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The Production of Marketable Vegetable Transplants Using Sustainable Locally Sourced Soilless Media Amendments

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THE PRODUCTION OF MARKETABLE VEGETABLE TRANSPLANTS USING SUSTAINABLE
LOCALLY SOURCED SOILLESS MEDIA AMENDMENTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfilment of the
requirements for the degree of
Master of Science

in

School of Plant, Environmental and Soil Sciences

By
Amber Dawn Parker
B.A., University of California, 2002
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Terra, thank you for teaching me to see the
resource that waste provides.
Practice.

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ABSTRACT

Public demand for sustainable local and organic food products has led these systems to become one of the fastest growing sectors in the agricultural food market. Consumers are willing to pay a premium for food produced using organic or sustainable practices. Local and small-scale farmers are striving to develop sustainable and in some cases USDA certified organic systems in production of vegetables and fruit. Warm season crops are commonly produced using transplants. Evaluation of nutrient availability is needed for the use of readily available local waste-streams byproducts, such as manures and composts, for amendments or fertilizers in order to manage plant fertility in vegetable transplant production.

The objectives of this research were to identify optimum transplant media mixes using locally sourced amendments and evaluate optimal rates and application method for OMRI approved post-applied fish hydrolysate fertilizer in organic basil transplant production. In the first experiment fish hydrolysate (FH) 2:4:1 (N:P:K) was applied as a fertilizer source as a drench or foliar application based on nitrogen application rates of 0, 20, 40, and 80 kg N ha⁻¹ wk⁻¹. The second experiment evaluated vermicompost (VC) at 10, 20, and 40% and composted broiler litter (CB) at 5, 10, and 20% as amendments to a commercial germinating mix treated with or without weekly applications of FH 80 kg N ha⁻¹ as a drench.

Application rate and placement of FH affected basil transplant growth in a 38 day period. In general, FH at ≥ 40 kg N ha⁻¹ wk⁻¹ applied as a drench during basil transplant production resulted in taller plants, thicker stem diameters, and the greater biomasses compared to FH applied directly to leaves 28 days after initial treatment (DAIT). Vermicompost rates had a negligible effect on basil height, stem diameter, and total biomass compared to the control. However, weekly drench applications of FH based on nitrogen rate of 80 kg N ha⁻¹ provided acceptable nutrition for basil growth in VC substrate combinations of 0, 10, 20 and 40% within a 38-day period. Composted broiler

litter was not an effective transplant media substrate. Basil grown in the CB treatment at rates of 5 and 10 % were not different than the control and deleterious effects were observed at 20%.

CHAPTER 1 LITERATURE REVIEW

Organic Agriculture

Organic farming is the fastest growing sector in U.S. agriculture (Dimitri and Greene, 2002; Dimitri and Oberholtzer, 2005; Greene, 2013) and has nearly doubled since the end of the 1990's after the development of the in 1990 Organic Foods Production Act (OFPA) that mandates standards for U.S. organic products (Dimitri and Green, 2002; Greene et al., 2009). Sales of certified organic fruits and vegetables have quintupled from \$3.6 billion in 1997 to \$28 billion in 2012 (Bagi, 2013; Greene, 2013). Acreage of certified organic farmland more than doubled between 1992 and 1997 (Dimitri and Green, 2002; Dimitri and Oberholtzer, 2005; Greene et al., 2009) and organic vegetable and fruit acreage continues to increase 6% and 4%, respectively (Greene, 2013; Oberholzer et al., 2005).

Fresh produce (vegetables, fruits and herbs) is the leading sector in organic product sales, which accounted for 43% of organic food sales in 2012 (Greene, 2013). United States Department of Agriculture (USDA) surveys reported that consumers are willing to pay a premium for organic products (Greene et al., 2009; Oberholzer et al, 2005) and prices have been reported as higher than comparable conventional items (Greene, 2013). In addition, organic food sales increased 15-21% each year, compared to only 2-4% for total food (Dorais, 2007), which indicates continued and increasing demand for growth in this agriculture sector.

It has been reported that the key drivers in the demand of organic food products are consumer perceptions that organically produced food provides safer health standards for farmers and reduces agricultural residues in food and drinking water compared to commercial conventional agricultural practices (Cambell et al. 2014; Chassy et al, 2014; Dimitri and Green, 2002). In addition, consumers are concerned with environmental impacts associated with conventional agriculture (Chassy et al, 2014; Padgitt et al., 2002). Organic production practices are perceived to be a viable alternative.

The Environmental Protection Agency and World Health Organization (WHO) reported that nitrites from agricultural run-off are the primary pollutant of rivers and lakes and rank fifth in degradation of estuaries (Padgitt et al. 2002). The 1996 National Water Quality Inventory reported agricultural pollutants, including nitrites and pesticides, ranked first as causal agents for degrading estuaries and the WHO reported these pollutants contribute to fish kill (World Health Organization, 2011). Moreover, nitrites were reported as the most frequently detected chemical in drinking water sourced from ground water (Padgitt et al. 2002). In response, the US government has increasingly promoted organic production practices through the use of incentives such as the Organic Cost Share program. This program was funded at \$11.5 million annually and was included in the U.S. Farm Bill, the Agricultural Act of 2014, H. R. 2642 (US Congress, 2014).

Sustainable, Local and Small Scale Agriculture

According to the USDA Sustainable Agriculture Research and Education program, the primary goals of sustainable agriculture farm practices are as follows: 1) to provide a more profitable farm income, promote environmental stewardship, by protect and improve soil quality, reduce dependence on non-renewable resources (i.e. fuel, synthetic fertilizers and pesticides), 2) and minimize adverse impacts on wildlife, water quality and other environmental resources, and 3) promote stable, safe and prosperous farm families and communities (Ziemenski, 2010). Sustainable agriculture embodies the above listed aims and aligns with those of USDA certified organic agriculture, which have been referred to as alternative farming systems, (Anonymous, 2015). Organic agriculture production as defined by the USDA National Organic Program, however, is a certification process with specific production protocols, including allowable substances, reporting and third-party certification. Both sustainable agriculture and certified organic agriculture tend to be practiced primarily on small to medium-scale family vegetable farms (Ziemenski, 2010). This is especially important as small family farms and ranches (sales <\$250,000) accounted for 90 % of all the farms in the U.S. and own about 68

percent of all farm assets and 60 percent of total farm and rangeland, while producing 25 percent of our food and fiber products in 2004 (Hoppe and Banker, 2007). Successful small scale vegetable operators market on-farm and at farmers' markets in many of the cities as well as through direct and indirect wholesale outlets (Johnson et al., 2012).

Farmers markets are an important sales outlet for small-scale agricultural producers (USDA, 2011b) including those that use organic and/or sustainable production practices. Nationally the estimated number of farmers markets has increased over 400 percent from 1994 to 2014 with over 8,268 farmers markets currently operating in the U.S. (USDA, 2014). In addition, Louisiana has approximately 80 farmers markets (USDA, 2015) with an increasing demand for organic and sustainably produced local products and often a price premium for local. In order to meet the increasing demand for sustainably and/or organically produced local food, farmers need to be particularly aware of inputs that can be sourced locally and the sustainable production practices that they employ. With the requirements of Food Safety Modernization Act (FSMA) that will soon be implemented, farmers need an objective evaluation of local sustainable resources that can be used in production as well as readily available organic products for use in fertility management in vegetable production.

Vegetable Transplant Production

Quality and vegetable crop yield often depends on having an adequate stand and resulting plant spacing. Proper spacing in the field is important as this relates to optimizing yield and plant productivity while minimizing required inputs such as fertilizers and pest management. In general, annual vegetable crops are seeded directly in the field or planted through the use of transplants. The latter is often practiced for various reasons as transplants often minimize risk, reduce the length of the growing season, optimize use of land and renewable resources, and increase the success of plant establishment.

The use of transplants is an important aspect of establishment for vegetable production in the United States (Russo, 2005, Styler and Koranski, 1997). Growing transplants instead of direct seeding is a regular practice for small seeded crops for consistent field establishment and season extension (Wien, 1997). Transplants are commonly produced using soilless substrates which should provide sufficient aeration, plant support and root development (Styler and Koranski, 1997). Conventional vegetable transplants use sterile soilless media substrate mixes that are commonly composed of one or more ingredients including: coconut core, peat, pine bark, perlite, vermiculite, wetting agents and synthetic fertilizers (Greer, 2005; Guertal et al., 1997; Styler and Koranski, 1997).

Media quality is determined by physical and chemical properties (Fonteno et al., 1995; Kuepper and Everett, 2004; Russo, 2005). The physical properties of soilless media include water holding capacity (WHC), air porosity (AP) and cation exchange capacity (CEC) and bulk density. The chemical properties include pH, soluble salts (EC) and the various nutrients (Styler and Koranski, 1997). The initial recommended ranges of chemicals in most soilless media are a pH of 5.8 – 6.2, EC 0.4 to 1.0 mmhos, NO₃ 40 to 60 ppm, NO₄ < 10ppm, Phosphorus 5-8ppm, and Potassium 50-100 ppm (Styler and Koranski, 1997). Well-developed roots and shoots in transplants is crucial in order to support crop establishment and development in the field (Gravel et al. 2012). Transplant media is generally low in nutrient availability; therefore supplemental granular or liquid fertilizers are necessary for successful transplant production (Wien, 1997). Manipulation of nitrogen levels aids in the control of growth in greenhouse production of transplants (Liptay and Nichols, 1993). Producers seeking to produce transplants without the use of synthetic fertilizers must use organic sources to provide nitrogen in the required amounts and timing during production.

Local Waste Steam By-products as Transplant Substrate Amendments

As of October 21, 2002 under the USDA's National Organic Program (NOP) all products sold in the United States as certified organic must comply with the NOP and the Organic Food Production

Act of 1990 (the Act) which was enacted to regulate standards for organic products (USDA, 2002).

Organic certification requires growers to use organically grown seed, materials, and prescribed practices (USDA, 2002). The materials approved for organic production are listed on the National List of Approved Substances (Kuepper and Everett, 2004; USDA, 2002). The products that are allowed are reviewed by the Organic Materials Review Institute (OMRI) and/or the Washington State Department of Agriculture (WSDA) Organic Food Program (Coleman, 2012). These organizations determine if products are allowable by investigating the inert and active ingredients and comparing them to NOP standards.

Availability and transportation cost of organic fertilizers and pesticides are barriers to organic certification for many growers (Hammac II et. al, 2007; Russo and Taylor, 2010). Increasing demand for organically and/or sustainably produced products encourages local small-scale farmers to use these farming systems and also to use local waste-stream by-products such as manures and composts as fertilizers during plant production (Gagnon and Berrouard, 1994; Greene, 2001; Hartz, 2002; Ogles et. al, 2015; Russo and Taylor, 2010). Production of vegetable transplants is a specialized industry unto itself (Kubota and Kroggel, 2006) and organically produced seedlings are seldom commercially available, so farmers who wish to comply with organic standards are forced to produce their own transplants (Larrea, 2005). Transplant seedling sales can be an extra source of revenue for some small/medium scale growers (Hulshart and Elliot, 2012) and this appears to be a good opportunity for a few growers in order to meet local demand for organic transplants.

