EFFECT OF SOILLESS MEDIA ON THE GROWTH OF *ANTHURIUM ANDRAEANUM* INFECTED BY *RADOPHOLUS SIMILIS*

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ABSTRACT

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Four soilless media, 1:1 (v/v) pine bark compost-perlite, volcanic cinder, 2:1 (v/v) cinder-peat, and a 1:2:1 (v/v/v) rockwool-cinder-peat, were evaluated in the greenhouse for their effects on the growth of *Anthurium* cultivars 'Alii' and 'Midori' and on the population increase of burrowing nematode *Radopholus similis* (BN). Nine months after inoculation with 2 000 BN per plant, root weights of 'Alii' differed among media. Plant growth expressed as shoot and root dry weight, root vigor, shoot damage, number of new leaves and flower number was less affected by nematode damage in cinder than in the other media. These effects were also more pronounced in 'Alii' than in 'Midori'. The role played by cinder in reducing BN damage was not due to improved plant growth, because uninoculated plants grew better in pine bark compost-perlite or rockwool-cinder-peat than in cinder. Orthogonal contrast analysis indicated that nematode damage on 'Alii' was favored by the presence of organic matter in the medium.

Key words: anthurium, cinder, organic matter, planting medium, *Radopholus similis*, regulatory nematology.

RESUMEN

Wang, K.-H., B. S. Sipes y A. R. Kuehnle. 1997. Efecto de medios sin suelo en el crecimiento de *Anthurium andraeanum* infestado por *Radopholus similis*. Nematrópica 27:77-84.

El efecto de cuatro medios sin suelo (compost de corteza de pino-vidrio volcánico, ceniza volcánica 1:1 (v/v), ceniza - composta vegetal 2:1 (v/v) y lana mineral-ceniza-composta vegetal 1:2:1 (v/v/v)) sobre el crecimiento de las variedades de *Anthurium*: 'Ali' y 'Midori' y en el aumento del nematodo barrenador, *Radophilus similis* (BN) fue evaluado en el invernadero. Después de nueve meses de la inoculación de 2 000 BN por planta, el peso de las raíces y ramas de la variedad 'Ali', mostró diferencias en los diferentes medios. Estos efectos fueron más pronunciados en 'Ali' que en 'Midori'. Las plantas sin inocular, crecieron mejor en el medio de composta de corteza de pino-vidrio volcánico o en el de lana mineral-ceniza-composta vegetal en comparación con el medio de ceniza, por lo que el efecto de la ceniza en la reducción del BN, no ocurrió a consecuencia del mejoramiento del crecimiento de la planta. El análisis ortogonal de contraste, indicó que el daño causado por los nematodos en la variedad Ali, estuvo favorecido por la presencia de material orgánico en el medio.

Palabras claves: anthurium, ceniza, material orgánico, medio de plantío, nematología regulatoria, *Radopholus similis*.

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INTRODUCTION

Burrowing nematode (BN), *Radopholus similis* (Cobb) Thorne is a common pest of *Anthurium* and causes anthurium decline (Hara *et al.*, 1988). Reduction in flower yield can reach 50% among infested plants (Aragaki and Apt, 1984). The efficacy of the nematicide, fenamiphos, used to control BN in *Anthurium*, was recently reduced, due to a reduction in the permissable application rates.

Quarantine restrictions in Hawaii's primary plant export destinations, namely Japan, California, Arizona, and Texas, prohibit entry of all potted plants contaminated by any burrowing nematode (L. Wong, Hawaii State Department of Agriculture, personal communication; Evans and Greczy, 1995). Only limited soilless media, such as peat, sphagnum, bark charcoal, perlite, vermiculite, rockwool, pumice, and volcanic cinder are permitted for exported potted plants. Many of these appear suitable for *Anthurium*, which grows well in media that are well-aerated and have a high water holding capacity (Higaki *et al.*, 1994). However, nematode eradication in *Anthurium* sp. production sites is difficult (Goo, 1995). Additional non-pesticidal methods of control are highly desirable.

