CONVERTING INSECT COLONY WASTE INTO A POTTING SUBSTRATE

Stewart Reed, Nancy D. Epsky, Robert R. Heath, USDA-ARS, Miami, FL, USA;
Ricardo Joseph, Florida International University, and USDA-ARS, Miami, FL, USA

Abstract

Insect rearing generates both solid and semi-solid waste that is generally discarded in landfills. A study was initiated to determine if the semi-solid insect colony waste product and vermiculite used in insect rearing could be combined and used as a growth substrate for plants. The semi-solid larval diet was washed through the vermiculite used as an insect pupation substrate. The resulting material was drained and air-dried for approximately seven days. This material was tested as a potting substrate in two studies. In the first study radish (Raphanus sativus L.) was grown in either a commercial potting mixture or in blends of colony waste (CW) and equal parts compost plus peat (CP) in ratios of 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 CW:CP. In the second study squash was grown in CW:sand (S) mixtures in ratios of 0:100, 20:80, 30:70, 50:50, 70:30, 80:20 and 100:0. Mixes of 80:20 and 100:0 CW:CP had radish germination rates equal to that of both the commercial potting mix and 0:100 CW:CP. Radish plants grown in 80:20, 60:40 and 40:60 CW:CP resulted in shoot dry weights higher than that produced in the commercial mix and significantly higher than the 100:0, 20:80 and 0:100 CW:CP. Squash plants grown in 20:80, 50:50 and 30:70 CW:S developed more nodes than those grown in only sand (0:100 CW:S). Both shoot and root dry weights for squash were highest in the 20:80 CW:S treatment. No substance in the CW appeared to be detrimental to plant growth. As a potting substrate there were no differences in plant performance among the CW, the commercial mix or the CP.

Introduction

The rapid growth in horticultural production has led to the need to replace expensive imported Canadian peat with alternative low cost potting substrates. A potting substrate should provide an appropriate matrix for seed germination, support for the growing seedling, and allow rapid gas exchange between the rhizosphere and atmosphere. In addition, the substrate should have adequate nutrient and water holding capacity. Organic material may have several effects on plant performance, such as, the effect of humic substances on membrane permeability and enzyme activity (Pinton et al., 1992), a stimulation of growth and nutrient adsorption (Ayuso et al., 1996), and an enhanced microbial activity. Inorganic materials with high cation exchange capacities (CEC) include vermiculite can be used as potting substrates. The high CEC can provide a steady stream of nutrients despite the high volume of irrigation water passing through the pots. However, if used alone the greater bulk density of inorganic material may affect germination and subsequent growth. Agricultural and industrial waste with appropriate physical characteristics offer attractive sources of potting substrates. However, these materials may contain pathogens, pesticides, heavy metals and other substances harmful to plant growth.

Tephritid fruit flies are often reared in large numbers for use in pest management activities such as sterile insect release (Knipling 1955). The mass rearing facility in Florida can produce up to three million flies per week (Holler and Harris 1993). The process uses large quantities of agar-based media for larval rearing and inert substances such as vermiculite as a pupation substrate. This process generates two different types of insect colony waste: the spent vermiculite with any insect debris and the semi-solid remains of the agar-based media. These materials are generally discarded. A study was initiated to determine if the colony waste could be combined and used as a growth substrate for plants.

Materials and Methods

Media preparation: Waste materials were obtained from the fruit fly colony maintained at USDA, ARS, Subtropical Horticulture Research Station in Miami, FL. The semi-solid agar-based media or diet contains 91.6 mL HCl, 1296.43 g wheat germ, 1296.43 g torula yeast, 1296.43 g sugar, 65.36 g agar, 21.61 g methyl 4-hydroxybenzoate, 21.61 g sodium benzoate and 10.80 g cholesterol in a total volume of 20 liters of water. The diet was poured into 58.42 x 27.94 x 5.08 cm trays, a layer of eggs added and incubated at 26 °C for eight days. Mature larvae were removed from the diet for subsequent pupation by washing with tap water.

Materials and Methods cont.

Vermiculite preparation: One kg of mature larvae was placed on 4 liters of vermiculate for pupation. After 12 days, pupae were removed and spent vermiculite was stored in dry plastic drums.

