WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.6 (1) : 89-91. 2008
www.world-food.net

Pot production of pecan seedlings with 'Cynthiana' grape pomace

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Received 5 September 2007, accepted 29 November 2007.

Abstract
In the last 10 years grape production in Oklahoma has risen from 68 ha to more than 212 ha. With the increase in grape growing and wine making comes the need to find appropriate means for disposal of the winery waste bi-product, pomace. The objective of this study was to determine if grape pomace could be used as a substrate component for producing pecan (*Carya illinoinensis* Wangenh. C. Koch.) seedlings. The pomace, consisting mainly of 'Cynthiana' (*V. aestivalis* L.), was mixed in 10% increments by volume with a soilless medium from 0 to 100%. Each increment had 10 replications for a total of 110 pots. 'Giles' pecan seeds were pre-germinated and planted one per pot. Initial electrical conductivity was extremely high (> 4000 µmhos/cm) at 20% or greater grape pomace. Inclusion of grape pomace up to 30% had no detrimental effect on pecan seedling growth. Root growth of seedlings established in substrates containing 40% or more grape pomace was significantly less than the 0 to 30% pomace. At 80% or greater pomace content, plant mortality was 80% or more and the plants that were not dead had minimal root development. Leaf necrosis symptoms consistent with saline conditions were observed on many of the pecan seedlings. The observed damage with 50% or greater pomace content may be due to the high salinity of the grape pomace, where EC levels exceeded 8000 µmhos/cm. In this study, 'Cynthiana' grape pomace did not improve pecan seedling growth and development over the control treatment and was detrimental at higher volume percentages.

Key words: *Vitis aestivalis*, *Carya illinoinensis*, soilless media, biowaste, grape, pot production.

Introduction

Winegrape production has increased dramatically in Oklahoma since the turn of the century. In the last 10 years grape production has risen from 68 ha to more than 212 ha (unpublished), with many acres producing French American hybrid or American grapes. The number of licensed wineries has also grown substantially from four in 2001 to 50 in 2007 (unpublished). With this increase in grape growing and wine making comes the necessity to find appropriate ways to dispose of the pomace, a winery waste bi-product. Grape pomace has been used in previous studies as a substrate component to produce various crops, such as strawberries (*Fragaria × ananassa* Duch.) and ornamental plants[1, 2]. A few applications of grape pomace have been researched. Most research has focused on determination of microbiological characteristics and potential pathogenic properties of the composted product [3]. Mandelbaum *et al.* [3] reported that composted grape pomace suppressed *Pythium aphanidermatum* (Edson) Fitzp. alone and in mixtures with peat. They also stated that grape pomace compost may have application to greenhouse and nursery production of species susceptible to *P. aphanidermatum*. Linderman and Davis [4] showed that composted grape pomace in combination with mycorrhizal fungi was beneficial for plant growth of onion (*Allium cepa* L.). They surmised that the excess P provided by the grape pomace could be beneficial in situations that were P-limiting.

Other studies have reported that pH, carbon:nitrogen (C:N) ratio, and moisture content of recently compressed grape waste can produce a satisfactory compost product [1, 2, 5]; although reports of electrical conductivity (EC) levels have varied from adequate [2] to high [6]. A high EC could prove problematic to a crop like pecans that has a low salt tolerance [7]. Overall, Manios [2] suggested that composted grape pomace benefits the physical structure of a growth substrate and has the added bonus of a slow release of nutrients.

The objectives of this study were to determine the optimum amount of grape pomace to use as a component of a soilless substrate for producing pecan seedlings and to determine if 'Cynthiana' pomace is suitable for use as a growth medium

Materials and Methods

Composted grape pomace was collected 6 April 2006 at Summerside Winery in Vinita, Okla. from material that was crushed the previous September. Exact composition of the pomace was unknown, but the majority constituent (>90%) was 'Cynthiana' with minor amounts of 'Vignoles', 'Cabernet Franc' and 'Chambourcin'. The pomace was mixed in 10% increments by volume with MetroMix 300 (Sun Gro Horticulture, Vancouver, B.C., Canada) from 0 to 100%. Each increment had 10 replications for a total of 110 pots in a completely randomized design. 'Giles' pecan seeds were pre-germinated according to the protocol of Smith *et al.* [8] and planted one per 10 cm x 10 cm x 35 cm pot. All nuts had radical development before planting. Initial bulk media nutrient testing was done with the saturated media extract method (SME) [9] (Table 1). Plants were grown in a shade house and watered daily, or as necessary. They were fertilized in accordance with

Table 1. Pre-plant bulk measurements of media pH, nitrate-N, P, K, B and EC for various levels of 'Cynthiana' grape pomace.