Numerous studies examining the use of animal and plant based waste stream by-products in the production of organic transplants reported variable results. Manures, composts, plant and animal meals, and other by-products have been evaluated for use in fertility management of sustainable vegetable transplant production (Gagnon and Berrouard, 1994; Raviv et al., 2005; Russo, 2005; Russo and Taylor, 2006; Russo and Taylor, 2010; Treadwell et al., 2011; Zhai et al., 2009; Gravel et al.,

2012). The results of the studies demonstrated the differences in transplants production practices and also inconsistency and variability in the media (Gravel et al., 2012; Treadwell et al., 2011). Several of these materials, such manures and composts, can be sourced locally but need investigation as to their properties and in particular their nutritional value for use in vegetable transplant production. Other products such as fish based fertilizers may require transport from long distances and therefore can be quite expensive even though they offer advantages over more locally sourced materials.

Fish-based Fertilizer

Currently there are two major types of liquid fish-based fertilizers which are available for use as fertilizer application after planting: fish emulsion (FE) and fish hydrolysate (FH), also called fish silage (USDA, 2006). These are readily available OMRI approved commercially products in the marketplace from various sources. After fish waste by-products are commercially processed they are important materials in agriculture. They may be sustainable resources in vegetable production as fertilizer, soil amendments, or plant growth substrates (Henderson and Strombom, 1995; Illera-Vives, 2012).

Each of these commercial products is derived from marine fishing industry waste, but they differ in the processing to make them fertilizer. Fish emulsion is produced under heat with either an acid or alkaline solution to accelerate decomposition and separate oils from the emulsion (Kristinsson and Rasco, 2000). In contrast, fish hydrolysate involves fish waste undergoing hydrolysis using naturally occurring enzymes to decompose fish proteins. This process is often referred to as a cold-press, because it is conducted at ambient temperatures compared to the more energy intensive FE production (USDA, 2006). Once processed, the fish-based products can be used as fertilizers, soil amendments, or plant growth substrates (Aung and Flick, 1980; Arvanitoyannis and Kassaveti, 2008; Henderson and Strombom, 1995; Illera-Vives et. al, 2012). In general, fish byproducts processed as fertilizers, depending on the source and location within the United States, have nitrogen and

phosphorus concentrations between 2 to 10% and 2 to 6%, respectively (Card et. al, 2014). These properties make them suitable for examination for use in transplant production as well as field-scale vegetable production.

Previous research has demonstrated that fish-based fertilizers can be suitable alternatives to synthetic fertilizers for fruit and vegetable production of various crops (Blatt, 1991; DeMoranville, 1990; Ogles et al., 2015; Smagula and Dunham 1995). Blatt (1991) reported that fish fertilizer silage applied at 100 kg N ha^{-1} produced marketable yields of broccoli, cabbage and sweet corn. DeMoranville (1990) reported that FH not only could be used in cranberry production, but was less likely to leach compared to commercially available soluble fertilizers. Smagula and Dunham (1995) showed that FH applied at an N rate of $67.2 \text{ kg N ha}^{-1}$ resulted in a higher stem rate and yield in high bush blueberries. More recently, Ogles et al. (2015) demonstrated that yellow squash and collards grown at the recommended N rate of 152 kg N ha^{-1} and 110 kg N ha^{-1} , respectively, using FH were comparable to conventionally grown product in local markets even though yields were lower. Ogles et al. (2015) indicated that premium prices for the sustainably grown products were sufficient to offset reduced yields in the local markets.

Studies have previously been conducted to evaluate FH in comparison to other commercially available organic fertilizers in field studies on the impact of fertilizer application location on soil leaching. Eaton et al. (2013) evaluated four organic liquid fertilizers and one conventional standard liquid fertilizer 20-2-20 in container production of marigold and calibrachoa. Organic liquid fertilizer treatments included: an organic-chemical based, FH, oilseed extract (OE) and a rotation of FH and OE weekly, with a total of 8 g N pot^{-1} . They reported that FH produced the best results of the organic fertilizers tested for both plant species. However, FH had the highest level of N leaching primarily in the form of ammonium as Nitrogen ($\text{NH}_4\text{-N}$), nearly six times that of chemical fertilizer. Fish hydrolysate combined with oilseed or alfalfa reduced leaching by approximately 60% and 80%

respectively. Eaton et al., concluded that for organic fertilizers to perform best and more sustainably they should be combined together as they behave synergistically. Schupp et al. (1993) reported that fish hydrolysate used as a foliar application at a 2.76 g L⁻¹ nitrogen rate on dwarf ‘Delicious’ and ‘Golden Delicious’ apples trees reduced fruit set and increased fruit russeting. In addition, Bhat et al. (2013) reported the use of FH as an organic fertilizer in greenhouse tomato produced acceptable yields and soil-drenching applications were found to be better than foliar applications in increasing vegetative growth and yield in greenhouse tomato production.

In addition to fish-based products used as fertilizers, several studies have reported reduced disease incidence and improve seed vigor through the use of these products (Abbasi et. al., 2003; Abbasi, et. al. 2004; Horii et. al., 2007). Abbasi et al. (2003) found reduced disease severity on peppers when FE was applied as a 0.5% foliar application weekly to peppers and tomatoes. Other research demonstrated suppression of *Rhizoctonia* and *Pythium* damping-off as well as improved plant growth of radish and cucumber seedlings when FE was added to peat-based soil media mix (Abbasi et al., 2004). Furthermore, Horii et al. (2007) recorded improved seed vigor in soybean and tomato when fish fertilizer was used at 2.5mL L⁻¹ application during seed priming.

Vermicompost

Vermicompost (VC), often referred to as worm castings, is an organic material processed by various species of earthworms, principally *Eisenia fetida* and *E. Andrei* (Atiyeh et al, 2000; Edwards and Burrows, 1988; Paul and Metzger, 2005). In the conventional compost process, a thermophilic biooxidation process, relies on microorganisms break down and stabilize complex organic material into mineral forms releasing heat, CO₂ and water. In contrast, vermicompost is a biological process through which stabilization of organic material is achieved as wastes pass through the gut of an earthworm (Ayiteh et al., 2000). As worms process organic material, microbial activity is stimulated increasing mineralization and waste transforms into humus-like material (Atiyeh et. al, 2000; Paul and

Metzger, 2005). Various organic materials are used as parent material for vermicomposting. Suitable materials for vermicomposting include manure, kitchen waste, paper mill waste, sewage sludge, coffee pulp and yard waste (Atiyeh et al 2002; Orozco et al, 1996; Paul and Metzger, 2005). Compared to conventional compost, VC has been reported to have significantly higher plant available nutrients (PAN) with larger more diverse microbial populations (Atiyeh et al., 2000; Edwards and Burrows, 1998; Tognetti et al., 2007).

The end product, vermicompost, is a finely divided peat-like material that balances porosity, aeration, drainage, water holding capacity. Because of these properties, VC has potential as a substrate for soilless media (Atiyeh et al., 2000; Atiyeh et al. 2002; Edwards and Burrows, 1988; Matta et al., 2008; Zaller, 2007). One of the potential concerns with vermicompost is that nutrient content varies depending on the parent material (Atiyeh et al. 2000; Paul and Metzger, 2005). Vermicompost is composed of primarily C, H and O, and contains nutrients such as NO_3 , PO_4 , Ca, K, Mg, S and micronutrients which show comparable effects on plant growth and yield as conventional soluble fertilizers (Orozco et al., 1996; Singh et al., 2008). Vermicompost has previously shown to have beneficial effects on plant growth, beyond nutrient availability. These benefits have attributed to the effect of plant-growth regulators (Arancon et al., 2004) and humic-acids (Ayiteh et. al, 2002). Humic acids in VC were shown by Ayiteh et al. (2002) to improve nutrient uptake in plants, resulting in hormone-like responses.

Previous research indicated that VC is a suitable substrate in soilless media for vegetable transplants. Atiyeh et al. (2000) showed increased germination, growth, and flowering of tomato seedlings using VC as a substitution for peat moss in soilless media with the greatest growth at 10% - 20% VC and soilless substrate (Metro-mix 360) by volume. Arancon et al., (2004) concluded the addition of VC improved physical structure of the media and provided humic acids and/or plant growth regulators and enhanced beneficial microorganisms. They reported that the largest increase (45%) in

fruit yield was from peppers grown in pots with 40% VC and 60% soilless substrate (Metro-mix 360) with a 17% higher number of fruits. Paul and Metzger (2005) reported VC at 10% and 20% rates in soilless substrate resulted in greater height, stem diameter, leaf area, chlorophyll content and total dry weight of peppers. Additionally, eggplant and pepper transplant quality were to some extent improved. Growth increases up to 40% were recorded in dry shoot tissue and leaf area of tomato and green pepper (Bachman and Metzger, 2008). Zaller (2007) reported vermicompost was a suitable substitute to peat in potting media. However, they concluded the effect of VC was dependent on its origin with results differing between tomato varieties. It is apparent that more research is needed to examine the usefulness of vermicompost in soilless media for the production of vegetable transplants.

Poultry Litter

The United States is one of the leading producers of poultry with annual production at approximately 20,000 metric tons (USDA, 2011a). Specifically, broiler chicken production has increased in the Southeast which has become a major production area (Hammac II et. al, 2007). With the increase in broiler production, there is a need to manage poultry waste (Lasekan et. al. 2013; Sharply et. al., 2013; Wood et. al, 1996). Broiler litter has been shown to be an alternative to commercial fertilizer (Hammac et. al 2007; Lasekan et. al. 2013; Sharply et. al., 2013) and is a readily available product in the South that is frequently used by sustainable producers as a soil conditioner and amendment to soilless media to some extent (Sharply et. al. 2013; Wood et. al, 1997).

Pelletized broiler litter has been found to be a good source of nitrogen and phosphorus and an economical alternative to synthetic fertilizer (Hammac II et. al, 2007). However, annual field use of poultry litter can increase soil phosphorus over time to high concentrations, which can be harmful to plant development, and have potentially negative environmental impacts (Szogi and Vanotti, 2009; Sharply et al., 2013). For this reason alternative uses for this by-product is needed.

Research indicates composted poultry litter may be a promising substrate for greenhouse production (Bi et al., 2010; Flynn et al., 1996; Guertal et al., 1997). Guertal et al. (1997) examined composted poultry litter as a 50:50 mix with a soilless mix (Fafard, Buffalo, NY). ‘Rutgers’ tomato showed significantly higher marketable yield, while both ‘Bonnie’ and ‘Big Boy’ yields were unaffected with higher unmarketable yields. Overall, it was concluded that composted PL was a suitable substrate if uniformly prepared. Flynn et al. (1996) reported that broiler litter composted with peanut hulls mixed with soilless mix (Promix) at a ratio of 3 parts compost:1 part Promix produced the highest lettuce fresh weight yields. They concluded that composted broiler litter used as a potting substrate or component would be a suitable alternative to field applications. However, the pH of substrate mixes needed to be adjusted to suit the desired crop requirements because the pH of this material was below lettuce tolerance level for mixes with 50% compost or higher.

