An Analysis of the Quality of Compost Produced from Vermicomposting Fresh Cut Flower Waste[1]

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Abstract

Higher levels of pesticide applications are used when growing cut flowers when compared to other crops such as tomatoes, lettuce, and rice, much of the floriculture industry production occurs in developing countries where less environmental regulations may be in place compared to those in the United States. Therefore, special consideration should be given to cut flower disposal from floral shops due to the potential excessive leaching of pesticides into land and waterways. Most retail florists in the industry dispose of their floral waste into municipal dumpsters. There are an estimated 13,200 retail flower shop locations in the United States, comprised of single location and multiple location companies. While the United States Department of Agriculture (USDA) has stringent guidelines to prevent the importation of pests and plant diseases, there are no regulations on the disposal of spent floral crops that may contain residues of pesticides or other chemicals. Vermicomposting is a method of composting used for pollution abatement while having the added benefit of acting as an alternative waste management method to traditional landfill dumping. The castings produced are a valuable commodity for agricultural, horticultural, and related industries. The main objective of this research was to analyze the quality of compost produced from vermicomposting fresh cut floral waste. Analysis of results was based on the U.S. Composting Council's Tests Methods for the Examination of Composting and Compost used by the U.S. Composting Council's Seal of Testing Approval (STA) program. When compared to STA standards, pH, soluble salts, organic matter, total nitrogen, carbon, carbon-to-nitrogen, bioassay, and respirometry all were found to be within normal ranges for compost sold in the horticulture industry. Chemical analysis found the level of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc all to be well below set industry standards. Additionally, the vermicompost was lab tested for 23 herbicides and insecticides. Of those, one herbicide (clopyralid) and two insecticides (clofentezine and lufenuron) were found in the sample in trace amounts, and well below Environmental Protection Agency (EPA) set industry standards for acceptable trace amount in U.S. products. Results indicated floral waste collected from retail flower shops can be incorporated into a vermicomposting system to create a quality compost suitable for use in the horticulture industry.

Index words: environmentalism, floriculture, residual pesticides, sustainability, waste management, worm castings, floral material.

Significance to the Horticulture Industry

In recent years there has been a push in the floral industry towards sustainable practices and an environmental awareness of the impacts of the business (Papas 2021, Thursd 2020). At the biennial Trend Summit 2020 Conference, Symposium, and Workshop in which professionals within the floral industry meet to discuss current trends and the direction in which floral design should be guided to keep pace with an ever-changing world, the first statement on sustainability was crafted, which states, in part, a belief in the zero-waste hierarchy to rethink, redesign, reduce and repurpose (Thursd 2020). This research investigated if floral waste could be used in a vermicomposting system to create a vermicompost that could be used within the horticulture industry. Results suggest floral waste has the potential to be used in a vermicomposting system to create a quality compost suitable for use in the horticulture industry.

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Introduction

The use of pesticides became an essential element in agriculture after the second world war because of the benefit of increased production (Tiryaki and Temur 2010). Certain pesticides are formulated to be applied in water and are persistent. Through leaching, pesticides can migrate from their intended environment to the environment at large, ending up as trace particles in plants, people, and animals (Tiryaki and Temur 2010). The general population is most often exposed to pesticides through residues in food and from consuming drinking water contaminated with pesticides (Damalas and Eleftherohorinos 2011). Incorrect use of registered pesticides can lead to health issues in individuals while also degrading the environment (Damalas and Eleftherohorinos 2011).

Greater risk of exposure to pesticides has been found to occur in developing countries due to the use of pesticides that are otherwise banned or restricted in other countries (Damalas and Eleftherohorinos 2011). One study investigating the use of synthetic pesticides on varying types of crops in Thailand found the highest levels of pesticide use were on cut flowers and greenhouse vegetables (Schreinemachers et al. 2011). Furthermore, the use of pesticides on cut flowers in Ecuador is common and widespread; the most common pesticides being used there are organophosphates, dithiocarbonates, and pyrethroids (Handal et al. 2015). Another study investigating the amount of trace residue of insecticides from cut flowers on florists' hands showed the most common insecticides to be found were clofentezine, lufenuron, and flonicamid, and the insect repellent N-Diethyl-meta-toluamide (DEET) (Toumi et al. 2017). Due to the relatively high level of pesticides applied to cut flowers when compared to other pesticide applied to such crops as tomatoes, lettuce, and rice, special consideration should be given to cut flower disposal due to the potential leaching of pesticides into land and waterways (Schreinemachers et al. 2011, Singh et al. 2017).