Colony waste preparation: The bottom of a 19 L (five-gallon) bucket was removed and securely replaced by a 0.25 mm-screen with a < 16-mesh nylon insert to create a mixer. The bucket was filled 2/3 to the top with spent vermiculite. As the vermiculite was continually stirred, two trays of spent larvae diet were carefully washed with running tap water through a 2-mm screen (to collect remaining mature larvae) into the bucket. Mature larvae remaining on the screen were washed until diet media was completely removed. Water used to wash the larvae was allowed to drain through the spent vermiculite. The spent vermiculite/diet media wash was air dried at ambient temperature prior to use as a potting substrate (colony waste, CW).

Plant studies: Two plant growth studies were conducted to determine if the insect colony waste could be an acceptable substitute for soil as a potting substrate.
Study 1 was conducted outside in a screened enclosure. Treatments included a commercial potting mixture (equal parts compost plus peat (CP)) or a blend of 100:0, 80:20, 60:40, 40:60, 20:80 or 0:100 CW:CP. There were 10 replicates of each treatment for a total of 70 pots. One radish (Raphanus sativus L.) seed was planted 1.3 cm deep in each 3.7 L pot. An automated overhead sprinkler system was set up to irrigate the pots twice a day delivering 60 to 70 mL per pot. Ten g of 10-10-10 fertilizer (N as ammonium nitrate and urea, P as diammonium phosphate and K as muriate of potash with minor amounts of Mn, Cu and Zn as sulfates and Fe-EDTA) plus 2 g triple super phosphate were applied to the surface of each pot. Pots were monitored to determine percent germination, the number of days from planting to emergence (DTE) and the number of days after emergence to develop the first node (DTFN). All plants were harvested on 5 May 2005, 23 days after planting. Shoots were cut off at the soil surface and oven dried at 55 °C before dry weights were determined. The remaining potting mix was gently washed from the roots. Roots were similarly oven dried before dry weight determination.

Table 1. Nutrient content in ppm of insect colony waste filtered through vermiculite used in insect rearing.

Sample Date	NO^3	NH^4	P	K	Mg	Ca	Zn	Fe	Cu
6/13/2005	8 M*	230 VH	4.1 M	290 VH	106 VH	90 VL	4.2 H	217 VH	1.8 H
5/5/2005	10 M	47 L	1.3 L	91 M	184 VH	660 H	3.2 M	191 VH	1.5 H
6/24/2005	9 M	219 VH	3.2 M	310 VH	110 VH	130 VL	5.4 H	211 VH	2.0 H

* M = moderate, VH = very high, H = high, L = low, and VL = very low.

Study 2 was conducted in a greenhouse with squash (Cucurbita pepo L.) planted in one of seven different mixtures of CW and sand (S) in ratios of 0:100, 20:80, 30:70, 50:50, 70:30, 80:20 and 100:0 CW:S. Enough of each potting mixture to fill a 15 L pot was mixed with 10 g of 10-10-10 fertilizer and 2 g triple super phosphate and added to pots. There were 10 pots containing each CW:S mixture for a total of 70 pots. Each pot was watered to field capacity (FC). Pots were maintained at FC with daily watering (60-130 mL of water). Plant height was measured at 13 and 21 DAP. Plants were harvested 21 DAP dried and weighed as described above. Soil compaction in kg cm-2 was measured with a Pocket Penetrometer (Forestry Suppliers, Inc., Jackson, MS). Pot temperature was measured between 10:00 A.M. and 12:00 P.M. at the soil surface with an infrared thermometer (Raytek Corporation, Santa Cruz, CA).

Statistical analysis: An ANOVA and mean separation were performed using Fishers' Least Significant Difference Test in SAS System, ver. 9.1. (SAS, 2003) at $\alpha < 0.05$.

Results

Table 1 lists the nutrient content of the insect colony waste collected on three separate dates. The pH of fresh colony waste ranged between 6.0 and 6.8. Nitrogen, K, Mg, Zn, Fe and Cu content gave values in a range high enough to support optimum plant growth for one growing season. Phosphorus and Ca analysis gave values that were determined to be low enough to recommend supplemental additions of these nutrients. Plants in both studies were fertilized as described in the Materials and Methods section.

The percent germination and growth rate of radish plants is given in Table 2. CW:CP ratios of 80:20 and 100:0 had germination rates equal to that of both the commercial potting mix and 0:100 CW:CP. Radish seedling emergence in 100:0 CW:CP was significantly slower than all other treatments. However, the radish growth rate from emergence to development of the first node (DTFN) for the 100:0 CW:CP treatment was similar to all other treatments except the 0:100 CW:CP. The 0:100 CW:CP had the slowest growth rate. At the time of harvest only the 40:60 CW:CP (5 plants), 60:40 CW:CP (3 plants) and 20:80 CW:CP (1 plant) had plants that developed a third node.

