Agrotechnology
ISSN: 2168-9881

Moonilall et al., Agrotechnology 2016, 5:2
DOI: 10.4172/2168-9881.1000153

Research Article Open Access

The Effects of Insect Rearing Waste Compost on *Helianthus annuus* and *Tithonia rotundifolia*

Nall I Moonilall[1], Reed S[2] and Jayachandran K[1]*

[1]Department of Earth and Environment, Florida International University, Miami, FL, USA
[2]USDA/ARS Subtropical Horticulture Research Station, Miami, FL, USA

Abstract

In recent years, there has been a greater demand for growing substrates for ornamental plants. However, as cost rises and quantities of these materials become more limited, alternative forms of growing media are now being sought. A study was conducted to test the efficacy of using insect rearing waste as an alternative growing media for plants. Common sunflower (*Helianthus annuus* L.) and Mexican sunflower (*Tithonia rotundifolia* (Mill) S.F. Blake) were grown in different ratios of insect colony waste compost (ICW) combined with cardboard (Cb) (ICW+Cb) and nursery mix (NM) mixtures. The purpose of this experiment was to determine whether insect colony waste (ICW) from fruit fly rearing would sustain plant growth. Selective characteristics of the potting substrates revealed that the ratio of 100:0 ICW+Cb:NM had a 7.6 pH, 0.86 dS m^{-1} EC (salinity), 0.46 g cm^{-3} bulk density, and 50.1 percent water holding capacity at saturation. For common sunflower, there was a significant difference between the 100:0 and 0:100 ICW+Cb:NM blends for plant height, with the 100:0 ICW+Cb:NM mixture having the greatest height. For the Mexican sunflower, the 100:0 ICW+Cb:NM produced significantly more leaves and had a greater stem diameter than some of the other mixtures of potting substrate. There was no indication that the insect colony waste combined with cardboard (ICW+Cb) would inhibit plant growth. ICW+Cb have the potential to be used as an alternative substrate for growing plants.

Keywords: Soilless substrate; Potting media; Flowering plants; Ornamental plants; Container production

Introduction

Within the agricultural and horticultural industries, there has been an increased demand for substrates in which plants are grown and propagated. Much of these growing substrates require the use of harvesting techniques that are detrimental to the environment. Aspects of the surrounding environment are altered when harvesting these materials. This can result in damaging effects to a species' habitat or any other ecological process or service that is obtained from that area. An example of this can be seen during the harvesting of sphagnum peat moss and the effect there is on this wetland habitat [1,2]. Furthermore, peat and other organic soils, found in cold regions, are currently classified as net carbon (C) sinks [3]. Harvesting from these systems combined with projected climatic change in the future may transform these systems into a net carbon source. Soil organic carbon (SOC) will be lost from these systems as a result [3]. It is estimated that organic peat soils make up about one-third of the total SOC pool in the world [4]. Therefore, these systems assist greatly with the sequestration of carbon dioxide (CO_2). With the rising costs and limited supplies of some of the substrate materials used within the agricultural and horticultural industries, growers are looking for alternative substrates, which are economically and environmentally sound, to cultivate plants [1].

An ideal growing substrate should allow for proper plant growth and development, seed germination, and adequate nutrient and watering holding capacity. Chemical and physical properties also should be taken into consideration when selecting a growing media [5]. An understanding of physical characteristics such as bulk density, particle size distribution, porosity, and pore distribution along with chemical properties such as pH, electrical conductivity, and cation exchange capacity are needed when choosing a growing media [7,8]. Both organic and inorganic materials could be used in developing an alternative-growing medium. Materials such as peat, sawdust, wood fiber, coconut fiber, coir, compost, pumice, vermiculite, and perlite are often times mixed to form a soilless growing media [5,8]. Ideally, it is unwise to use a single particular material to grow plants because this may limit certain desirable characteristics. For example, vermiculite may provide adequate water and nutrient holding capacity but may not provide sufficient drainage. Similarly sawdust or coir could improve water holding capacity, however, nitrogen (N) may be immobilized due to a high C:N ratio. A combination of multiple materials would help to correct some limitations reached by only using one particular material. Furthermore, compost has the potential to sequester carbon and soil structure and aggregation within the soil [4]. Ultimately, the selection of materials used in a growing media includes cost, availability, and experience in using the material [5].