The manager of The University Florist, a full-service retail flower shop located on the campus of Mississippi State University, stated during a personal interview, that on average, 27 kg (60 lb) or 0.14 m^3 (5.0 ft^3) of fresh cut floral waste is disposed of weekly, or an estimated 1,415.20 kg (3,120 lb) or 7.36 m^3 (260 ft^3) per year, from this single retail flower shop (T. Bowden 2019, personal communication, 22 February, 2022). There are an estimated 13,200 retail flower shop locations in the United States (Dun and Bradstreet 2019). States with the highest employment levels of florists included California, Texas, Florida, Missouri, and New York (Bureau of Labor Statistic 2018).

In 2019, the United States imported \$1.31 billion worth of fresh cut flowers (World City 2020). Of the top ten fresh cut flower exporters to the U.S., seven (Colombia, Ecuador, Mexico, Guatemala, Costa Rica, Peru, and Thailand) are considered developing nations (United Nations 2019, World City 2020). While the United States Department of Agriculture (USDA) has stringent guidelines to prevent importation of pests and plant diseases, there are no regulations on pesticide residues in floral crops (USDA 2020). Also, there is a lack of regulation regarding the maximum residue limits allowed on cut flowers, which has led to cut flowers often being sprayed at the maximum recommended dosage of pesticide up until the time of harvest and then shipped directly to market (Toumi et al. 2017). Research investigating residual pesticides on fresh cut flowers found on average 10 active substances per sample and a pesticide load of 15.72 $mg \cdot kg^{-1}$of flowers (Toumi et al. 2016).

Composting is one technique used for pollution abatement in waste management while having the added benefit of acting as an alternative waste management strategy to traditional landfill dumping and has the means to produce a valuable commodity for agricultural, horticultural, and related industries (Walker et al. 2006). According to the U.S. Environmental Protection Agency (EPA), offsite or community composting is one of several environmentally friendly ways to offset waste that would otherwise enter a landfill and is often easier to implement at a local level when decision makers and the general public see the value of such a program (Bradley 2014, EPA 2019). Composting has been proposed as the best available practice to offset the organic fraction of municipal solid waste (Arrigoni et al. 2018). Composting contributes to reducing waste transportation, treatment cost, and landfill volume. Composting is also an innovative way to involve waste generators in their own waste treatment, raising community environmental awareness (Arrigoni et al. 2018). Compost has also been found to break down pesticides through "mineralization," the breakdown of organic compounds into their inorganic and mineral states, volatilization into the atmosphere, and undergoing biotransformation that renders the pesticide inactive (Michael and Doohan 2003).

Vermicomposting is a type of composting whereby worms are incorporated to biologically digest organic materials in combination with microorganisms (Abbasi et al. 2009). Vermicomposting degrades organic matter faster when compared to other composting methods (Rahman et al 2020). The process of vermicomposting makes elements like N, P, K, and Ca more readily available to plants by breaking the organic matter down through microbial activity (Hidalgo and Harkess 2002). The final chemical composition of vermicompost depends on the composition of the initial organic waste and the degree to which the worms have worked the waste (Handreck 1986). The time to decomposition depends on the initial waste mixture being processed but is typically accomplished within 45-60 days (Sharma and Yadav 2017, Shouche et al. 2011). Vermicomposting was also shown to be effective in biotransforming certain pesticides into an oxide (Caceres et al. 2011).