Sweet Basil

The genus *Ocimum spp.*, in the Lamiaceae family collectively known as basil, has more than 50 known species and varieties (Simon, 2007). It is believed to have originated from the Indo-Malayan region (Paton, 1996), while other reports suggest *Ocimum* occurs naturally in sub-tropical and tropical regions of Asia, Africa and the Americas. In the sixteenth century basil was introduced to Europe from India through trade with the Middle East. Over the next century, Europeans brought basil to the New World (Stobart, 1982).

World-wide, basil is cultivated for its pharmaceutical/medicinal properties, as a culinary spice in both fresh and dried forms, also processed for essential oils, and planted as an ornamental crop (Morales and Simon, 1996; Shahzad et. al 2012). Historically basil extracts were used in traditional medicine because it contains compounds that have insecticidal, nematocidal, and fungistatic properties (Albuquerque, 1996; Simon, 1999). The phenylpropene compounds in the essential oils derived from

basil govern the flavor and are reported to act as pollinator attractants, as well as pest or herbivore deterrents (Gang et al., 2002).

This herb is polymorphic having several botanical varieties, cultivar names, and chemotypes within each species that are morphology similar (Simon et al., 1999). Also basil readily hybridizes among species which further complicates taxonomic classification. Sweet basil, *Ocimum basilicum*, is an herbaceous aromatic plant typically cultivated as an annual herb and is the most commercially significant of the genus (Vieira et al., 2003). This popular cultivar is harvested for its young tender leaves, and sold as fresh or dried. It is among the most commercially important annual culinary herbs grown in the United States (Begum, et al. 2002; Makri and Kintzios, 2007). *Ocimum b.* ‘Genovese’ is an Italian strain traditionally cultivated for culinary use (Makri and Kintzios, 2007). This basil variety has dark green simple opposite leaves 5 to 10 cm in length with white flowers arranged in a terminal spike (Makri and Kintzios, 2007; Morales and Simon, 1996). *Ocimum b.* grows as a bush 30–130 cm tall depending upon the cultivar. The combination of linalool, methylchavicol, 1,8-cineole are responsible for this basis species’ pungent aroma (Simon et al., 1999).

Basil is commonly propagated through seeds in the early spring as day length increases (Simon, 2007), although it is also easily propagated through cuttings. Basil is susceptible to cold injury and is grown best at temperatures between 17 to 27° C and prefers well-drained soils (Makri and Kintzios, 2007). Rangappa and Bhardawj, (1998) found the optimum nitrogen rate for field grown sweet basil was be 50 to 75 kg N ha⁻¹ in Virginia. Simon, (2007) reported a recommended side-dress application of 16.8 to 33.7 kg N ha⁻¹ following the first harvest. Fusarium wilt (*Fusarium oxysporum f. sp. basilici*), Bacterial leaf spot (*Pseudomonas cichorii*), Gray mold (*Botrytis cinerea*), Damping-off or Root rot (*Rhizoctonia solani*; *Pythium* spp.), and Root-knot nematode (*Meloidogyne* spp.) are common diseases found in basil. Furthermore, Basil downy mildew (*Peronospora belbahrii*) is fairly new and widespread destructive pathogen now spreading throughout North America that has potential for

complete crop loss if not controlled (Tran, 2006; Johnny's, 2011). Other pests include root knot nematode, aphids, Japanese beetle, leaf-miner and whiteflies (Johnny's, 2011)

Conclusion

As organic and sustainable agriculture continue to grow, objective analysis of commercially and locally available products that can be used as sustainable soil amendments, fertilizers and composts in vegetable and herb production is of value for growers seeking to employ these practices (Delate, 1999; Hartz et al., 2010; Russo and Taylor, 2006; Treadwell et al., 2007). Warm season crops, which have an exceptionally long season in the Deep South, are commonly produced using transplants. Evaluation and nutrient availability of commercial locally produced and readily available media amendments and fertilizers in vegetable transplant production is needed. An expected outcome is to identify a soilless media mix and post-plant fertility treatment that will produce vigorous and large transplants in the shortest time utilizing locally available resources that satisfies the needs of a sustainable grower. More research in sustainable agricultural practices is needed to provide agricultural professionals with information that is relevant to small-scale sustainable growers. Consistent information on the use for organically derived amendments that are readily available, and testing of commonly recommended fertilizer treatments, is limited in agriculture, especially in the South. While profit has been the driver of research, the increasing consumer demand of sustainably produced food products may be a motivator for producers to practice sustainable systems and agricultural professionals to evaluate other means of fertility in production.

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CHAPTER 2

EVALUATION OF FISH HYDROLYSATE AS AN ORGANIC SOURCE OF NITROGEN FOR BASIL TRANSPLANT PRODUCTION

Introduction

Increased public demand for organic food products has led organic farming to becoming one of the fastest growing sectors in the agricultural market (Greene et al., 2009). According to the United States Department of Agriculture (USDA), select consumers are willing to pay a premium for food products perceived to be produced using sustainable or organic practices (Dennis et al., 2010). In turn this has incentivized the organic fruit and vegetable production by local and small farmers. These growers seek to use readily available local waste-streams, such as manures and composts, as amendments or fertilizers (Greene et. al., 2001; Hartz, 2002; Ogles et. al., 2015) to manage plant fertility.

Warm season crops, which have an exceptionally long season in the Deep South, are commonly produced using transplants. Evaluation is needed of nutrient availability of these locally produced and readily commercially available media amendments and fertilizers for use in vegetable transplant production. Furthermore, certified organic vegetable transplants that comply with USDA regulations are not widely available commercially, leading many organic growers to produce their own (Larrea, 2005).

In the Gulf of Mexico region of the United States, an area with a robust seafood industry, fish waste is a readily available nutrient-rich resource. Historical evidence and research have shown fish-based fertilizers are suitable for nutrient management in organic production of various food commodities (Blatt, 1991; DeMoranville, 1990; Smagula and Dunham, 1995). Fish byproducts processed as fertilizers, depending on the source and location within the United States, have nitrogen and phosphorus concentrations between 2 to 10% and 2 to 6%, respectively (Card et. al, 2014).

Additionally, several fish-based fertilizers are available in dry and liquid forms that allow pre- and post- planting fertilizer applications (Hartz et al., 2010; USDA, 2006)

Currently there are two major formulations of liquid fish-based fertilizers available for post-planting application: fish emulsion and fish hydrolysate (USDA, 2006). Each product is derived from marine fishing industry waste, but differs in fertilizer processing. Fish emulsion is produced under heat with either an acid or alkaline solution to accelerate decomposition to segregate oils from the emulsion (Kristinsson and Rasco, 2000). In contrast, fish hydrolysate involves fish waste undergoing hydrolysis using naturally occurring enzymes to decompose fish proteins. This process is often referred to as a cold-press, because it is conducted at ambient temperatures compared to the more energy intensive fish emulsion process (USDA, 2006). Once processed, fish-based products can be used in agriculture as fertilizers, soil amendments, or plant growth substrates (Aung and Flick, 1980; Arvanitoyannis and Kassaveti, 2008; Henderson and Strombom, 1995; Illera-Vives et. al, 2012).

Research has demonstrated fish-based fertilizers can be suitable alternatives to synthetic fertilizers during fruit and vegetable production of various crops (Blatt, 1991; DeMoranville, 1990; Smagula and Dunham, 1995; Ogles et al., 2015.) Blatt (1991) demonstrated fish fertilizer hydrolysate applied at 100 kg N ha^{-1} produced marketable yields of broccoli, cabbage and sweet corn. In cranberry production fish hydrolysate was suitable as a fertilizer and was also less likely to leach compared to commercially available soluble fertilizers (DeMoranville, 1990). Fish hydrolysate, 2:4:2 (N:P:K), applied at $67.2 \text{ kg N ha}^{-1}$ increased stem length, flower bud density and yield in high bush blueberries (Smagula and Dunham, 1995). More recently, Ogles et al. (2015) demonstrated yellow squash and collards grown at the recommended N rates of 152 kg N ha^{-1} and 110 kg N ha^{-1} fish hydrolysate respectively, could compete in local markets even though yields were lower compared to conventional production practices. This study reported premium prices for sustainably grown products were sufficient to offset reduced yields (Ogales et al., 2015).

One area that has not been fully documented concerning fish hydrolysate application is the organic production of transplants such as basil. In adherence to USDA regulations within the Organic Foods Production Act of 1990 under the National Organic Program (NOP) enacted October 21, 2002 certified organic production requires organically produced transplants (USDA, 2002). Allowable materials for use in organic production are itemized on the National List of Approved Substances (Kuepper and Everett, 2004). Products are reviewed by the Organic Materials Review Institute (OMRI) and/or the Washington State Department of Agriculture (WSDA) to ensure that materials meet standards outlined in the NOP (Coleman, 2012). Scientific research and anecdotal accounts suggest fish hydrolysate may be a suitable post application fertilizer source. Therefore, the objectives of this research were to evaluate fish hydrolysate rate and application method for organic basil transplant production.

Materials and Methods

Plant material and substrate

Experiments were conducted in the autumn of 2014 in the greenhouse at the Hill Farm Teaching Facility located at Louisiana State University in Baton Rouge, La. The greenhouse daily temperatures averaged 25 C. Certified organic Genovese basil cv. ‘Dolly’ (Johnny’s Selected Seed Co., Winslow, Ma.) seed were grown in polystyrene plastic inserts with 6 cells measuring 6 cm x 5.5 cm x 5.9 cm (606 pack inserts Johnny’s Seed Co., Windslow, Ma.) with trays holding six inserts. Inserts were filled with a soilless sphagnum peat-lite substrate (Farfard Super-fine Germinating Mix, Agawam, Ma) with a pH 6.5 containing no additional nutrients or wetting agents. Basil was seeded at a depth of 3 mm and immediately irrigated until the substrate was saturated. Throughout the experiments trays were irrigated twice a day at 0.59 L m⁻¹ using overhead nozzles.

Fertilizer treatments

Fish hydrolysate (FH) (Neptune's Harvest, Gloucester, Ma.), 2:4:1 (N:P:K) was applied as a fertilizer source beginning 10 days after sowing, once plants had developed the first set of leaves. Fish hydrolysate was applied as a drench or foliar application based on nitrogen application rates of 0, 20, 40, and 80 kg N ha⁻¹ wk⁻¹. Foliar fish hydrolysate (FHF) applications were applied with water as the carrier at 31 L ha⁻¹ using a single nozzle boom. Fish hydrolysate applied as a drench (FHD) in a solution at 313 L ha⁻¹. Treatments were arranged in a randomized complete block design with six replications. Fish hydrolysate foliar and drench applications were applied weekly for a total of four weeks.

Basil Sampling

Plant height and stem diameter were recorded 14 and 28 days after initial treatment (DAIT). Basil was harvested 28 DAIT with two plants per experimental unit. Basil shoots were excised at the substrate interface, dried at 40 C for 72 h, and mass determined gravimetrically. Roots were gently washed free of substrate, dried at 40 C for 72 h, and mass determined gravimetrically. Basil leaf tissue samples were submitted to the LSU Ag Center Soil Testing Lab, Baton Rouge, La. for analysis. Samples were taken from both blocks for tissue nutrient tissue analysis. A sample of fish hydrolysate fertilizer (Neptune's Harvest™) was collected and submitted to the LSU Ag Center Department of Agricultural Chemistry for analysis (Table 2.1).