Suitable media with characteristics unfavorable for nematodes would be useful to facilitate crop production. We tested the hypothesis that type of media can influence the growth of *Anthurium* and its infection by BN. The goal is to maintain *Anthurium* production despite the difficulty in nematode eradication, enabling high levels of production including nematode-free materials for export using nematode-free growing medium. However, if plants become contaminated with BN, these plants should be able to maintain their high quality for local markets. To this end we sought to identify and characterize soilless media effective in controlling anthurium decline and to determine whether the effect was due to an increase in plant vigor or to a decrease in nematode infection.

MATERIALS AND METHODS

Plant materials and growing media: Twelve uniformly sized *Anthurium andraeanum* Linden 'Midori' and 'Alii' plants were transplanted into 3.8 liter black plastic pots filled with 3 liters of each of four media, 1:1 (v/v) #3 perlite-pine bark compost (Cascade Forest Products Inc., Arcata, CA); volcanic cinder (0.64 to 1.25 cm diameter); 2:1 (v/v) cinder-peat moss; or 1:2:1 (v/v/v) cinder-peat moss-rockwool (medium size, 1 part water resistant and 1 part water absorbent; Capogro, Chicago, IL). Plants were grown on a 60-cm raised bench under 65% shading in a glasshouse at the University of Hawaii at Manoa. Plants were hand-watered and alternately fertilized in each pot with 8 g of slow release Osmocote (14-14-14, N-P-K) or organic fertilizer (5-15.5-14.5; Bandini Pro., Los Angeles, CA) every 3 months. Plants were grown in these conditions for 1 month prior to nematode inoculation. 'Alii' and 'Midori' plants were about 30 cm and 20 cm tall, respectively, and with established root systems at inoculation.

Nematode inoculation: Radopholus similis, population HA11, collected from *Anthurium* in Paradise Pacific Farm Kurtistown, Hawaii and maintained in callused alfalfa root tissue in vitro (Ko *et al.*, 1996) was used as inoculum. Tissue was placed in a mist chamber for 24 hours to collect the nematodes. The number of nematodes was determined and the inoculum adjusted to give approximately 2 000 BN in 10 ml of water. The inoculum was applied in a 1.5-cm radius around the base of each plant.

Pots were arranged in randomized complete blocks with inoculation time serving as a block. Plants in separate blocks were sequentially inoculated at weekly intervals. Each block of plants consisted of four media and two nematode treatments, i.e., inoculated and uninoculated (control), with two replicates for each treatment in a block. Since analysis of variance (ANOVA) showed no difference among inoculation times (or blocks), data were pooled over the three inoculation times. Thus there were six replications for each treatment.

Evaluation methods: The experiment was conducted for 9 months with weekly assessment of the number of new leaves, mildly chlorotic leaves, yellow leaves, necrotic leaves, and flowers. Plant vigor was expressed by new leaf numbers, flower numbers, ratio (inoculated/uninoculated) of plant fresh and dry weights, root vigor index, and shoot damage index. A root vigor index was defined as: Root Vigor Index = root fresh weight × root vigor level, where root vigor level was defined as follows: level 1—black and rotten; level 2—brown and corky; level 3—fresh but slender; and level 4—fresh and fleshy. A shoot damage index was defined as: Shoot Damage Index = (% level 1 leaves × 1) + (% level 2 leaves × 2) + (% level 3 leaves × 3) + (% level 4 leaves × 4), where leaf damage levels were as follows: Level 1—mild chlorosis, Level 2—yellow, Level 3—partly necrotic, and Level 4—totally necrotic. At the end of the experiment, shoot and root fresh and dry weights were determined. In addition, nematodes were extracted from the media and from plant tissues in a mist chamber. The logarithm ($\log_n$) of cumulative nematode number was used to equalize the variance.