Systems of processing organic waste with earthworms can vary in simplicity and technology requirement (Edwards and Bates 1992). Simple low-cost systems are often comprised of windrows, heaps, or bins in which waste is added in layers at regular intervals, allowing the earthworms to process each layer as they move up through the organic waste (Edwards and Bates 1992). Optimal moisture and temperature maintenance lead to maximum productivity of worms. These conditions can vary depending on the species of earthworm being used to vermicompost (Edwards and Bates 1992). Approximately 0.45 kg (1 lb) of mature worms (approximately 800-1,000 worms) can eat up to half a pound of organic material per day (EPA 2016).

Past research conducted on the vermicomposting of fresh floral waste indicated compost obtained from vermicomposting of fresh flower waste contained nutrients beneficial for plant growth and was an ecofriendly method of disposing of flower waste while at the same time creating a valuable product (Jain 2016, Sharma and Yadav 2017, Tiwari and Juneja 2015). The main objective of this research was to compare the compost produced from vermicomposting fresh cut floral waste against set U.S. industry standards.

Material and Methods

The research was conducted at the R. R. Foil Plant Science Research Center at Mississippi State University in the horticulture greenhouses headhouse from Aug. 2020 – Jan. 2021.

Material collection. Floral waste was collected from the University Flower Shop, a fully functioning retail flower shop, located on Mississippi State University campus. Floral waste was sorted from non-compostable material by the University Florist staff and stored in a trashcan without the use of garbage bags until collection. Flowers used in this study were sourced primarily from South American cut flowers farms in Colombia and Ecuador.

Horse (*Equus caballus* Linnaeus, 1758) manure was collected to be used as an amendment to the vermicompost system. The manure was collected from free range horses fed predominantly on grass that was not treated with insecticides or herbicides. Horse manure has been found to be an excellent composting material due to its ability to decompose quickly while having low odor potential (Rynk et al. 1992). Additionally, horse manure has been found to be a suitable growth medium for worms and does not need any pretreatments, such as washings to remove salts (Norbu 2002).

Dried material such as leaves, and small branches were collected from the cut flower garden located at Mississippi State University. The garden from which the dried material was collected was not treated with insecticides or herbicides.

Worm selection. Vermicomposting was used in the study due to the nature of worms being able to rapidly break down organic matter over a relatively short period of time, typically within 60 days from the time the organic matter is introduced into the composting system, in addition to their ability to process pesticides into neutral compounds. For this experiment, redworm (*Eisenia fetida* Savigny, 1826), also commonly called a red wiggler worm, was selected. It is used regularly in vermicomposting and naturally colonizes in organic waste (Edwards and Bater 1992). Redworms are known to be more durable and more tolerant of temperature and moisture changes in compared to other species of worms (Edwards and Bater 1992).

Vermicompost stacking bins creation. Waste selected for vermicomposting was initially shredded using a mulcher (SuperHandy Wood Chipper Shredder Mulcher Ultra Heavy Duty 7HP 212cc, Great Machinery Corp., Ontario, CA) at a reduction ratio of 15:1. Four separate bins were created, each containing 0.02 m^3 (0.81 $ft^{3)}$ (25%) floral waste and 0.02 m^3 (0.81 ft^3) (25%) horse manure which were combined with 0.04 m^3 (1.62 ft^3) (50%) dried leaf material. Proportions were selected based on past research which found an equal mixture of manure and floral waste to produce the most nutrient-rich vermicompost (Jain 2016). A total of 0.09 m^3 (3.24 ft^3) of the mixture of floral waste, horse manure, and dried leaves was placed into each 1117.34 L (31 gal) rectangle shaped plastic bins for a total of four bins, 0.36 m^3 (12.96 ft^3) total waste. Approximately 1.8 kg (4 lb) (4,000+) worms were placed into each bin. The number of worms added to each bin was determined based on the initial amount of waste being introduced to the bin and the average rate worms can consume organic matter (EPA 2016).