Table 2.1: Analysis of fish hydrolysate fertilizer_z.

%		mg L ⁻¹					
Ca	0.044	Al	354	Cr	1.71	Fe	323
Mg	0.102	As	<6	Co	<0.2	Mo	<0.8
Na	1.14	B	0.04	Cu	<4	Pb	<1.2
S	0.845	Ba	22.6	Ni	1.48	Se	<16
NH ₃	0.359	Cd	<.2	Mn	8.88	Zn	25.9
NO ₃ -	<.02						

_z Neptune's Harvest™ (Gloucester, Ma.),

Experimental design and statistical analyses.

Treatments were arranged in a randomized complete block design with six replications. Data were analyzed by analysis of variance using the mixed procedure (SAS Institute, Inc., Cary, NC) with method of application and application rate as fixed factors. Means were separated using Tukey's honest significant difference (HSD) test at $P < 0.05$. Data from the two experiments were pooled for each measurement for the interaction terms of 'exp*date*rate*method' for measurements collected at 14 and 28 DAIT or 'exp*rate*method' for measurements collected only at 28 DAIT at a P values ≤ 0.2 .

Results

Basil growth parameters

Basil height increased over the 28-day experimental period as FH application rates increased from 20 to 80 kg N ha⁻¹ wk⁻¹ for foliar (FHF) and drench (FHD) treatments (Figure 2.1).

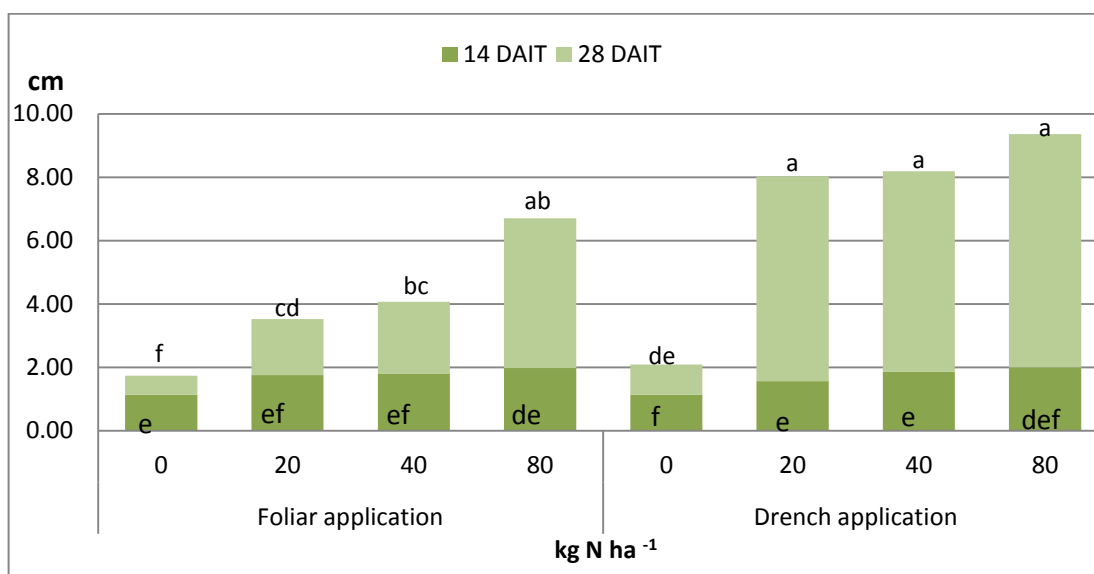


Figure 2.1: Effect of fish hydrolysate application foliar or drench application at 0, 20, 40, 80 kg N ha⁻¹ wk⁻¹ on basil transplant height at 14 and 28 days after initial treatment (DAIT) in 2014 greenhouse studies in Baton Rouge, La.

z Means with the same letter within and among bars are not significantly different at $P \leq 0.05$ using Tukey's HSD.

During the first 14 DAIT FHF resulted in no significant differences between treatments or application methods. Basil attained heights of 1.14, 1.76, 1.81, and 1.98 cm for FHF applied at 0, 20, 40, and 80 kg N ha⁻¹ wk⁻¹ compared to 1.14, 1.56, 1.87, and 2.0 cm for basil treated with FHD at equivalent rates. However, during the final 14 days of the experiment, basil fertilized with FHD applied at 0, 20, 40, and 80 kg N ha⁻¹ wk⁻¹ increased in height .95, 6.47, 6.32, and 7.36 cm from 14 DAIT compared to increases of .60, 1.77, 2.26, and 4.72 cm for basil fertilized with FHF at corresponding rates during the same period.

Unlike height measurements, the majority of basil stem diameter growth occurred during the first 14 DAIT for all FH treatment combinations (Figure 2.2).

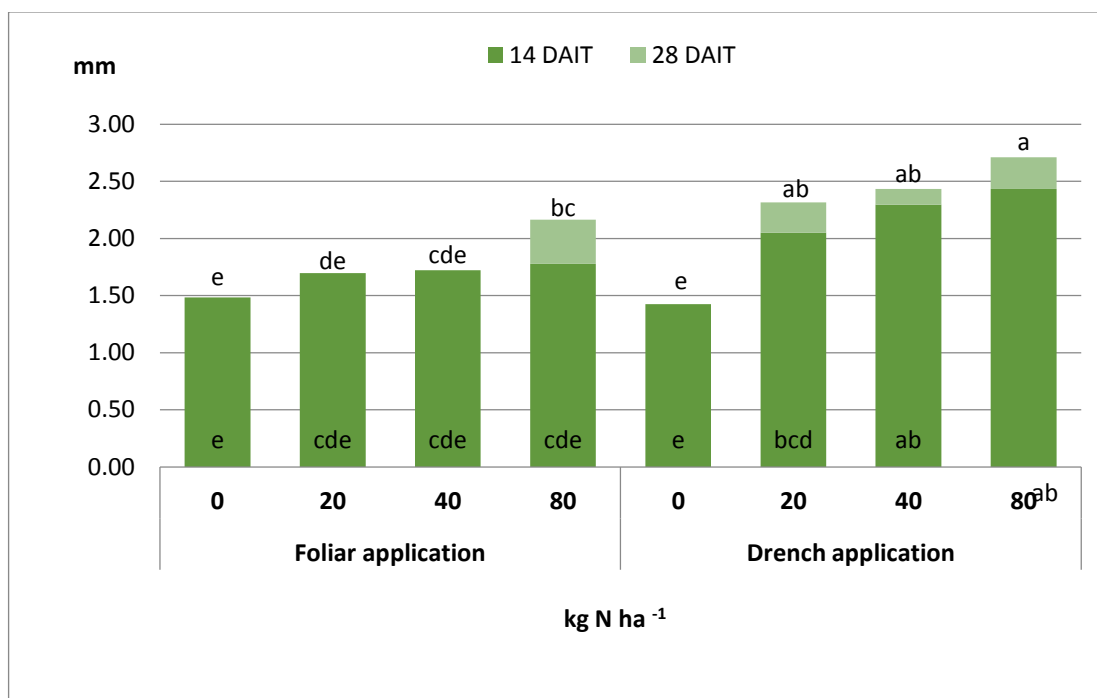


Figure 2.2: Effect of fish hydrolysate application foliar or drench application at 0, 20, 40, 80 kg N ha⁻¹ wk⁻¹ on basil transplant stem diameter 14 and 28 days after initial treatment (DAIT) in 2014 greenhouse studies in Baton Rouge, La

^z Expected values of the same letter within and among bars are not significantly different at P ≤ 0.05 using Tukey's HSD.

Basil treated with FHD resulted in stem diameters of 1.48, 1.70, 1.72, 1.78 mm at 0, 20, 40, and 80 kg N ha⁻¹ wk⁻¹ compared to FHF-treated basil 1.42, 2.05, 2.30, 2.43 mm at the corresponding rates. In general, stem diameter increased as FH application rate increased per application method. However, stem diameters for FHF-treated basil slightly declined or remained the same at 0, 20, and 40 kg N ha⁻¹ wk⁻¹ with an increase of 18% at 80 kg N ha⁻¹ wk⁻¹ compared to increases of 11, 6, and 10 % for FHD-treated basil at the same application rates 14 to 28 DAIT. At the conclusion of the study, basil fertilized with FHD at 20, 40, and 80 kg N ha⁻¹ wk⁻¹ and FHF 80 kg N ha⁻¹ wk⁻¹ resulted in the tallest and thickest stems for basil transplants fertilized using FH.

Changes observed above regarding the effects of FH on basil height and stem diameter also occurred with basil biomass 28 DAIT. Although differences between experiments were evident, in general, increasing FH application rate resulted in increased shoot, root and total basil biomass increases (Table 2.2). For example, in the first experimental run FHF-treated basil applied at 0, 20,

Table 2.2: Basil transplant biomass at 28 days after initial treatment as affected by fish hydrolysate with foliar or drench application at 0, 20, 40, 80 kg N ha⁻¹ wk⁻¹ in 2014 greenhouse studies in Baton Rouge, La

kg N ha ⁻¹		Shoot		Root		Total							
		Exp 1 ^{yz}	Exp 2	Exp 1	Exp 2	Exp 1	Exp 2						
		-----g plant ⁻¹ -----											
Foliar	0	0.42	de	0.19	d	0.18	cd	0.08	c	0.60	de	0.27	d
	20	0.73	cd	0.37	bcd	0.26	bc	0.14	bc	0.98	cd	0.51	bcd
	40	0.80	bc	0.46	bc	0.26	bc	0.18	abc	1.06	bc	0.64	bc
	80	1.02	bc	0.61	ab	0.28	ab	0.20	abc	1.30	bc	0.81	ab
Drench	0	0.31	e	0.27	cd	0.12	d	0.13	bc	0.43	e	0.40	cd
	20	0.91	bc	0.76	a	0.30	ab	0.26	a	1.21	bc	1.02	a
	40	1.10	b	0.76	a	0.33	ab	0.27	a	1.43	b	1.03	a
	80	1.54	a	0.73	a	0.35	a	0.24	ab	1.89	a	0.97	a

^z Expected values within a column not followed by the same letter are significantly different at P ≤ 0.05 using Tukey's HSD.

^y Exp = Experiment

40, and 80 kg N ha⁻¹ wk⁻¹ resulted in total biomasses of 0.60, 0.98, 1.06, and 1.30 g plant⁻¹ compared to 0.43, 1.21, 1.43, and 1.89 g plant⁻¹ for corresponding rates of FHD-treated basil. Differences between FH application methods were less consistent between experimental runs with the first experimental run resulting in greater shoot, root, and total biomass accumulations. In particular, total biomass of FHD-treated basil at 80 kg N ha⁻¹ wk⁻¹ resulted in higher biomass compared to all other FH treatments. In contrast, the second experiment basil stem diameters were not different when applied at 20, 40, 80 kg N ha⁻¹ wk⁻¹ FHD and 80 kg N ha⁻¹ wk⁻¹ FHF.