Pomace %	Soil pH	NO_3-N ($mg \cdot kg^{-1}$)	NH_4-N ($mg \cdot kg^{-1}$)	P ($mg \cdot kg^{-1}$)	K ($mg \cdot kg^{-1}$)	B ($mg \cdot kg^{-1}$)	EC (μmhos/cm)
0	6.0	157	3	34	241	0.4	3,400
10	6.2	171	14	68	531	0.6	3,990
20	7.2	165	24	132	1,474	0.9	5,510
30	6.9	149	25	185	1,964	1.0	6,120
40	7.1	119	39	237	2,357	1.2	6,720
50	7.6	82	40	280	2,847	1.2	7,680
60	7.5	56	79	419	3,291	1.5	8,880
70	7.6	0	59	613	4,446	1.6	10,540
80	7.5	0	51	619	5,032	1.9	11,710
90	7.7	1	.[z]	935	6,434	2.1	14,450
100	7.5	0	76	1,136	7,487	2.4	17,970

[z]Missing observation.

guidelines established previously where all treatments were fertilized monthly with 13 g/pot Osmocote 14N-6P-11.6K (Grace-Sierra International, Milpitas, California, USA) and at 45-d intervals with soluble trace element mix at 45 $mg \cdot L^{-1}$ (Peters Plant Products, Marysville, Ohio, USA) until the solution drained the pot. Zinc was applied as a foliar spray until run-off at 2-week intervals using 3.6 $g \cdot L^{-1}$ of 36% $ZnSO_4$ [10]. The nuts were planted on 14 Apr. 2006 and harvested four months later on 14 Aug. 2006. Destructive measurements at the end of the study included plant height, trunk caliper, and fresh and dry weights of leaves, stem, and roots. Dry weights were determined by drying the tissues at 65°C for 5 d in paper bags and then weighing. Data were analyzed with analysis of variance in JMP 5.1 (SAS Institute, Cary, N.C.) using the Fit Model procedure and means were separated by *t*-test.

Results and Discussion

There are no specific guidelines for nutrient requirements of container-grown pecan seedlings; however, substrate analysis interpretation for woody ornamentals [14] included in the very high category: pH above 6.5, EC above 3000 μmhos/cm and K above 80 mg $.kg^{-1}$. All of the pre-plant measurements in this study were above those levels. Initial media pH of the control (0%) pomace treatment was 6.0. The pH rose with increased pomace amounts (Table 1). Arvanitoyannis *et al.* [6] reported that compost from grape pomace ranged in pH from 6.5 to 8.5. The 100% grape pomace treatment in this study fell in the middle of that range (7.5). Inbar *et al.*[11, 12] also had similar results with the pH of composted grape pomace being either 6.7-7.0 or 7.7.

Potassium concentrations also increased dramatically with increased grape pomace (Table 1). 'Cynthiana', a popular American cultivar mainly grown for wine production and the main component of the grape pomace used in this study, has higher concentrations of K than most other grapes, up to double the amount [13]. After the harvesting process, $K_2S_2O_5$ was also added, thus contributing to the high concentrations of K observed. Inbar *et al.*[11] showed that composted *V. vinifera* L. grape pomace had high concentrations of K, but leaching was not needed for adequate growth.

Growth and biomass parameters for the control (0%) were similar to those in another study on 'Giles' pecan seedlings [10]. Manios [2] suggested that a by volume ratio of 30% or less composted grape pomace would result in better plant growth and development than higher ratios. Up to 30% pomace had no detrimental effect on growth of the pecan seedlings (Table 2). A decline in growth occurred with concentrations greater than 30% pomace. However, the addition of grape pomace up to 30% did not significantly increase pecan growth. Height, caliper and fresh weights of shoots and leaves were not detrimentally affected up to 30% pomace; however, root dry weight was highest with no pomace and decreased as pomace increased.

Manios [2] noted that one of the main problems with many types of biowaste compost is high EC that results in phytoxicity. High EC indicates high salt content, and pecans have a poor tolerance for salinity, with a high threshold of 1,900 μmhos/cm [15] and seriously decline when EC rises above 4,000 μmhos/cm[7]. The EC of the 0% pomace treatment was 3,400 μmhos/cm which is within an acceptable range [7]. The EC of the 10% pomace treatment was 3,990 μmhos/cm, just below what is considered problematic levels for pecans [7]. Arvanitoyannis *et al.* [6] noted that EC levels ranged from 1570 to 4,100 μmhos/cm in composted grape pomace, and Inbar *et al.*[12] found 1,700 μmhos/cm in composted material and 3,300 μmhos/cm in non-composted

Table 2. Biomass measurements of pecan seedlings after four months of growth in various amounts of 'Cynthiana' grape pomace.