Lids with half inch predrilled holes spaced at 3.81 cm (1.5 in) intervals, to allow for air ventilation, were used to cover each bin. A moisture meter was used to ensure the moisture of all bins was maintained at approximately 70% by taking three readings (Soil Moisture Meter; Guangzhou Amittari Instruments Co., Guangzhou, China) within each bin and averaging. Bin temperature was monitored bi-weekly to ensure optimal temperature range 20-30 C (68-86 F) for vermicomposting with Eisenia fetida (REOTEMP Heavy Duty Compost Thermometer, San Diego, CA).

Table 1. Concentrations of herbicides and insecticides detected in cut floral waste, horse manure, and dried material mixture both before and after vermicomposting in the study of an analysis of the quality of compost produced from vermicomposting fresh cut flower waste.

Pesticide/chemical[z]	Concentration before vermicomposting ($ug{\cdot}kg^{-1}$) (wet wt basis)	Concentration after vermicomposting ($ug{\cdot}kg^{-1}$) (dry wt basis)
Clopyralid	9.07	1.41
MCPA	144	0.00
Clofentezine	0.00	13.9
Lufenuron	0.00	172

[z]1 $ug{\cdot}kg^{-1}$ = 0.001 ppm.

Vermicompost bins feeding schedule. After initial establishment and introduction of worms, the vermicompost bins remained undisturbed for 3 weeks. After 3 weeks, a second set of bins, each with an additional 0.09 m^3 (3.24 ft^3) of bedding material comprised of floral waste, horse manure, and dried leaves, were created and stacked upon the initial bedding material in each of the initial four bins. Each of these new bins included half inch predrilled holes positioned along their bottom and sides at 3.81 cm (1.5 in) spacing. A third and final set of bins were stacked upon the second set of bins after a 3-week period using the same ingredients and percentages as previously stated, within the same sized containers with the same method of predrilling holes along the bottom and sides. Worms migrated from the lower established bins to the upper bins through the pre-drilled holes as the food supplies diminished within the oldest bins. A total of 1.10 m^3 (38.88 ft^3) of floral waste, horse manure, and dried leaf material was added across the four stacking bin systems, 0.27 m^3 (9.72 ft^3) per each stacking vermicompost bin. The worms were then allowed to further decompose the material for 12 weeks.

Sample collection and quality analysis. Two samples of the initial base floral waste, horse manure, and leaf material used throughout the vermicomposting process were collected and sent for analysis to determine the average concentration of herbicides and insecticides within the mixture before vermicomposting (Table 1).

After full decomposition through the vermicomposting process, vermicompost from all bins were mixed together and passed through a 6-mm tumble screen to separate the worms from the finished material, to create one single uniform pile, and to remove any remaining non-organic matter, such as plastics and metals, that may have accidently made their way into the vermicomposting stacking bin system. Collection of samples followed sampling specifications recommended by the Agricultural Analytical Services Laboratory at Pennsylvania State University (2021) and Anatek Labs (2021).

A total of two test samples of the vermicompost material were collected after the vermicomposting processes. For each test sample, the screened vermicompost was collected from three different depths at five locations forming two 3.78 L (1.0 gal) composite samples representative of the overall vermicompost created. One sample was sent to the Agricultural Analytical Services Laboratory's U.S. Composting Council's Seal of Testing Approval (STA) program at Pennsylvania State University (University Park, PA) which tested the sample for percent solids, bulk density, organic matter, pH, soluble salts, total nitrogen, particle size, total carbon, carbon:nitrogen ratio, phosphorus, potassium, calcium, magnesium, aluminum, iron, manganese, sodium, sulfur, arsenic, cadmium, copper, lead, molybdenum, mercury, nickel, selenium, and zinc. Respirometry and bioassay tests were also conducted there to help determine overall maturity and stability of the sample (U.S. Composting Council 2002). Another sample was sent to Anatek Labs (Moscow, ID) for the analysis of residual herbicides and insecticides. These tests evaluated whether vermicomposting rendered the final compost product safe and valuable for horticultural applications.

