmer, 1991; Tränkner, *1995, personal communication*). The disease suppression characteristics of compost teas has so far not been considered to have a relationship to pH or other chemical traits, and is definitively associated with facultative anaerobes more than strict aerobes and can be dependent on the nature of the compost substrate (see Table 2).

Table 2: Influence of various natural substrates on the infection of Tomatoes exposed to *Fusarium oxysporum*†

Substrate for Extract	Infection index 0.5 g inoculum
Control Soil, Ap-Horizon	0.91 d*
Bark humus	0.64 a
Commercial Yardwaste Compost	0.78 c
Prepared Soil:clay:peat+fertilizer	0.72 b
Horse Manure compost	0.60 a

* treatments followed by the same letter are not significantly different at $P \leq 0.05$ by Duncan's test
† after Tränkner, 1993.

Solid Compost vs. Liquid Extracts

In addition to compost teas, there is considerable basis for soil applications of macro amounts of finished compost. Compost is well known for imparting suppressiveness directly to the soil (Kloepper, 1980). In addition, trials have shown significant differences in antiphytopathogenic effects between composts, green manures and livestock manures. In one study, soils receiving composts over three years showed increasing antipathogenic traits against *S. trifoliorum*, with some instances of 100% control. Soils receiving fresh green waste and non-composted livestock manures over the same period in contrast gave no pathogen reduction (Dittmer, 1991). In other words, use of solid compost applied directly to soils or container media should not be curtailed even when compost teas are available.

The difference between the use of soil-applied composts and watery compost extracts can perhaps best be summarized in that the teas give immediate but very short-term control of surface spreading pathogens, while soil composts act more slowly over a longer period of time and require much larger amounts. For long term effects in solid media, it is not unusual that at very least 5% by volume and often as much as 40% compost in the seedling mix are required to bring about effective disease control (Budde & Weltzien, 1990). In contrast, a whole hectare of vineyard can be covered with extract prepared from only less than 100 kilos of compost (York & Brinton, 1995).

Seed Dips or Seed-Baths with Compost Teas

Seeds dips with manure composts have long been advocated by biodynamic farmers in Europe. Current research shows the suppressive effects of the teas as dip are apparent with control of *Pythium* on alfalfa (Table 3). It is clear that increased use by farmers of seed-baths should and could be made as a substitute for conventional seed coatings with questionable fungicides such as Captan.

Table 3: Effect of various seed treatments on incidence of Pythium on alfalfa seedlings after 6 days germination

Seed treatment	Proportion (%) of Pythium-infected alfalfa seedlings in compost seeding substrate		
	Steamed	Untreated	Infected soil cover
Untreated	6 a*	17 a	43 a
Soaked in Water for 1 hour	4 ab	23 b	36 b
Soaked in Compost extract,1 hour	1 c	6 c	15 c

A significant increase of compost usage in California vineyards has been noted (Fetzer, 1995). As an overview, we have surveyed research trials conducted in Europe employing various manure compost extracts in cases involving common fungal pests of grapes (Table 4). The data indicate satisfactory to excellent control in many cases.

Table 4: Preparation, use and results of compost extracts for reducing grape fungi (Tränkner, 1992)

	Grape Disease Causative Agent			
	Plasmopara viticola	*Botrytis cinerea*	*Pseudopeziza tracheiphila*	*Uncinula necator*
Compost Tea Type:	Horse	Dairy	Horse	Horse
Extract Ratio	1: 9	1: 4	1: 10	1: 3
Extract Time	3 days	7 d	7-14 d	3 d
Spraying Interval	8 - 14 d	7 - 10 d	12 d	10 d
Disease Reduction	90 %	48 %	55 %	94 %

In virtually all the viticulture cases, the significant reduction of the pest in question has been observed in conjunction with a yield increase. The results for each individual trial have been previously reported (Tränkner, 1992).

Compost Extracts Compared to Standard Fungicides

How does compost tea perform compared to common fungicides? We examined research which concerned itself with Horse manure compost tea effects over two years versus sulfur and conventional fungicide on grapes (Table 5 — see also Photo).

Table 5: Spray effects on downy mildew (*Plasmopara viticola*) incidence on whole grapes in the Ahr-Valley (Ketterer, 1990).

TREATMENT	Berry Infection Index (%)	
	light infection season	Heavy infection season
CONTROL	10.5 b*	83.5 a
Wettable Sulfur	16.5 a	—
Sulfur + Compost Extract	3.0 c	—
Compost Extract †	3.5 c	20.0 c
Standard Fungicide	2.0 c	7.5 c

* Treatments followed by the same letter are not significantly different at $P \leq 0.05$ by Duncan's test
† 800-1,500 liters/ha sprayed each time for 12 intervals over the season

In both a light and heavy infection year, composts performed very well and resulted in significant reduction over controls, and did not differ significantly from standard fungicides.

These and other results underscore the significant effects that properly prepared compost teas can achieve when used in substitution for, or in conjunction with, standard fungicide control programs. Increased research and trials in the field is likely to promote this "value-added" composting on an even broader scale in agriculture.

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