Basil Tissue Nutrient Concentrations

The highest concentrations of nutrients, N, P, K, Ca, Mg, S, B, Cu, Mn, and Zn were resulted from FHD-applied basil tissue and corresponded to increases of FH application rates. Increases of Al concentrations were highest in FHF-applied basil tissue and increased as rate of FH application increased (Figure 2.3). Basil tissue nutrient analysis showed generally higher percent N, P, Ca, and Mg concentrations for FHD-treated basil as compared to FHF-treated basil. Furthermore, the highest rate of FHF application, 80kg N ha⁻¹ wk⁻¹, resulted in basil tissue Ca and S percent concentrations 17.7 and 13.2 % respectively lower than the lowest FHD application 20 kg N ha⁻¹. Basil tissue for FHF-treated with 20, 40, and 80 kg N ha⁻¹ wk⁻¹ had higher Al at 35.3, 62.4, and 70.9 % higher concentrations, respectively, as compared with FHD-applied basil at corresponding rates with no difference between the control. Iron concentrations for FHF-treated basil tissue at 40 and 80 kg N ha⁻¹ wk⁻¹ were 12.4 and 33.5% higher respectively than FHD-treated basil tissue at corresponding rates, whereas 0 and 20 kg N ha⁻¹ wk⁻¹ FHD-treated basil tissue were 19.7 and 5.7% higher than the FHF-treated basil at corresponding rates.

Discussion

The results of this study indicate that marketable organic basil transplants can be produced within a 38-day period using OMRI approved FH as a post-applied fertilizer source. However, the

		Chemical composition													
		%						ppm							
kg N ha ⁻¹		N	P	K	Ca	Mg	S	Al	B	Cu	Fe	Mn	Mo	Zn	
Foliar	0	0.99 e	0.33 d	2.07 e	0.83 b	0.45 d	0.16 d	28.56 b	23.29 d	3.23 d	52.38 c	24.28 c	0.27	28.01 b	
	20	1.45 de	0.36 d	2.60 de	0.83 b	0.51 d	0.26 cd	43.77 ab	25.26 cd	3.37 bcd	84.89 bc	26.68 c	0.33	30.42 b	
	40	1.85 de	0.40 cd	3.03 cd	0.83 b	0.54 d	0.33 bc	53.34 ab	27.23 cd	3.26 cd	105.43 ab	25.87 c	0.94	27.89 b	
	80	2.87 c	0.56 b	3.94 ab	0.93 b	0.69 c	0.46 ab	74.34 a	33.01 bc	5.15 ab	148.18 a	32.27 c	0.57	33.79 ab	
Drench	0	1.19e e	0.36 d	2.62 de	0.92 b	0.51 d	0.21 cd	25.27 b	24.44 d	4.96 abcd	65.22 bc	29.77 c	1.02	32.51 ab	
	20	2.67c c	0.52 bc	3.66 bc	1.13 a	0.81 bc	0.47 a	28.31 b	39.18 ab	4.78 abcd	89.05 bc	38.27 bc	1.49	32.29 ab	
	40	3.74 b	0.62 b	3.98 ab	1.17 a	0.91 ab	0.54 a	20.04 b	41.51 ab	5.12 abc	92.37 bc	50.74 bc	1.15	34.62 ab	
	80	4.42 a	0.75 a	4.44 a	1.23 a	1.02 a	0.53 a	21.63 b	43.93 a	5.82 a	98.61 bc	79.12 a	0.29	39.10 a	

Figure 2.3: Basil transplant tissue nutrient concentration at 28 days after initial treatment as affected by fish hydrolysate with foliar or drench application at 0, 20, 40, 80 kg N ha⁻¹ wk⁻¹ in 2014 greenhouse studies in Baton Rouge, La.

^z Expected values within a row not followed by the same letter are significantly different at $P \leq 0.05$ using Tukey's HSD.

application rate and placement of FH affected basil growth and the duration necessary to achieve marketable size within the observed period. In general, FH applied at ≥ 40 kg N ha⁻¹ wk⁻¹ as a drench during basil transplant production resulted in the highest basil heights, thickest stem diameters, and greatest biomass compared to FH applied directly to leaves at corresponding FH application rates 28 DAIT. Differences in FH efficacy between foliar or drench applications are most likely a function of basil growth and development during transplant production from seed. Many plants post-germination use available carbohydrates to promote leaf production and to increase photosynthesis capacity so that over time photosynthates can be funneled into root growth (Tanaka et al., 1973). During this developmental period, juvenile leaves can be characterized as having thinner cuticles compared to more developed cuticles found on mature leaves (Fernandez et al., 2013; Kannan, 1986). Cuticle thickness and composition have been reported to govern uptake of nutrients and chemicals over time (Eickert and Fernandez, 2012; Fernandez et al., 2013).

Effect on of basil growth FH uptake may also explain changes observed in height and stem diameter for FHD. As leaves matured over the 28 DAIT, uptake of FHF was most likely mediated rather mediated as a function of plant nutrient demand given the positive response of basil growth to increasing FHF and FHD application rates. Other studies have shown that there is a decline in rate of foliar nutrient uptake in many citrus species as leaves age (Eickert and Fernandez, 2012). Basil stem diameter and height were similar during the first 14 DAIT for FHF and FHD-treated basil, but by 28 DAIT FHD-treated plants at ≥ 40 kg N ha⁻¹ wk⁻¹ had accelerated in growth compared to all other treatment combinations. Insufficient development of basil roots during the first 14 DAIT most likely limited FHD uptake and in turn limited overall growth. However, as basil root systems became more robust, increases in root architectural parameters led to greater FHD uptake that lead to higher basil growth (Mengel, 1995). This suggests basil roots may be more efficient at absorbing nutrients from FH through roots than leaves as basil seedlings mature. At the end of the 38 day experimental period

foliar treated basil at 80 kg N ha⁻¹ resulted in similar growth as basil treated with FHD at 20 kg N ha⁻¹ wk⁻¹.

Although foliar application of fertilizer has been shown as an effective means of nutrient uptake depending on species and age, leaves are also be more susceptible to absorbing other elements and compounds (Fernandez et al., 2013). The capacity for leaves to absorb inorganic compounds that are not always beneficial to the plant is known as ‘occult precipitation’ (Kannan, 1986). In the case of FHF-treated basil, higher concentrations of Al and Fe were reported at 28 DAIT when applied at 80 kg N ha⁻¹ wk⁻¹ compared to FHD-treated basil. In particular, Al has been shown to be deleterious to plant growth, often by limiting root growth (Delhaize and Ryan, 1995). In most cases plant roots exclude Al unless soil conditions, such as acidic soils, provide conditions for increased Al solubility (Delhaize and Ryan, 1995). In contrast, Fe absorbed by the plant through foliar applications could be of benefit for basil growth and color. In terms of this study, there is potential to introduce higher Al and Fe into plant tissues through FHF applications and this may either have beneficial or deleterious effects on basil growth. Furthermore, considerations of seasonal and regional differences in the parent material of FH were outside the scope of this work but may result in different effects during foliar application as a fertilizer source.

Fish hydrolysate applied as a drench application is an effective post-applied fertilizer for organic basil transplant production. Basil transplants treated with 40 kg N ha⁻¹ wk⁻¹ FHD had comparable results to basil treated with 80 kg N ha⁻¹ wk⁻¹ FHF in height, stem diameter, biomass, and for many nutrients. This demonstrates drench application of FH is the most effective method. Although FHD application for basil treated with 80 kg N ha⁻¹ wk⁻¹ had the highest response to treatment in height, stem diameter, biomass and to a large degree plant nutrient concentration, the growth increase did not correspond to a doubling of the application rate of 40 kg N ha⁻¹ wk⁻¹. The results of this study suggest that FH applied as a drench at > 40 kg N ha⁻¹ wk⁻¹ provides acceptable

nutrient uptake and growth for productions of marketable organic basil transplants under greenhouse conditions.

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CHAPTER 3

PRODUCING BASIL TRANSPLANTS USING COMPOSTED BROILER LITTER OR VERMICOMPOST IN GROWING MEDIA

Introduction

Increased public demand for organic food products has led organic farming to become one of the fastest growing sectors in the agricultural market (Green et al, 2009). According to the United States Department of Agriculture (USDA), some consumers are willing to pay a premium for food produced using organic or sustainable practices (Dennis et al., 2010; Ogles et al., 2015). In turn this has incentivized local and small farmers to develop organic production systems. This has increased the use of readily available local waste-streams, such as manures and composts, as amendments or fertilizers to manage plant fertility (Greene, 2001; Hartz, 2002; Ogles et. al., 2015).

Under the USDA National Organic Program (NOP) all products sold in the United States as certified organic must comply with the Organic Food Production Act of 1990 (the Act) which was enacted to regulate standards for organic products (USDA, 2002). For crops to be USDA certified, organic growers are required to use organically grown seed and materials (USDA, 2002). The materials approved for organic production are listed on the National List of Approved Substances (Kuepper and Everett, 2004; USDA, 2002). Organic transplants need to comply with regulations set by the NOP and are not widely available commercially; leading many organic growers to produce their own transplants (Larrea, 2005). In order to meet the increasing demand for organically produced local food, farmers need to be particularly aware of inputs that can be sourced locally and the sustainable production practices that they employ.

The use of transplants is an important aspect of establishment for vegetable production in the United States (Russo, 2005; Styler and Koranski, 1997; Wien, 1997). Growing transplants instead of direct seeding is a regular practice for small seeded crops for consistent field establishment and season extension (Wien, 1997). Transplants are commonly produced using soilless substrates which should

support sufficient aeration, plant support and root development (Styler and Koranski, 1997).

Conventional vegetable transplants use sterile soilless media substrate mixes that commonly consist of peat, pine bark, perlite, vermiculite, wetting agents and synthetic fertilizers (Greer, 2005; Styler and Koranski, 1997).

A barrier to organic production for growers is the limited availability of organic fertilizers and pesticides and/or expensive transportation costs (Hammac II et. al, 2007; Russo and Taylor, 2010). The increase in demand for sustainably local vegetables has spurred small-scale farmers to develop alternative farm operating systems. These growers seek to use local waste-stream by-products such as manures and composts as fertilizers during plant production (Gagnon and Berrouard, 1994; Greene, 2001; Hartz, 2002; Ogles et. al, 2015; Russo and Taylor, 2010). Production of vegetable transplants is a specialized industry unto itself and organically produced seedlings are seldom commercially available. Farmers who seek certification must produce their own transplants (Kubota and Kroggel, 2006; Larrea, 2005). Transplant seedling sales can be an extra source of revenue for some small/medium scale growers seeking to meet local demand for organic transplants (Hulshart and Elliot, 2012).