There are a variety of waste types that have been successfully used to cultivate plants. Table 1 summarizes various studies that have been done and shows results of using various waste streams. With regards to insect colony waste (ICW), the state of Florida rears sterile fruit flies for pest management purposes [9]. Some of the rearing facilities in Florida can produce up to a million flies on a weekly basis, while other facilities can produce in the hundred millions. As a result, a large amount of insect waste and waste material used to rear the insects are generated. The spent vermiculite with insect droppings and solid remains from an agar-based media used to rear flies is usually discarded. Cardboard is

***Corresponding author:** Jayachandran K, Department of Earth and Environment, Florida International University, SW 8th Street, Miami, FL, USA, Tel: 3053486553, 3053486137; E-mail: jayachan@fiu.edu

Received November 07, 2016; **Accepted** December 07, 2016; **Published** December 14, 2016

Citation: Moonilall NI, Reed S, Jayachandran K (2016) The Effects of Insect Rearing Waste Compost on *Helianthus annuus* and *Tithonia rotundifolia*. Agrotechnology 5: 153. doi: 10.4172/2168-9881.1000153

Author(s)	Type of waste stream	Plant used
[13]	Composted pig manure and perlite	*Cucumis sativus* (cucumber)
[14]	Pruning waste compost	*Lolium perenne* L. (perennial ryegrass) *Cupressus sempervirens* L. (cypress)
[15]	Grape (*Vitis vinifera*) stalk and grapevine marc	*Cucumis melo* (melon) *Solanum lycopersicum* (tomato) *Lactuca sativa* (lettuce) *Capsicum* (pepper)
[16]	Combinations of yard compost, raw coir, composted manure, forest compost, composted bark, and cattle manure compost	*Viburium tinus* L.
[17]	Various waste materials (pine bark, coconut (*Cocos nucifera*) fiber, and sewage sludge compost)	Coniferous plants: *Pinus pinea*, *Cupressus arizonica*, and *Cupressus sempervirens*
[18]	Municipal solid waste compost	*Solanum lycopersicum* (tomato)
[19]	Sewage sludge sugarcane trash compost and synthetic aggregates	*Lactuca sativa* L. (lettuce)
[20]	Biodegradable urban resources (biosolids and greenwaste) biochar	
[8]	Wood fiber, coconut fiber, and rockwool	*Solanum lycopersicum* (tomato)
[21]	Ground reed canary grass (*Phalaris arundinacea*) straw	*Fragaria x ananassa* (strawberry)
[22]	Spent mushroom substrates	*Solanum lycopersicum* (tomato) *Cucurbita pepo* L. (courgette) *Capsicum annum* L. (pepper)
[23]	Grass and pruning waste compost, vermicompost, and slumgum compost	*Rosmarinus officinalis, Cupressocypceris leylandii, Lactuca sativa, Allium cepa Petunia x hybrid Viola tricolor*
[24]	Municipal solid waste, sewage sludge composts, and bark	*Pistacia lentiscus* L.
[25]	Pine bark	*Fragaria x ananassa* (strawberry)
[26]	Palm waste	*Cucumis sativus* (cucumber)
[27]	Sawdust, powder of coconut coir, powder of maize (*Zea mays*) core, powder of soybean (*Glycine max*) stalk, and powder to peanut (*Arachis hypogaea*) hull	*Impatiens hawkeri* (impatiens)
[28]	Sawdust, powder of coconut coir, powder of maize (*Zea mays*) core, powder of soybean (*Glycine max*) stalk, and powder to peanut (*Arachis hypogaea*) hull	*Cyclamen persicum*
[29]	Almond (*Prunus dulcis*) shell waste	*Cucumis melo* (melon) *Solanum lycopersicum* (tomato)
[2]	Sweet corn tassels	*Solanum lycopersicum* (tomato)
[30]	Wood pellet biochar and pelletized wheat (*Triticum aeestivum*) straw biochar	*Solanum lycopersicum* (tomato) *Tagetes patula* (marigolds)
[31]	Potato (*Solanum tuberosum*) anaerobic digest and wood pellet biochar, wheat straw biochar, and pennycress presscake	*Solanum lycopersicum (tomato) Tagetes patula (marigolds)*
[32]	Spent mushroom substrate, perlite, and vermiculite	*Cucumis sativus* (cucumber) *Solanum lycopersicum* (tomato)
[33]	Biochar combined with humic acid	*Calathea insignis*

Table 1: Summary of studies on various waste streams as alternative growing media.

a material that is most times discarded after use but can serve a variety of purposes. A study conducted by Chong [10] looked at incorporating cardboard with compost to be used for growing plants in containers.

The objective of this research study was to test the efficacy of insect colony waste plus cardboard (ICW+Cb) as an alternative growing media for successful growth of *Helianthus annuus* and *Tithonia rotundifolia* and to determine characteristics of the ICW+Cb used. It was hypothesized that amendments of ICW+Cb would increase growth and development of both species of plants being grown in this media.