The pH is a measurement of active acidity/alkalinity or hydrogen ion concentration in the compost (U.S. Composting Council 2001). In conducting tests on the compost, pH readings were taken from a slurry of vermicompost and deionized water at a 1 to 5 ratio created from each sample. The slurry was then shaken at room temperature for 20 min, allowing all salts to dissolve. The pH measurement was then measured from this mixture with an electronic pH meter, conducted by Pennsylvania State University. However, pH readings were "not a measure of the total acidity or alkalinity and cannot be used to predict the effect of compost on soil pH" (U.S. Composting Council 2002). The electrical conductivity, determined through soluble salts amounts was also measured from a slurry of vermicompost and deonized water at a 1 to 5 ratio (Montoya et al. 2013, U.S. Composting Council 2002).

Percent moisture and solid readings were determined at the compost quality testing labs at Pennsilvania State University, by first taking the weight of a sample of the vermicompost. The sample was then dried at 70 (+5) C and re-weighed. The second weight determined percent solids and the evaporated weight determined percent moisture. The percent organic matter was measured by quantifying the amount of solid material combusted relative to the original oven dried sample (Montoya et al. 2013, U.S. Composting Council 2002). Total nitrogen includes all forms of nitrogen: organic nitrogen, ammonium and nitrate. Total nitrogen was calculated using the Total Kjeldahl Nitrogen Semi-Micro Kjeldahl technique. Total carbon was analyzed using the CO_2 Detection Method. This method uses a carbon analyzer (Leo CR-12), combustion, water vapor and an infrared detector to determine the total amount of carbon dioxide produced in the compost sample (Montoya et al. 2013, U.S .Composting Council 2002). The total oxide forms of phosphorus and potassium amounts were also measured (U.S. Composting Council 2002).

Bioassay tests and respirometry (CO_2 evolution) conducted by Pennsylvania State University were used to measure the overall stability and maturity of the compost sample at the compost quality testing laboratory. Bioassay tests analyzed cucumber (*Cucumis sativus* L. 'Marketmore 76′) seedling emergence and vigor to identify potential phytoxin presence. Respirometry was used to measure the relative microbial activity which is an indicator of stability in the sample (U.S. Composting Council 2002).

The sample sent to Anatek Labs was analyzed for methiocarb, 2,4,5-T, 2,4,5-TP, 2,4-D, 2,4-DB, acifluorofen, bentazon, chloramben, clopyralid, dalapon, DCPA, dicamba, dichlorprop, dinoseb, MCPA, MCPP, pentachlorophenol, picloram, triclopyr, clofentezine, flonicamid, lufenuron, and DEET. EPA method 8151 was used to determine the levels of 2,4,5-T, 2,4,5-TP, 2,4-D, 2,4-DB, acifluorofen, bentazon, chloramben, clopyralid, dalapon, DCPA, dicamba, dichlorprop, dinoseb, MCPA, MCPP, pentachlorophenol, picloram, and triclopyr within the vermicompost. Method 8151 is a capillary gas chromatographic method for determining certain chlorinated acid herbicides and related compounds in aqueous, soil and waste matrices. Method 8151 provides extraction, derivatization, and gas chromatographic conditions for the analysis of chlorinated acid herbicides in water, soil, and waste samples (EPA 1996).

EPA method 632 was used to determine the level of methiocarb in the vermicompost. A measured volume of the sample material, approximately 1 L (0.26 gal), is extracted with methylene chloride using a separatory funnel. The methylene chloride extract is dried and concentrated to a volume of 10 mL or less. High-performance liquid chromatographic (HPLC) conditions permit the separation and measurement of the compounds in the extract by HPLC (EPA 1992).

EPA method 8321B was used to determine the levels of clofentezine, flonicamid, and lufenuron. This method provides reversed-phase high-performance liquid chromatographic (RP/HPLC) and thermospray (TS) mass spectrometric (MS) conditions and ultraviolet (UV) conditions for the detection of the target analytes. A gradient elution program is used on the liquid chromatograph to separate the compounds. Quantitative analysis may be performed by either TS/MS or UV detection, using either an external or internal standard approach (EPA 2007).