Analysis of variance of the three-way factorial experimental design (media × cultivar × nematode) was conducted to determine effects of media and cultivars on plant growth and nematode reproduction. ANOVA and Waller-Duncan multiple range test was used to analyze differences among treatments. Orthogonal contrasts were used to analyze differences in BN damage to *Anthurium* sp. based on the presence or absence of compost, cinder, peat, rockwool, and organic matter (defined as compost or peat).

RESULTS

Among the four media tested, 'Alii' grown in cinder showed the least damage from BN infection in terms of the root and shoot dry weight ratios, shoot damage index ratio, root vigor index ratio, number of new leaves, and flower number (Fig. 1A-F). Although 'Midori' had a stronger root system than 'Alii' as indicated by its higher root weights and root vigor indices (Table 1), roots of inoculated 'Alii' grown in cinder were not as heavily damaged by the nematodes as shown by their dry weight ratios, higher root vigor index ratio, and lower shoot damage index ratio (Fig. 1A-D). Compared to 'Alii,' plant growth of inoculated 'Midori' was not much affected by the media. However, root vigor and new leaf formation increased ($P = 0.04$) for 'Midori' in pine bark compost-perlite compared to some of the other media (Fig. 1D,E).

Comparison of the uninoculated root systems of both cultivars showed that 'Alii' had fleshier roots with fewer lateral roots, whereas 'Midori' had finer roots with many lateral roots (data not shown). Additional observations revealed that infected 'Alii' tended to abscise unhealthy leaves in a shorter period compared to 'Midori', which retained chlorotic leaves with less leaf abscission.

Uninoculated 'Alii' and 'Midori' had poorest growth in cinder and better growth in pine bark compost-perlite, cinder-peat, and rockwool-cinder-peat (Table