Materials and Methods

Insect colony waste plus cardboard

The United States Department of Agriculture-Agriculture Research Service Subtropical Horticulture Research Station (USDA-ARS-SHRS) in Miami, Florida provided materials for the compost, which included cardboard (Cb) from greenhouse cooling pads and insect colony waste (ICW) from fruit fly rearing. Insect colony waste consisted of a semi-solid agar-based media used in fruit fly larval rearing and spent vermiculite bedding used for pupation. A detailed explanation of the creation and process of obtaining the ICW can be found in Reed et al. [9].

The ICW was a result of media (or diet) used to rear fruit fly (*Anastrepha suspensa*) larvae and the vermiculite used during the pupation of the mature fruit fly larvae. The media that was created for the fruit fly was done by adding 1,296.43 g wheat germ, 1,296.43 g torula yeast, and 1,296 g sugar, 91.6 mL HCl, 65.36 g agar, 21.61 g sodium benzoate, 21.61 g methyl 4-hydroxybenzoate, and 10.80 g cholesterol into 20 L of water. Eggs of *A. suspensa* were then added to trays (58.42 cm × 27.94 cm × 5.08 cm) containing two liters (L) of media. The trays were stored in the fruit fly colony room at the USDA-ARS-SHRS at 26°C. At the end of eight days, the mature larvae were removed from the diet by washing with tap water. One kilogram (kg) of mature larvae was then added to four liters of vermiculite and allowed to pupate. At the end of 12 days, the pupated larvae were removed from the vermiculite and the spent vermiculite was stored in plastic barrel drums. To prepare the colony waste, two trays containing the larvae diet was washed through a 2 mm sieve into a bucket (19 L) containing 2/3 volume of spent vermiculite. The bottom of the bucket was removed and replaced with a 0.25 mm screen mesh. Mature larvae were thoroughly washed to remove any diet that was left. The water used to do the washing was allowed to drain freely in the bucket with the spent vermiculite. The resulting mixture of vermiculite and diet media wash was composted for duration of six weeks and allowed to air dry. The compost was then stored until needed [9].

Cardboard used for this study was dried and chipped into dimensions of 2 cm by ½ cm and combined with the ICW. The ICW+Cb were then composted for six months at the USDA-ARS-SHRS. The compost was turned every two weeks. Prior to potting, the material was steamed for 24 h at 100°C, allowed to cool, then steamed again for an additional 24 h at 100°C.

Potting substrate	pH	Salinity (dS m^{-1})	B_d (g cm^{-3})	PW_{Sat}
0% ICW+Cb: 100% NM†	5.8	0.07	0.137	42.9
30% ICW+Cb: 70% NM†	7.5	0.39	0.258	44.7
70% ICW+Cb: 30% NM†	7.4	0.71	0.384	48.4
100% ICW+Cb: 0% NM†	7.6	0.86	0.463	50.1

Potting substrate consisted of composted insect colony waste with cardboard (ICW+Cb) plus different blends with a nursery mix (NM) containing 50% pine bark, 10% sand, and 40% coir pith.

Table 2: Potting substrate mean values for pH, salinity, bulk density (B_d) and percent water holding capacity at saturation (PW_{Sat}) for different treatment groups of potting substrates to be used in plant study.

Potting substrate	Plant height	Number of leaves	Stem diameter	Number of buds
0% ICW+Cb: 100% NM	27.5 b*	21	9.5	1
30% ICW+Cb: 70% NM	30.2 ab	21.8	9.7	0.7
70% ICW+Cb: 30% NM	31.1 ab	20.5	10.9	0.9
100% ICW+Cb: 0% NM	33.2 a	19.7	10	0.9

*Mean values in columns followed by a common letter are not significantly different at *p*=0.05. ns: Not significantly different at *p*=0.05.

Table 3: Common Sunflower (*Helianthus annuus*) mean values for height (cm), number of leaves, stem diameter (mm), number of buds, produced in different insect colony waste plus cardboard compost (ICW+Cb): nursery mix (NM) ratios.

Experimental design

A greenhouse plant growth study was conducted at one of the greenhouses at the USDA-ARS Subtropical Horticulture Research Station. The two plant species tested were common sunflower (*Helianthus annuus* L.) and tithonia (*Tithonia rotundifolia* (Mill.) S.F. Blake). The two species were grown in a mixture of composted insect colony waste plus cardboard (ICW+Cb) and a nursery mix (NM) in the following ratios: 0:100, 30:70, 70:30, and 100:0 ICW+Cb to NM. The nursery mix consisted of 50% pinebark, 10% sand, and 40% coir pith.