EPA method 8270D was used to determine the level of DEET in the vermicompost. This method analyzes semi-volatile organic compounds using gas chromatography or mass spectrometry. The semi-volatile compounds are introduced into the GC/MS by injecting the sample extract into a GC equipped with a narrow-bore fused-silica capillary column. The GC column is temperature-programmed to separate the analytes, which are then detected with an MS connected to the GC (EPA 2014).

Data Analysis. Frequency and descriptive data were reported for each protocol on compost quality standard attributes. No true control pile of compost was included within the study since, in typical compost quality testing, compost samples are compared to overall compost quality standards for the industry (Montoya et al. 2013, Meier et al. 2014, Walsh and Waliczek 2020).

Results and Discussion

The bedding material was tested for the following herbicides and insecticides both before and after vermicomposting (Table 1). The U.S. Compost Council does not

Table 2. Compost quality test results of vermicompost created from cut floral waste, horse manure, and dried material using the U.S. Composting Council's Seal of Testing Approval program standards in the study of an analysis of the quality of compost produced from vermicomposting fresh cut flower waste.

Variable (units)[z]	Results (wet wt basis)	Results (dry wt basis)	Normal range (USCC)[y]
pH	7.0	-	5.0-8.5
Soluble salts (mmho·cm^{-1})	3.54	-	1-10
Solids (%)	37.4	-	50-60
Moisture (%)	62.6	-	40-50
Organic matter (%)	15.9	42.5	30-70 (dry wt)
Total nitrogen (%)	0.4	1.1	0.5-2.5 (dry wt)
Carbon (%)	9.2	24.5	<54 (dry wt)
Carbon-to-nitrogen (ratio)	21.60	21.60	<21:1 (dry wt)
Phosphorus (%)	0.20	0.52	-
Potassium (%)	0.33	0.87	-
Calcium (%)	0.29	0.77	-
Magnesium (%)	0.07	0.19	-
Arsenic (mg·kg^{-1})	0.6	1.6	<75
Cadmium (mg·kg^{-1})	<0.2	<0.5	<85
Copper (mg·kg^{-1})	7.3	19.5	<4300
Lead (mg·kg^{-1})	2.2	6.0	<420
Mercury (mg·kg^{-1})	0.010	0.025	<840
Molybdenum (mg·kg^{-1})	1.7	2.6	<57
Nickel (mg·kg^{-1})	1.1	3.0	<75
Selenium (mg·kg^{-1})	<0.9	<2.5	<100
Zinc (mg·kg^{-1})	25.1	66.9	<7500
Bioassay: emergence (% of control)	100.00	-	>90 (very mature)
Bioassay: seedling vigor (%)	100.00	-	>95 (very mature)
Respirometry (mg carbon dioxide/g organic matter/d)	1.8	-	1-2 (stable)

[z]1 mmho·cm^{-1} = 1 dS·m^{-1}, 1 mg·kg^{-1} = 1 ppm, 1 mg/g = 1000 ppm.

[y]U.S. Composting Council (2002).

have established normal ranges of herbicides and insecticides found within compost. Rather, the EPA has established maximum herbicide and insecticide residue limits allowed for a wide variety of food commodities (U.S. Compost Council 2002, USDA 2021). Of the 23 insecticides and herbicides for which tests were conducted, one herbicide (clopyralid) and two insecticides (clofentezine and lufenuron) were found in trace amounts in the sample after vermicomposting (Table 1). However, clofentezine and lufenuron were not detected in the samples taken before vermicomposting, indicating negative dissipation rates (i.e. higher concentrations in the finished material compared to the input material). This effect has been found in past research investigating the dissipation of pesticides in compost systems and is most likely due to sampling uncertainties (Kupper et al. 2008). Past research has found the total errors, i.e. combined sampling and analytical errors, resulting from a compost field study to be approximately 30% (Brandli et al. 2006, Kupper et al. 2008).