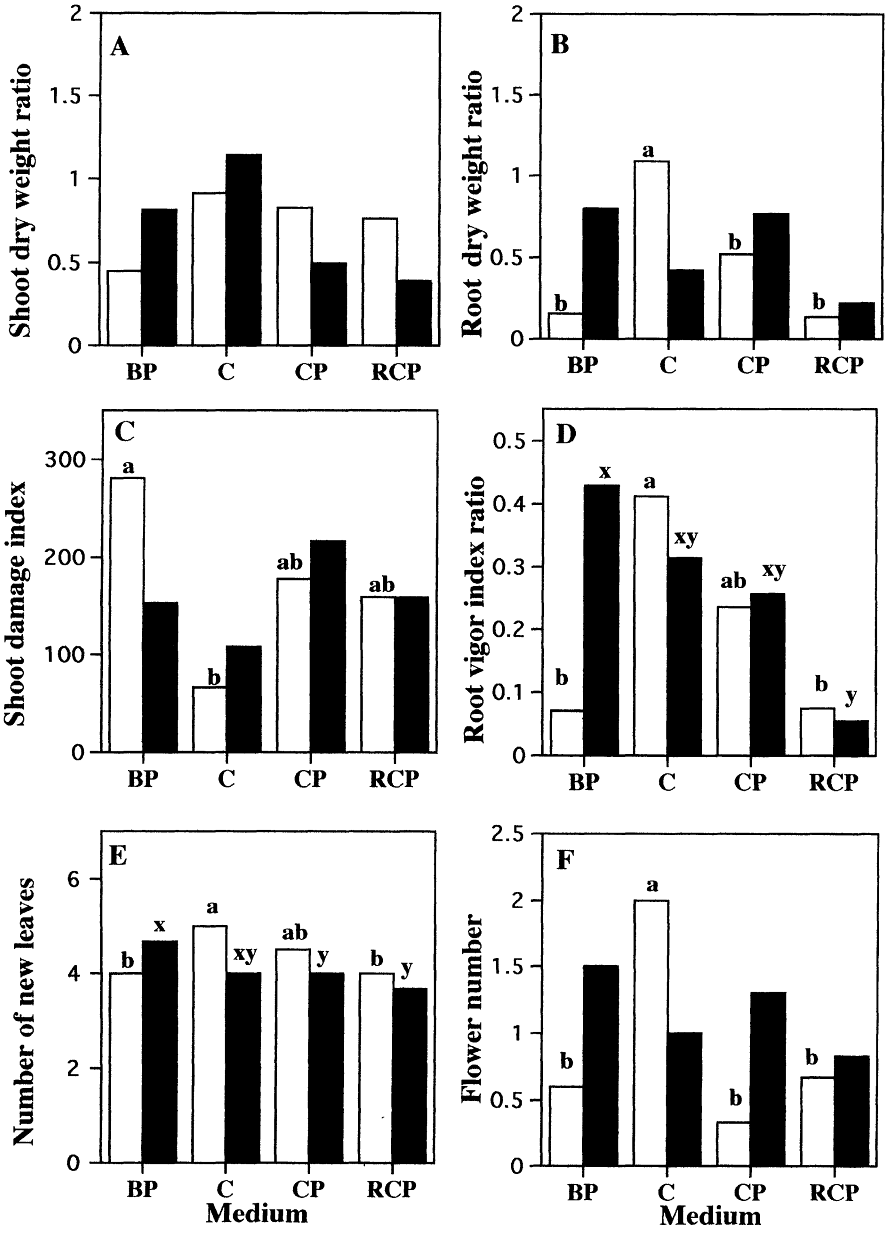

Fig. 1. Shoot dry weight ratio (A), root dry weight ratio (B), shoot damage index (C), root vigor index (D), number of new leaves (E), and flower number (F) of *Anthurium* 'Alii' (white bar) and 'Midori' (black bar) in four media, 9 months after inoculation with *Radopholus similis*. Ratios are inoculated/uninoculated values. BP = 1:1 (v/v) pine bark compost-perlite, C = cinder, CP = 2:1 (v/v) cinder-peat, and RCP = 1:2:1 (v/v/v) rockwool-cinder- peat. Shoot damage index = Σ (% leaves of each of four leaf damage levels × level of leaf damage); root vigor index = root vigor level × root fresh weight. Bars with the same or no letter are not different according to the Waller-Duncan k-ratio t-test (k = 100), where a, b, and c are used for 'Alii' and x and y are used for 'Midori'. Data are means of 6 replicates.

1). The dry root weights of uninoculated 'Alii' plants in cinder and cinder-peat were half of those in the other treatments. However dry root weights of nematode-infected 'Alii' were more than twice as high in cinder and cinder-peat as in the other two media. The differences in growth among the media were more pronounced in the roots than in the shoots.

Combined final nematode density from roots, shoots, and medium was highest ($P = 0.01$) in 'Alii' cultured in cinder (Fig. 2), a medium lacking organic matter. In the case of 'Midori', combined final nematode number did not differ among the media. However, nematode numbers in the shoots of 'Midori' cultured in cinder were lower than those cultured in rockwool-cinder-peat ($P = 0.074$).

The medium effect on the growth parameters in nematode infected 'Alii' was due to the presence or absence of organic matter or cinder (Table 2). Root fresh and dry weights and the root vigor index of 'Alii' showed differences ($P \leq 0.05$) for the organic matter or cinder orthogonal contrast. Although root dry weight of 'Alii' was different ($P \leq 0.05$) for the compost or rockwool contrasts, a greater difference ($P < 0.01$) was seen for the organic matter or cinder contrast. In the case of 'Midori', with no growth differences among media, orthogonal contrast was significant between media with or without rockwool (Table 1). This result is consistent with the higher number of nematodes in the shoot of rockwool-cinder-peat grown 'Midori'.