Numerous studies have been conducted to examine the use of animal and plant based agricultural waste stream by-products with variable results. Manures, compost, plant and animal meals, and other by-products have been evaluated for use in fertility management of vegetable transplant production (Gagnon and Berrouard, 1994; Gravel et al, 2012; Raviv et al., 2005; Russo and Taylor, 2010; Treadwell et al., 2011; Zhai et al., 2009). The results of the studies demonstrated the differences in transplants production practices and also inconsistency and variability in the media (Gravel et al., 2012; Treadwell et al., 2011). Several of these materials can be found locally, but need investigation as to their properties and in particular their nutritional value for use in vegetable transplant production.

Vermicompost (VC), often referred to as worm castings, is an organic material processed by various species of earthworms, principally *Eisenia fetida* and *E. Andrei* (Atiyeh et al, 2000; Edwards and Burrows, 1988; Paul and Metzger, 2005). In the conventional compost process, thermophilic biooxidation, microorganisms break down and stabilize complex organic material into mineral forms releasing heat, CO₂ and water (Ayiteh et al., 2000). In contrast, vermicompost is a biological process through which stabilization of organic material is achieved as wastes pass through the gut of an earthworm (Ayiteh et al., 2000). As worms process organic matter, microbial activity is stimulated increasing mineralization. This process transforms waste into humus-like material (Atiyeh et. al, 2000, Paul and Metzger, 2005).

Various organic materials are used as parent material for vermicomposting. Suitable substrates for vermicomposting include: manure, kitchen, yard, and paper mill waste, sewage sludge, coffee pulp and yard waste (Atiyeh et al 2002; Orozco et al, 1996; Paul and Metzger, 2005). Compared to conventional compost, VC has been reported to have significantly more plant available nutrients (PAN) with larger more diverse microbial populations (Atiyeh et al., 2000; Edwards and Burrows, 1988; Tognetti et al., 2007). Vermicompost is a finely divided peat-like material that balances porosity, aeration, drainage, water holding capacity. Previous research indicates that VC is a suitable substrate in soilless media for vegetable transplants (Atiyeh et al., 2000; Atiyeh et al. 2002; Arancona,et al. 2004; Bachman and Metzger, 2008; Edwards and Burrows, 1988; Zaller, 2007)

The United States is one of the leading producers of poultry with annual production at approximately 20,000 metric tons (USDA, 2011a). Specifically, broiler chicken production has increased in the Southeast which has become a major production area (Hammac II et. al, 2007). With the increase in broiler production, there is a need to manage poultry waste (Lasekan et. al. 2013; Sharply et. al., 2013; Wood et. al, 1996). Broiler litter has been shown to be an alternative to commercial fertilizer (Hammac et. al 2007; Lasekan et. al. 2013; Sharply et. al., 2013). This product is

readily available in the South that is frequently used by sustainable producers as a soil conditioner and amendment to soilless media to some extent (Sharply et. al. 2013; Wood et. al, 1997).

Pelletized broiler litter is a good source of nitrogen and phosphorus and an economical alternative to synthetic fertilizer (Hammac II et. al, 2007). However annual field application of poultry litter can increase soil phosphorus over time to very high concentrations, which can be harmful to plant development and have negative environmental impacts (Sharply et al., 2013; Szogi and Vanotti, 2009). For this reason alternative uses for this by-product are needed. Research indicates composted poultry litter may be a promising substrate for greenhouse production (Bi et al., 2010; Flynn et al., 1996; Guertal et al., 1997).

Objective analysis of commercially and locally available products that can be used as soil amendments, fertilizers and composts in vegetable and herb production, is of value for growers seeking to employ these sustainable and organic practices (Dennis et al., 2010; Hartz et al., 2010; Russo and Taylor, 2006; Russo and Taylor, 2010; Treadwell et al., 2007). Warm season crops, which have an exceptionally long season in the Deep South, are commonly produced using transplants. Evaluation and nutrient availability of commercial locally produced and readily available media amendments and fertilizers in vegetable and herb transplant production is needed.

Materials and Methods

Plant material and substrate

Experiments were conducted in the summer of 2014 in the greenhouse at the Hill Farm Teaching Facility located at Louisiana State University in Baton Rouge, La. The greenhouse daily temperatures averaged 36 C. Certified organic Genovese basil cv. ‘Dolly’ (Johnny’s Selected Seed Co., Winslow, Ma.) seed were seeded in polystyrene plastic inserts with 6 cells measuring 6 cm x 5.5 cm x 5.9 cm (606 pack inserts Johnny’s Seed Co., Windslow, Ma.) with trays holding six inserts. Inserts were filled with treatment combinations (Table 3.1) using soilless sphagnum peat moss

substrate Fafard Super-Fine Germinating Mix (FGM - Agawam, Ma) as the base media.

Vermicompost (VC) was mixed volumetrically at rates of 10, 20, and 40 % with FGM as a base.

Composted broiler litter (CB) was mixed volumetrically with rates of 5, 10, and 20 % CB with FGM as a base. Substrate treatment combinations were prepared by measuring the treatments into a 10 liter container and thoroughly mixing amendments with the standard germination media. Basil was seeded at a depth of 3 mm and immediately irrigated until media was saturated. Throughout the experiments trays were irrigated twice a day at 0.59 L m^{-1} using overhead nozzles.

Table 3.1: Substrate treatment of vermicompost (VC) at 10, 20, And 40% and composted broiler litter (CB) at 5, 10, and 20% as amendments evaluated for basil transplant production in greenhouse experiments in 2014 in Baton Rouge, La.

Type of mix	Percent (v/v) (CM/amendment)	Abbreviation
Commercial mix _z	100:0	Control
Vermicompost 10%	90:10	VC 10
Vermicompost 20%	80:20	VC 20
Vermicompost 40%	60:40	VC 40
Compost Broiler Litter 5%	95:5	CB 5
Compost Broiler Litter 10%	90:10	CB 10
Compost Broiler Litter 20%	80:20	CB 20

_z Fafard Super-Fine Germination Mix (Agawam, Ma)

Fertilizer treatments

Fish hydrolysate (FH) (Neptune's Harvest, Gloucester, Ma.), 2:4:1 (N:P:K) was applied as a drench application fertilizer weekly for a total of four weeks. Treatments began six days after sowing, once the plants established the first set of leaves. Fish hydrolysate was applied based on nitrogen an application rate of $80 \text{ kg N ha}^{-1} \text{ wk}^{-1}$ in solution at 313 L ha^{-1} to half the treatments with the remaining as a control.

Sampling

Plant height and stem diameter were recorded 14 and 28 days after initial treatment (DAIT). Basil was harvested 28 DAIT with two plants per experimental unit. Basil shoots were excised at the

substrate interface, dried at 40 C for 72 h, and mass determined gravimetrically. Roots were gently washed free of substrate, dried at 40 C for 72 h, and mass determined gravimetrically.

Bulk density, water holding capacity (WHC), pH, and electrical conductivity (EC) of the media treatments were calculated (Table 3.2). Measurements for pH and EC were recorded using the Hanna HI9811 portable pH/EC meter (Hanna Instruments, Woonsocket, RI). Both pH and EC were

Table 3.2: Substrate pH, electrical conductivity, and bulk density for treatment combinations of vermicompost (VC) at 10, 20, And 40% and composted broiler litter (CB) at 5, 10, and 20% as amendments to a commercial germinating mix (control) for basil transplant production experiments in 2014 in Baton Rouge, La.

Substrate	pH	EC ^z µS cm ⁻¹	WHC ^y %	Bulk Density g cm ⁻³
Control	6.54	1,046.67	77.54	0.14
VC 10	6.63	1,133.33	76.48	0.18
VC 20	6.59	1,466.67	87.83	0.20
VC 40	6.44	2,686.67	84.34	0.26
CB 5	7.59	5,780.00	80.58	0.16
CB 10	7.61	6,310.00	81.02	0.18
CB 20	7.97	7,914.67	86.11	0.25

^z EC = Electrical conductivity

^y WHC = Water Holding Capacity

calibrated using a combination electrode. The leachate was captured and measured directly by electrode emersion. Samples of each media treatment were sent to the LSU Ag Center Soil Testing Lab, Baton Rouge, La. for analysis (Table 3.3).

Experimental design and statistical analyses

Treatments were arranged in a randomized complete block design with eight replications. Data were analyzed using analysis of variance mixed procedure (SAS 4.0, Institute, Inc., Cary, NC). Means were separated using Fisher's Least Square Difference (LSD) at $P < 0.05$. Basil height data in both experiments were log transformed using the natural log to meet the normal distribution assumption of the Fisher's LSD. Log transformed data was back-transformed and reported in original scale. Data from the two experiments were pooled for each measurement for the interaction terms of

Table 3.3: Nutrient analysis of 7 substrate combinations: vermicompost (VC) at 10, 20, and 40% and composted broiler litter at 5, 10, and 20% as amendments to commercial germination mix (control) for basil transplant production experiments in 2015 in Baton Rouge, La.

Substrate	Calcium	Copper	Magnesium	Phosphorus	Potassium	Sodium	Sulfur	Zinc
mg L ⁻¹								
Control	4,183.89	2.30	1,582.90	120.33	267.74	249.51	652.13	9.38
VC10	5,155.42	2.68	2,663.44	188.52	183.50	202.71	272.14	18.48
VC20	5,312.88	2.82	2,409.69	259.73	207.30	197.32	192.08	36.51
VC40	5,238.51	3.13	1,808.93	349.72	398.60	201.52	156.62	54.57
CB5	5,130.33	44.01	4,352.38	8,977.30	15,734.20	1,155.58	2,524.58	52.93
CB10	5,040.56	98.57	4,649.04	22,370.80	27,821.20	889.81	5,361.37	88.20
CB20	4,569.69	120.10	4,514.31	32,596.90	45,015.90	3,236.62	8,953.84	51.21

‘week*N rate*media’ for measurements collected at 14 and 28 DAIT in VC substrate treatment combinations compared to the control and ‘week*media’ for CB substrate treatments compared to control at a P value of value ≤ 0.05 . Data from the two experiments were also pooled for each measurement for the interaction terms of ‘N rate*media’ in VC substrate treatment combinations compared to the control and ‘media’ for measurements collected only at 28 DAIT for a P value ≤ 0.05 .

Results

Basil Growth Parameter of Vermicompost (VC) Substrate Treatments

Basil height increased over the course of the 38-day experimental period for the VC substrate mixes (Figure 3.1). Increased height resulted from basil treated with weekly FH applications compared to non-FH-treated basil, however no differences were observed among the different substrate treatments. There were no differences due to substrate combinations for basil during the first 14 DAIT compared to the control (VC 0%), treated with or without FH. Heights of 7.06, 5.16, 5.59, 4.91cm were attained in FH treated basil grown in VC at rates of 0, 10, 20, and 40%, respectively, compared to 6.24, 5.04, 4.35, and 4.78 cm grown in corresponding substrate treatments. During the final days of the experimental period, basil grown with weekly applications of FH exhibited

increased height compared to non-FH-treated basil with no differences measured among substrate treatments. Heights of basil plants fertilized with weekly applications of FH were 57% higher than non-FH-treated basil irrespective of substrate treatments.