Clopyralid is listed as a persistent herbicide by the U.S. Compost Council (2015) and has an estimated half-life of 1-2 years in compost. Clopyralid has been deemed safe for plant use at concentrations of 0.003 ppm or less (U.S. Compost Council 2015). This study found 0.001 ppm or trace amounts in the sample (Table 1). Clofentazine belongs to the tetrazine group of insecticides and is used as an acaricide/ovicide (Ware and Whitacre 2004). In the sample, 0.013 ppm of clofentazine were found (Table 1), which meets EPA industry standards where residues are acceptable within the range of 0.02-7 ppm on varying food commodities (USDA 2021). Lufenuron is classified as a benzoylurea and acts as an insect growth regulator which attacks an insect's nervous system. It is taken up more by ingestion rather than by contact. Within the sample, 0.172 ppm of leufenuron were found (Table 1). The maximum residue limit on food commodities for lufenuron is 1.36 ppm (USDA 2021, Ware and Whitacre 2004).

When compared to STA standards, pH, soluble salts, organic matter, total nitrogen, carbon, carbon-to-nitrogen, bioassay, and respirometry from the tested samples were all found to be within normal ranges for compost sold in the horticulture industry (Table 2). Chemical analysis found the level of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc all to be well below set industry standards (Table 2).

The pH for the compost sample was 7.0 (neutral), and falls within the U.S. Compost Council's (2002) ideal range (5.0-8.5) for compost pH. Past research has found compost microorganisms operate best when the compost pH is neutral to slightly acidic (Trautmann et al. 1996).

Solid salts in the compost sample were 3.54 mmho·cm^{-1} which is well within the ideal range of 1.0-10.0 mmho·cm^{-1} (U.S. Compost Council 2002). Percent solids were low (37.4%) while moisture was high (62.6%) when compared to industry norms (Table 2). The higher moisture level and lower overall solids are most likely due to the nature of floral waste and the manure both being high in moisture content and the fact that worms will reduce the overall amount of organic matter in a compost pile over time (Palsania et al. 2008). This indicates a need for an adjustment to the bedding material used within the vermicomposting system. Dried or looser bedding material could be added to floral waste when creating the initial mixture to achieve ideal norms for compost as set by the U.S. Composting Council (2002).

The total nitrogen and carbon content were within ideal ranges (Table 2). The total carbon to nitrogen ratio was 21.60. Compost with carbon to nitrogen ratios of 30 or higher tend to immobilize nitrogen when added to soil while compost with lower carbon to nitrogen ratios tend to mineralize organic nitrogen, making it available to plants (U.S. Composting Council 2002).

Bioassay tests evaluated the maturity of the compost based on emergence of cucumber seedlings and their overall vigor. Compost is rated as ''very mature'' if emergence readings are greater than 90% and seedling vigor readings are greater than 95% (U.S. Composting Council 2002). Measurements of both seedling emergence and vigor for the vermicompost sample were 100%. Respirometry tests determined the vermicompost sample to be stable (Table 2).

Results showed floral waste collected from retail flower shops has the potential to be used in a vermicomposting system to create a quality compost suitable for use in the horticulture industry. This information is considered valuable due to the limited amount of research investigating the use of floral waste in compost systems. The vermicomposting process appeared to reduce the levels of some pesticide residues while others may have increased in concentrations during the course of the study. Residual chemicals in compost have been a major concern within the compost industry (Kupper et al. 2008). The study was limited in amount of floral waste composted and in the use of one type of composting system. Therefore, findings regarding herbicide and insecticide concentrations could vary in larger studies or when using other types of composting systems. The herbicide and insecticides analyzed in this study were also limited to only those tested for by the commercial laboratory. Testing for additional herbicides and insecticides is recommended in future studies.

In this study, the test protocol indicated the relative moisture of the finished vermicompost was higher than industry norms while the organic matter content was slightly low. This would indicate a need to make adjustments to the initial protocol by utilizing higher carbon content ingredients and/or a drier, looser bedding material in contrast to the manure blend used in this study. Additional research should investigate different floral waste ratio mixtures in a vermicomposting system. Additionally, a cost-benefit analysis is recommended to assess the economic viability of the products and processes involved in producing the end product.

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