Pomace %	Stem height (cm)	Caliper (cm)	Stem dry weight (g)	Leaf dry weight (g)	Root dry weight (g)	Total biomass (g)
0	31.3 ab[a]	6.0 ab	2.3 ab	6.0 a	10.5 a	18.7 a
10	32.4 a	6.0 ab	2.6 a	6.0 a	10.4 a	18.9 a
20	32.5 a	6.1 ab	2.2 ab	5.2 ab	9.8 a	17.2 a
30	36.5 a	6.4 a	2.7 a	6.1 a	9.8 a	18.6 a
40	26.5 a-c	5.3 ab	1.5 bc	3.1 bc	4.6 b	9.1 b
50	19.0 b-d	4.1 bc	1.0 cd	1.9 cd	3.2 bc	6.2 bc
60	14.0 c-e	2.4 c	0.7 cd	1.1 cd	2.6 bc	4.4 bc
70	11.8 d-f	2.4 c	0.6 cd	0.9 cd	2.6 bc	4.1 bc
80	0.0 f	0.0 d	0.0 d	0.0 d	0.1 c	0.1 c
90	1.9 ef	0.2 d	0.1 d	0.0 d	0.2 c	0.3 c
100	0.0 f	0.0 d	0.0 d	0.0 d	0.0 c	0.1 c

[a]Values followed by the same letter are not significantly different as determined by *t*-test, $P \leq 0.05$.

grape pomace. In this study EC was above 4,000 µmhos/cm at 20% grape pomace and increased as the percent of grape pomace increased (Table 1). Kotuby-Amacher *et al.*[15] stated that EC from 4000 to 8000 µmhos/cm restricts growth of many plants. Within the 20-50% range, the EC ranged from 5510 to 7680 µmhos/cm. Furthermore, from 60-90% grape pomace the EC ranged from 8,880 to 14,450 µmhos/cm, where only tolerant plants grow satisfactorily[15]. At an EC above 16,000 µmhos/cm only a few very tolerant plants will grow well, and the 100% grape pomace treatment was in this range.

Radical root development after planting and subsequent development of an expected tap root was either inhibited or terminated by the saline substrate at 50% grape pomace or higher. Of those that did establish in media where grape pomace comprised 50% and higher, there was serious retardation of root growth. From 50 to 100% pomace treatments the percent of plants that failed to establish a tap root were 11, 50, 56, 100, 100 and 100%, respectively. Beginning at 60% pomace, root system growth did not always initiate shoot growth. At 80% and greater pomace concentrations, plant mortality was extremely high (80-90%), and plants that did not die had only vestigial root development. Leaf necrosis symptoms consistent with saline conditions were observed on many plants, especially those at higher pomace treatments; yet, this could have been exacerbated by the extremely hot growing conditions during the summer of 2006 in Perkins, Okla. (31 d at 37.8°C or greater) because lesser symptoms were observed on the lower percentage treatments as well. Since salinity is correlated to osmotic potential, the pecan seedlings in this study were in competition with the salt in the substrate for water thus causing drought stress even though adequate water was available[16].

Conclusions

The greatest damage was conferred by the high salinity of the grape pomace as evidenced by the few surviving plants in the 50% or greater pomace treatments where EC exceeded 8000 µmhos/cm. Similar results were observed by Miyamoto and Storey [17], as they reported tree mortality at EC levels of 6000 to 8000 µmhos/cm. Potassium contributed heavily to the EC instead of Na, because Na readings did not exceed 108 $mg \cdot kg^{-1}$ and averaged 63 $mg \cdot kg^{-1}$ (data not shown). The inclusion of $K_2S_2O_5$ to the fruit after harvest, as well as the majority pomace component consisting of 'Cynthiana', contributed substantially to the high EC. Use of 'Cynthiana' grape pomace up to 30% as a component to a soilless substrate did not prove detrimental to above soil growth and overall survival of pecan seedlings. Although not significantly different, root system growth trended downward with an increase in grape pomace. Therefore, amounts of 'Cynthiana' grape pomace exceeding 30% would not be recommended as a component of growth media due to poor pecan plant growth and seedling mortality.

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