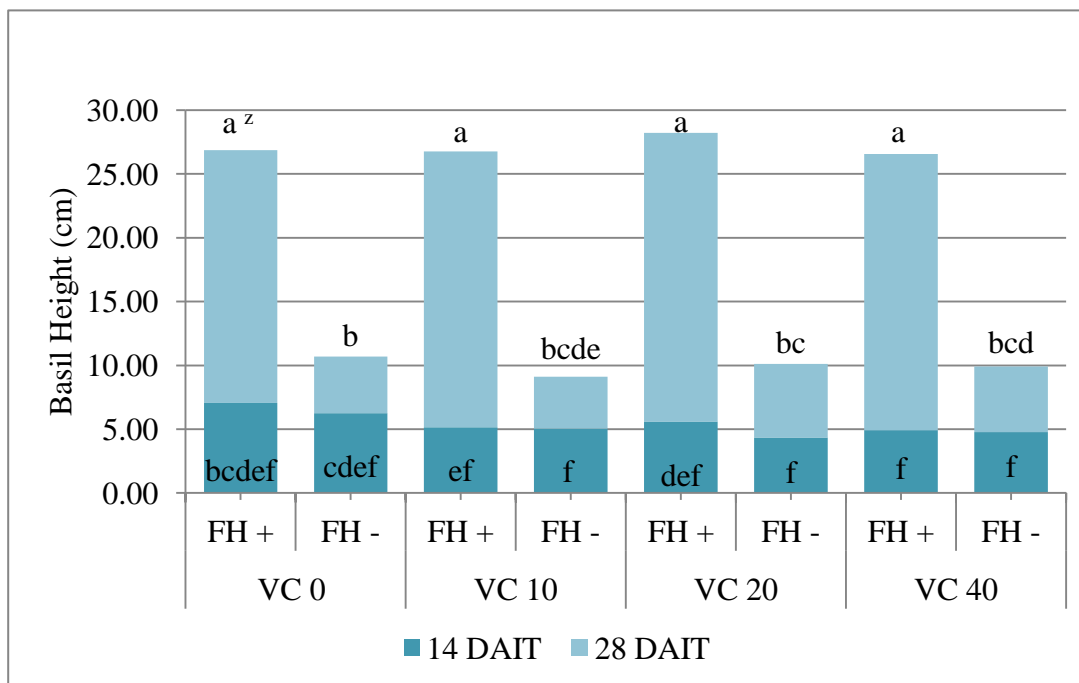


Figure 3.1: Effect of substrate combinations of vermicompost at 10, 20, and 40% as amendments to commercial germinating mix, with (+) or without (-) fish hydrolysate 80 kg N ha⁻¹ as a drench, on basil transplant height at 14 and 28 days after initial treatment (DAIT) in greenhouse experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD.

Similar trends as that with plant height were observed for stem diameter of basil grown in VC substrate mixes. There were differences in stem diameter between FH-treated compared to non-FH-treated basil, although there were no differences due to substrates (Figure 3.2). During the first 14 DAIT basil grown in VC substrate combinations resulted in no differences in stem diameter with or without FH, with the exception of basil grown FH-treated VC at 40%. During the final days of the experimental period basil grown with weekly applications of FH resulted in increased in stem diameter compared to non-FH-treated basil with no differences observed among substrate treatments. Basil

transplants that were fertilized with weekly applications of FH had 24% larger stem diameters of than non-FH-treated basil at any rate of VC treatment. At the conclusion of the study, basil fertilized with FH exhibited the tallest and thickest stems for basil transplants grown in VC substrate treatment combinations.

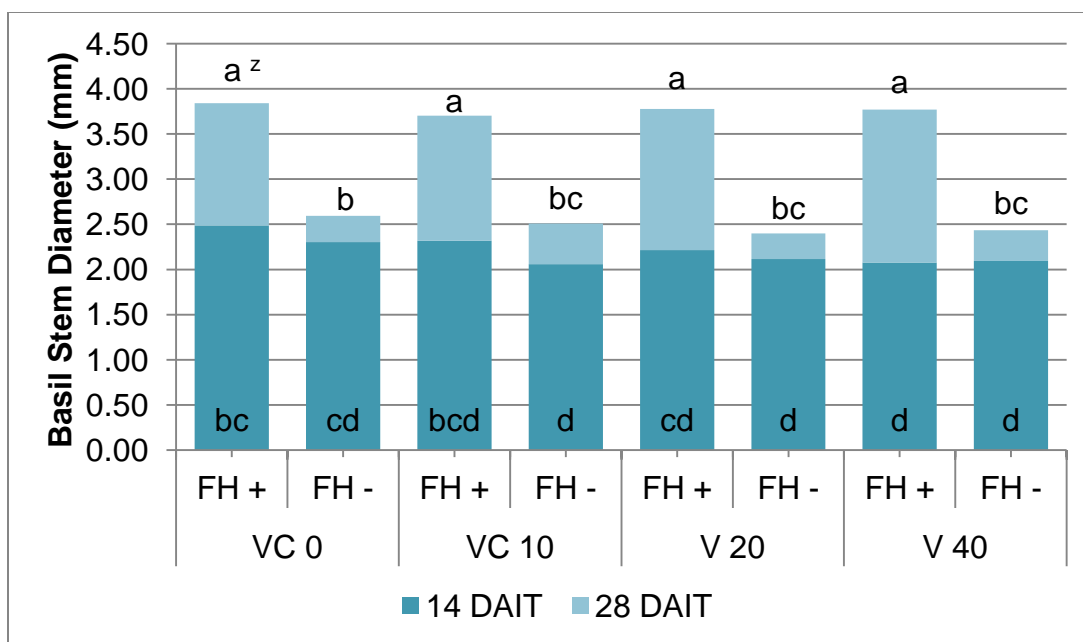


Figure 3.2: Effect of substrate combinations of vermicompost at 10, 20, and 40% as amendments to commercial germinating mix, with (+) or without (-) fish hydrolysate 80 kg N ha⁻¹ as a drench, on basil transplant stem diameter at 14 and 28 days after initial treatment (DAIT) in greenhouse experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD.

The results for total basil biomass 28 DAIT observed regarding the effects of FH on basil also occurred in height and stem diameter (Figure 3.3). Basil grown in substrate VC rates of 0, 10, 20, and 40% with weekly FH applications resulted in total biomass of 3.84, 3.70, 3.78, and 3.77 g, respectively, compared to non-FH-treated basil with 2.59, 2.51, 2.40, and 2.43 g in corresponding substrate mixes. In general, basil grown with weekly applications of FH exhibited significant increases in total biomass but no differences were observed among the substrate treatment combinations.

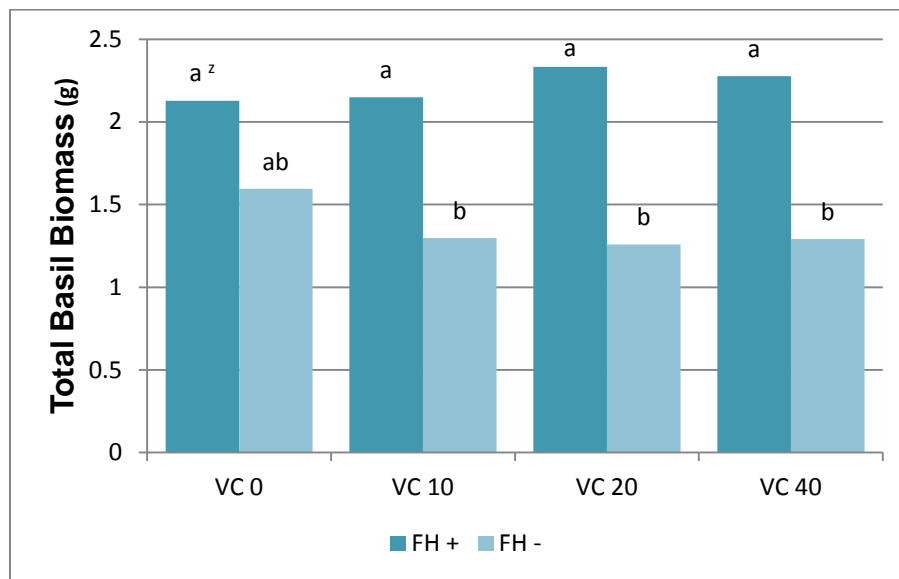


Figure 3.3: Effect of substrate combinations of vermicompost at 10, 20, and 40% to commercial germinating mix, with (+) or without (-) fish hydrolysate at 80 kg N ha⁻¹ as a drench, on total basil transplant biomass at 28 days after initial treatment in greenhouse experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD

Basil Growth Parameter of Composted Broiler Lister (CB) Substrate Treatments

In contrast to basil heights grown in VC substrate treatments, heights of basil grown in CB substrate mixes were not affected by weekly application of FH ($P > .949$). In general, during the first 14 DAIT as ratios of CB increased basil heights tended to decrease (Figure 3.4). In particular, basil grown in CB at 10% and 20% resulted in less height than either the control (CB 0%) or CB substrate treatment at 5% 14 DAIT. Basil grown in CB substrate rates of 0, 5, 10, and 20% 14 DAIT exhibited heights of 6.63, 4.72, 0.09 and 0.03 cm respectively. During the final 14 days difference in the heights of basil were not observed among CB substrate rates of 0, 5, and 10% which attained 16.9, 23.2 and 14.2 cm, respectively. However, 28 DAIT heights of basil grown at a substrate rate of 20% CB rate were comparable to CB at 5% and 10% rates 14 DAIT.

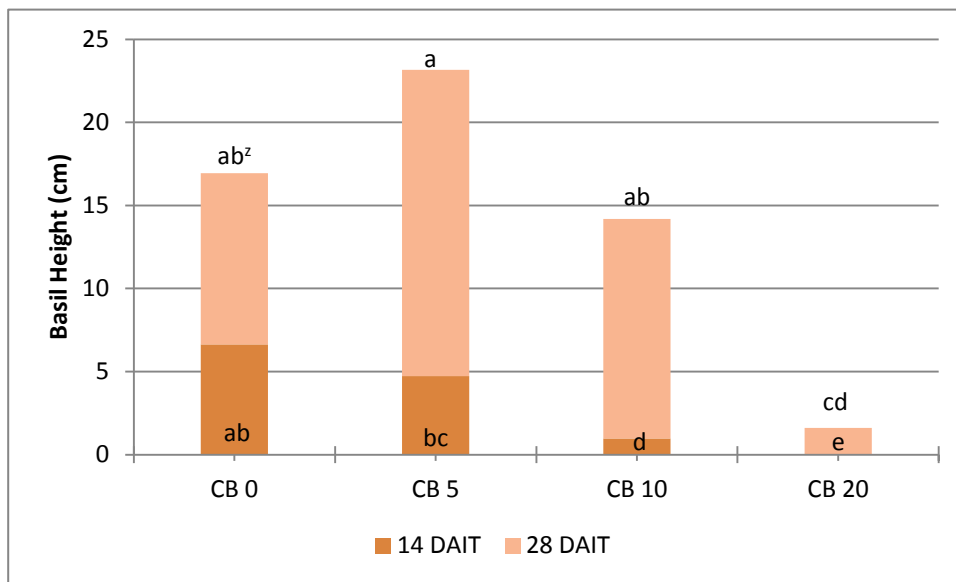


Figure 3.4 Effect of substrate combinations of composted broiler litter at 5, 10, and 20% as amendments to commercial germinating mix on basil transplant height at 14 and 28 days after initial treatment (DAIT) in greenhouse experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD

In contrast to height of basil grown in CB substrates, stem diameters of basil were affected by weekly applications of FH (Figure 3.5). Generally, as the rates of CB substrate increased basil stem diameter decreased at 14 DAIT with and without weekly applications of FH, with the exception of CB at 5%. By 28 DAIT no differences were observed in stem diameter of basil with weekly FH applications grown in CB substrates at rates of 0, 5, and 10% were 3.84, 4.09, 4.00 mm respectively. However, basil grown with 20% CB and treated with weekly FH applications resulted in a mean stem diameter of 1.73 mm.