Potting material was analyzed for pH, Electrical Conductivity (EC) (salinity), bulk density (B_d), and percent Water Holding Capacity (WHC) at saturation. To measure pH and salinity, a dual channel pH/ ion/ conductivity meter was utilized. For each of the four ratios of soil mixture, 90 mL of soil was measured out and combined with 90 mL of reverse osmosis water (ROH_2O). This created a 1 to 1 soil to water ratio by volume. This mixture was then shook for 30 min and then placed in a centrifuge. After being centrifuged, the liquid was decanted. Measurements of pH were taken first followed by electrical conductivity measurements for each of the potting material. Bulk density was obtained by gathering 135.37 cm^3 (cylinder with dimensions 5.98 cm for height and 5.37 cm for diameter) of each potting mixture and oven drying it at 110°C. Percent WHC at saturation was determined by obtaining 50 mL of each potting mixture respectively in a beaker and dripping water, from a burette, into the mixture until it became completely saturated. Each of the tests conducted on the potting mixes were completed in duplicate.

For the greenhouse study, seeds for the two flower species were planted in two inch uncovered liners and allowed to germinate. When plants were 5 cm in height, they were transplanted into 2.48 L pots (15.6 cm × 15.9 cm) with the appropriate potting mix. Approximately 8.036 g of fertilizer was added to each pot in each treatment group. The fertilizer used was a 13 N -13 P_2O_5 -13 K_2O blend of Nutricote® Total Controlled Release Fertilizer (Florikan E.S.A. Corp. Sarasota, Florida, U.S.A.). The components of the fertilizer were as follows: 13% total N (6.5% NO_3, 6.5% NH_4), 13% P_2SO_5, 13% K_2O, 1.2% magnesium (water soluble), 0.02% boron, 0.05% copper (water soluble), 0.20% iron (chelated iron), 0.06% manganese (water soluble), 0.02% molybdenum. Watering was accomplished utilizing drip irrigation three days a week for a total of 5 min each day. There was an initial amount of 157 mL of water being dispensed into each pot with an initial 10% of applied water leaching through the pot. Although not measured, it was observed that there was still adequate water draining from the pots. The design of the experiment was set up so that there was two plant species (*Helianthus annuus* L. and *Tithonia rotundifolia* (Mill.) S.F. Blake), four treatment groups (0:100, 30:70, 70:30, and 100:0 ICW+Cb to NM), and 10 replications per treatment. Once plants were transplanted into their respective pots, this signified the start of the experiment. Each pot was randomly sequenced at the end of each week. Plant data was taken at the 30 days and 60 days. Measurements that were recorded include plant height, number of leaves, stem diameter, bud count, and root mass. Stem diameter was measured using a caliper. The root mass was obtained after plants were harvested and washed to remove potting media. The roots were then excised at the base of the stem. Roots were oven dried at 45°C before weight was recorded. Plant height was measured from the base of the stem, right above the soil surface, to the top most leaf of the plant. Number of leaves and buds were counted respectively for those portions of the plant. The experiment lasted a period of 60 days until each plant had flowered.

Statistical analysis

Statistical analysis of the data was performed using SAS, version 9.4. The data collected for all plant parameters were subjected to analysis of variance using the general linear model (GLM) of SAS. The data that was collected were categorized into four treatment groups-0:100, 30:70, 70:30, and 100:0 ICW+Cb to NM. When there was an indication of a statistically significant difference at $p<0.05$, a post-hoc comparison utilizing the Tukey-Honest Significant Differences (HSD) test was carried out.

Results

Table 1 shows selective characteristics of potting substrates used for the different ICW+Cb:NM mixtures. The 100:0 ICW+Cb:NM mixture was the highest in pH, electrical conductivity, bulk density, and percent WHC at saturation followed by 70:30, 30:70, and 0:100 ICW+Cb:NM. The 0:100 ICW+Cb:NM yielded results that were lower than 100:0 ICW+Cb:NM. A pH of slightly alkaline was maintained in all mixtures above 30% ICW+Cb:NM. EC was low, with the 100% ICW+Cb:NM being suitable for salt sensitive plants. WHC increased as the percent ICW+Cb increased; however an increase to 42% ICW+Cb doubled B_d of the substrate. The amount of ICW+Cb used in a mixture should depend on the pH of the media and the drainage requirement of the plant.