Table 2. The percent germination, days to emergence (DTE) and days after emergence to develop the first node (DTFN) of radish (Raphanus sativus L.) in potting mixtures containing either a commercial potting mix, or 100:0, 80:20, 60:40, 40:60, 20:80 or 0:100 colony waste, compost:peat mixtures.

Potting mixture	Percent germination	DTE	DTFN
Commercial	100	3.4 b*	7.7 b
100% CW	100	5.1 a	7.8 b
80% CW	100	3.4 b	7.5 b
60% CW	90	3.1 b	6.6 b
40% CW	90	2.7 b	6.9 b
20% CW	90	2.9 b	7.8 b
0% CW	100	3.0 b	10.3 a

* Values followed by the same letter are not significantly different by Fisher's LSD test.

Table 3. Plant height and dry weight of radish grown in different colony waste: peat (CW:P) ratios.

Potting mixture	shoot dry weight (g)	root dry weight (g)
Commercial	0.48 bc*	0.096 bc
100% CW	0.28 d	0.035 c
80% CW	0.68 a	0.259 a
60% CW	0.70 a	0.135 b
40% CW	0.61 ab	0.093 bc
20% CW	0.35 cd	0.163 ab
0% CW	0.18 d	0.119 bc

* Values followed by the same letter are not significantly different by Fisher's LSD test.

Radish plants grown in CW:CP mixtures of 80:20, 60:40 and 40:60 resulted in shoot dry weights higher than that produced in the commercial mix (Table 3) and significantly higher than the 100:0, 20:80 and 0:100 CW:CP. Root dry weights were highest in the 80:20 CW:CP treatment.
In the second study, squash was grown in various CW:S ratios. As the sand content increased, resistance to penetration at the surface increased (Table 4). Regression of percent sand and penetration gave a correlation coefficient of r2 = 0.84. Plants grown in 20:80, 50:50 and 30:70 CW:S developed more nodes than those grown in only sand (0:100 CW:S). In addition, increasing the CW content had no effect on surface T °C in the pots.
Plant height was greatest 13 DAP in the 0:100 and 20:80 CW:S treatments (Table 5). At 21 DAP, plant height followed the order 20:80 > 30:70 ≥ 0:100 = 50:50 ≥ 100:0 = 80:20 ≥ 70:30. Both shoot and root dry weights were highest in the 20:80 CW:S ratio treatment.

Table 4. Potting substrate resistance to penetration (Pent), the number of plant nodes developed by harvest, and potting substrate surface temperature.

CW:S ratio	Pent (kg cm^{-2})	Node number	T (°C)
0:100	0.25 c*	4.5 c	34.4 ns[t]
20:80	0.37 a	6.9 a	34.6 ns
30:70	0.28 b	5.7 b	33.7 ns
50:50	0.25 c	5.8 b	34.7 ns
70:30	0.18 d	4.9 c	34.3 ns
80:20	0.17 e	5.2 bc	33.9 ns
100:0	0.08 f	5.2 bc	33.5 ns

* Values followed by the same letter are not significantly different by Fisher's LSD test.
[t] ns = not significant.

Summary

Nutrient analysis revealed low amount of P and Ca in colony waste. Nitrogen, K, Mg, Zn, Fe and Cu contents were high enough to support optimum plant growth for at least one growing season. As a potting substrate, there were no differences in plant performance between the 100:0 CW:CP, 0:100 CW:CP or the commercial mix. Overall, radish plants grown in 60:40 and 80:20 CW:CP mixtures performed best. Squash shoot and root dry weights were higher in 20:80 CW:S ratios. No substance in the CW appeared to be detrimental to plant growth.

Table 5. Plant height and dry weight of squash grown in different colony waste: sand (CW:S) ratios.

CW:S ratio	shoot height (cm)		shoot dry weight (g)	root dry weight g)
	13 DAP	21 DAP		
0:100	3.7 a*	11.7 b	0.64 d	0.36 bcd
20:80	3.8 a	16.9 a	2.85 a	0.73 a
30:70	3.1 ab	13.2 b	1.67 bc	0.38 bc
50:50	2.9 ab	11.7 b	1.98 b	0.46 b
70:30	2.5 b	8.3 c	1.13 cd	0.25 d
80:20	2.8 ab	10.1 bc	1.30 bcd	0.23 d
100:0	2.2 b	10.4 bc	1.17 cd	0.28 d

* Values followed by the same letter are not significantly different by Fisher's LSD test.

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