Basil grown without FH treatments at 5 and 10% CB substrate rates resulted in no differences and attained stem diameters of 3.53 and 3.58 mm respectively. However, stem diameter of basil grown without weekly FH treatments at a rates of 0, 20% CB substrate were not different. Overall, stem diameters of basil grown in CB substrates at rates 0, 5, and 10% were not different with or without FH with the exception non-FH treated basil at a rate 0% CB. At 28 DAIT, basil grown at 0, 5, and 10 %

generally showed no differences in stem diameter or height, however basil grown in CB substrates at a 20% rate were shorter and exhibited smaller stem diameters.

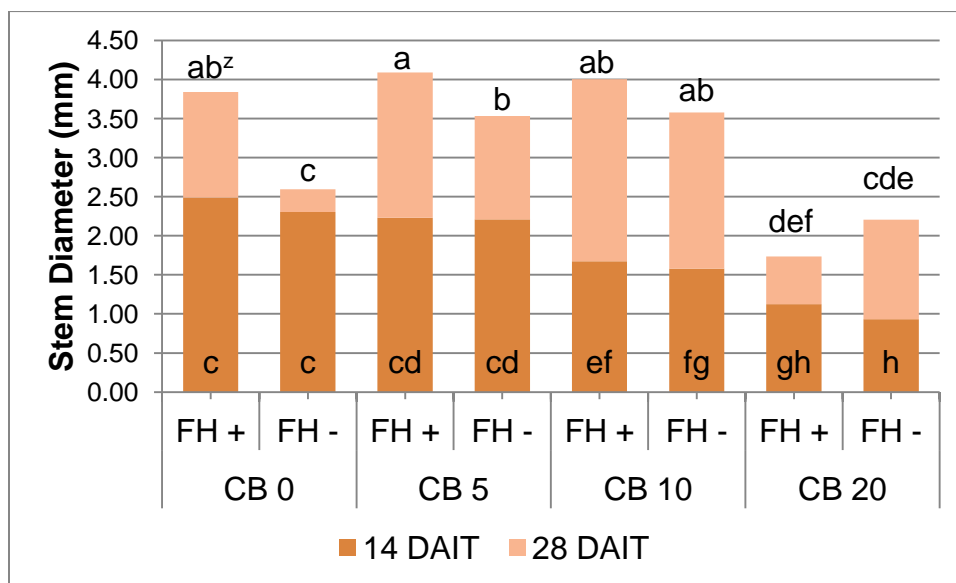


Figure 3.5: Effect of substrate treatment combinations of composted broiler litter at 5, 10, and 20% as amendments to commercial germinating mix, with (+) or without (-) fish hydrolysate at 80 kg N ha⁻¹ as a drench, on stem diameter at 14 and 28 days after initial treatment (DAIT) in basil transplant production experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD

As seen in heights of basil grown in CB substrate treatments, as ratios of CB increase basil total biomass tended to decrease (Figure 3.6) with the exception of CB5. Basil grown in CB substrate rates of 0, 5, 10, and 20% resulted in biomass of 1.86, 2.38, 1.54, and 0.57 g respectively. No differences were observed between CB substrate rates of 5 and 10% compared to the control. However, total biomass of basil grown in the CB at 20% was significantly less compared the control.

Discussion

This study suggests that up to 40% vermicompost can be a suitable substrate media for marketable basil transplant production in rates in combination with fish hydrolysate as a post-applied fertilizer. Vermicompost rates had no effect on basil height, stem diameter, or total biomass compared

to the control. However, weekly drench applications of OMRI-approved FH, based on Nitrogen rate of 80 kg N ha⁻¹, provided acceptable nutrition for basil growth in VC substrate combinations of 0, 10, 20 and 40% for the 38-day period.

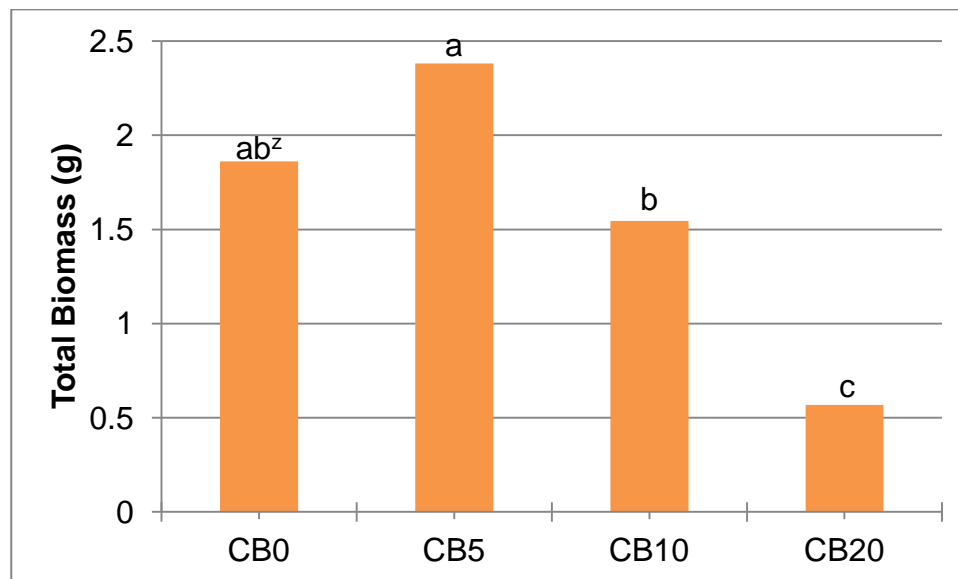


Figure 3.6: Effect of substrate combinations of composted broiler litter at 5, 10, and 20% as amendments to commercial germinating mix on basil transplant total biomass in greenhouse experiments in 2015 in Baton Rouge, La.

^z Means not followed by the same letter are significantly different at $P \leq 0.05$ using Fisher's LSD

Vermicompost can be used as a substrate alternative to commercial germination mix if it is readily available. However, VC did not appear to add nutritional value, nor did not inhibit basil growth. Fish hydrolysate was shown to be an effective fertilizer. Vermicompost may be of value to growers if it is produced locally to replace the expense of purchasing commercial germination mixes in transplant production. Physical and chemical characteristics of VC are similar to that of the control (Table 3.2 and 3.3), therefore it can be useful as a substitution for peat based mixes up to 40%.

Atiyeh et al. (2000) indicated potential issues with VC nutrient content depending on parent material. The parent materials of the VC evaluated in this study was horse manure and kitchen waste. Over the 38-day period at least 7 unintended plant species were identified growing in the VC substrate

treatments, including: Signalgrass (*Brachiaria decumbens*), Carpetweed (*Mollugo verticillata*), Bermudagrass (*Cynodon dactylon*), Redroot pig weed (*Amaranthus retroflexus*), Spurge (*Chamaesyce hirta*), Johnsongrass (*Sorghum halepense*), Goose grass (*Galium aparine*), and vegetable seedlings including members of the *Cucurbitaceae* and *Solanaceae* families. Horse manure has been shown to be a source of invasive weeds (Gower, 2006). Variability of this product complicates evaluation and broad recommendations for use of vermicompost in agriculture.

In contrast, composted broiler litter was not a suitable substrate in basil transplant production. During the first half of the experimental period, as rates of CB increased, there was a resulting decline in height and stem diameter. By 28 DAIT, substrate rates of 5% and 10% CB exhibited no differences in plant height, stem diameter and biomass compared to control. However, basil grown in a CB substrate at a rate of 20% basil resulted in slower growth.

In the evaluation of CB as a transplant media substrate, FH had no effect on height or total biomass. Salt concentrations of phosphorus (P), magnesium (Mg), and sodium (Na) were very high in CB substrate mixes in this study and generally increased as rates of CB increased, with the exception of Na in CB at 10% which was lower than 5 and 20% but nearly double that of the control (Table 3.3). In addition, poultry litter has been shown to increase soil phosphorous to high concentrations in field application (Szogi and Vanotti, 2009).

Heavy metals such as copper (Cu) at 5, 10, and 20 % were as much as 20, 42, and 52 times as high, respectively, as Cu concentrations in the control (Table 3.3). High Cu concentrations have been shown to be phytotoxic in celery, pac choi and Chinese cabbage, resulting in chlorotic immature leaves, browning, stunted, or inhibited growth (Yang et al., 2002) at 10 mg L⁻¹. Yang et al. (2002) also indicated that Cu tolerance was dependent on plant species.

In conclusion, vermicompost rates had negligible effect on basil height, stem diameter, and total biomass compared to the control. If available, VC can be used to replace commercial germination

mixes, while VC did not inhibit growth, it also did not add nutritional value. Weekly drench applications of OMRI-approved FH based on a nitrogen rate of 80 kg N ha^{-1} provided acceptable nutrition for basil growth in VC substrate combinations of 0, 10, 20, and 40% within a 38-day period. In contrast, CB is not an effective transplant media substrate. Basil grown in the CB treatment rates of 5 and 10% were not different than the control and deleterious effects were observed at 20%. Furthermore, high concentrations of salts and metals may limit CB effectiveness as a substrate for germination mixes, and therefore should not be recommended for use in greenhouse transplant production.

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VITA

Amber Dawn was born in Arkansas leaving after a few months when her father took her to Alaska. As a small child, she knew only the wilderness of the lakes and river beds of the Denali region and a small 10 student school. During her teen years her father moved to Colorado where they lived on a corn farm in the plains. She graduated high school in Fort Collins, Colorado and immediately joined the U.S. Marine Corps in aviation ordnance. She received her A.A. degree from Orange Coast Community College in 1999 and a B.A. degree in Sociology from the University of California, Santa Cruz in 2002. She has lived in Mexico and Japan as well as traveled by car through most of North America. In 2005, Amber Dawn drove to New Orleans after Katrina, to support friends with damaged properties to recover from the flood. She stayed to volunteer and work on rebuilding for 5 years. In 2011 she joined the Hollygrove Market and Farm, a local food hub, in an effort to address food justice from the soil up. She developed a teaching and mentoring project called NOLA Grow Your Own that mentors adults and youth in a garden classroom on site of the Market. She attended Louisiana State University on an assistantship to earn a Master of Science degree in horticulture, which she hopes to be awarded in December 2015. She is the proud seeing-eye-person to a Super Dog.