A statistically significant difference was indicated for plant height for the common sunflower: $F_{(3,36)}=3.19$, $p<0.035$. The results followed the order of 100:0 ≥ 70:30=30:70 ≥ 0:100 (Table 2). There was a significant difference between the 100:0 and 0:100 ICW+Cb:NM blend for plant height. Stem diameter, number of leaves, and number of buds were each similar in all treatments. No characteristic of ICW+Cb reduced growth compared to the commercial nursery mix control. Visual observation showed that plants grown in the 100:0 ICW+Cb had larger leaves overall than those grown in 0:100 ICW+Cb.

There were no treatment differences in plant height, number of buds and root weight with tithonia (Tables 3 and 4). Plant height for tithonia followed the order of 100:0>70:30>30:70>0:100. A statistically significant difference was found for stem diameter for tithonia: $F_{(3,28)}=9.67$, $p<0.0002$. An ICW+Cb:NM content of 100:0 produced plants with a greater stem diameter than the 0:100, 30:70, and 70:30

Potting substrate	Plant height	Number of leaves	Stem diameter	Number of buds	Root dry weight
0% ICW+Cb: 100% NM	32.6	88.0 ab	8.0 b	3.4	1.8
30% ICW+Cb: 70% NM	39.8	71.0 b	9.0 b	4.2	2.5
70% ICW+Cb: 30% NM	39.3	81.0 ab	8.9 b	3.1	2.8
100% ICW+Cb: 0% NM	38.8	97.3 a	11.0 a	4	4.2

*Mean values in columns followed by a common letter are not significantly different at p=0.05. ns: Not significantly different at p=0.05.

Table 4: Mexican Sunflower (*Tithonia rotundifolia*) mean values for height (cm), number of leaves, stem diameter (mm), number of buds, and root dry weight (g) produced in different insect colony waste plus cardboard compost (ICW+Cb): nursery mix (NM) ratios.

ICW+Cb:NM compost blends. A statistically significant difference existed for number of leaves for tithonia plants: $F_{(3,28)}$=4.70, p<0.01. The 100:0 mixture produced significantly more leaves than the 30:70 ICW+Cb:NM.

Discussion

There is no indication that ICW+Cb would inhibit plant growth. It was hypothesized that the amendments of ICW+Cb would increase growth and development of the two plants being grown. All plants grown in this study exhibited growth that would have been greater than or equal to growth using the Nursery Mix (NM). This is an indication that ICW+Cb can be an amendment with a tradition nursery to cultivate floral plants.

Composted ICW+Cb can be used in a combination with other materials to create a potting mix that is high in nutrients. Reed [9] reported that ICW contained moderate to very high levels of N, K, Mg, Fe, Zn, and Cu plus low to moderate levels of P. Fertilizer use would be minimized by utilizing ICW due to the high nutrients that are available for the plant for the duration of one growing season. Addition of composted ICW+Cb increased the bulk density and drainage while maintaining its ability to hold a higher content of water than the commercial nursery mix. A higher bulk density provides adequate structural support for large plants. Too much of an increase in bulk density can create a disadvantage where there is a reduction of porosity and thus air capacity for the potting media in which the plant is growing [11]. Furthermore, from a nursery management perspective, an increase in bulk density would result in higher transportation costs of the media due to increased weight [11]. Abad [12] provided evidence that the optimal range for bulk density for container media should be close to or less than 0.4 g cm^{-3}. All of the treatment groups within this study fell within that range except for 100:0 ICW+Cb:NM. Optimal pH range for both plant species is between pH 6.0-7.5. The soil pH values of the growing mixes with 30%, 70%, and 100% ICW+Cb all had values that fall within this range. The 0% ICW+Cb treatment group had a pH value lower than the optimal range for this species. The addition of the ICW+Cb allowed for the pH to increase with a minimum of 30% addition. Optimal availability for plant nutrient uptake for both macronutrients and micronutrients are available at pH levels of 6.0 to 7.5, the optimal pH at which sunflowers grow. Growing in a medium with the appropriate pH levels would ensure that nutrients are being obtained efficiently and that the plant is growing without limitations. Addition of up to 30% ICW+Cb to a potting substrate can reduce the amount of fertilizer and irrigation water applied to plants. This will have the potential to save growers money and at the same time conserve natural resources within the environment. Composted ICW+Cb could be a great component of soilless growing media and could, as a considerable waste product, be utilized as an amendment to boost productivity of plant growth.

Acknowledgements

We would like to give special thanks to the Subtropical Horticulture Research Station (USDA) and the Agroecology Program at Florida International University for their continued support of our academic endeavors. Funding for this project was provided by USDA NIFA Multicultural Scholars Program (2009-38413-05236). Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors.

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