Table 1. Effect of four nematode free soilless media[x] on the growth of *Anthurium* 'Alii' and 'Midori' maintained in pots, inoculated or uninoculated with *Radopholus similis* in a greenhouse for 9 months.

	Uninoculated			Inoculated		
	Dry weight (g)			Dry weight (g)		
Medium[x]	Root	Shoot	Root vigor index[y]	Root	Shoot	Root vigor index
'Alii'						
compost-perlite	6.27 ab[z]	16.71 ns	154.73 ns	0.84 b	4.61 ns	7.03 ns
cinder	2.76 b	14.41 ns	55.06 ns	2.94 a	12.70 ns	21.04 ns
cinder-peat	4.61 ab	10.45 ns	70.88 ns	2.11 ab	5.93 ns	13.02 ns
rockwool-cinder-peat	7.95 a	16.51 ns	109.39 ns	0.99 ab	10.10 ns	7.01 ns
'Midori'						
compost-perlite	6.42 ns	20.07 ns	228.80 ns	4.05 ns	13.93 ns	85.43 ns
cinder	5.32 ns	14.87 ns	91.63 ns	1.81 ns	10.33 ns	27.54 ns
cinder-peat	7.10 ns	26.58 ns	172.71 ns	4.32 ns	11.46 ns	31.84 ns
rockwool-cinder-peat	10.10 ns	55.10 ns	221.72 ns	2.15 ns	10.51 ns	11.84 ns

[x]1:1 (v/v) pine bark compost-perlite, cinder, 2:1 (v/v) cinder-peat and 1:2:1 (v/v/v) rockwool-cinder-peat.
[y]Root vigor index = root vigor level × root fresh weight.
[z]Data are means of six replications. Means followed by the same letter in the same column are not different within cultivar ($P \leq 0.05$), according to the Waller-Duncan k-ratio t-test (k = 100). ns = not significantly different.

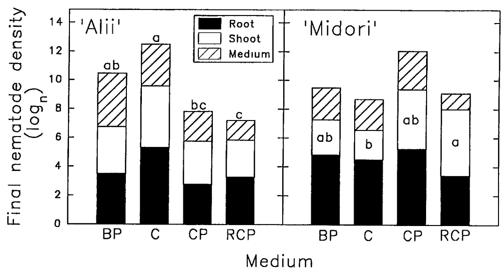

Fig. 2. Nematode number ($\log_n$ value) extracted from root, shoot, and medium of *Anthurium* 'Alii' and 'Midori' in four soilless media, 9 months after inoculation with *Radopholus similis*. BP = 1:1 (v/v) pine bark compost-perlite, C = cinder, CP = 2:1 (v/v) cinder-peat, and RCP = 1:2:1 (v/v/v) rockwool-cinder-peat. Bars or sections of bars with the same or no letter are not different according to the Waller-Duncan k-ratio t test (k = 100). Data are means of 6 replicates.

DISCUSSION

Cinder medium reduced BN damage on 'Alii'. This effect was not due to plant growth enhancement by cinder since both uninoculated cultivars grew poorly in cinder compared to other media with higher organic matter content. Rather, a reduction in BN damage for 'Alii' may have resulted from a decrease in early nematode infection. Nematode infection is influenced by many factors, including root density and vigor, and organic and moisture contents of the medium (Van Gundy *et al.*, 1964). This was exhibited somewhat by the lower number of nematodes in the shoots of 'Midori' grown in cinder. Lower number of nematodes could not be seen in cinder-grown 'Alii' because, after 9 months of nematode infection, roots of 'Alii' grown in media other than cinder were damaged more seriously than in the cinder, thus providing less available food for the nematode. However, in the case of 'Midori', the tolerance to the nematode resulted in no difference in root availability to nematodes. Thus, nematode infection of the shoot may reflect a suppressive effect of cinder on nematode infection. Low nematode infection of 'Alii' grown in cinder, particularly during the early infec-

Table 2. Orthogonal contrasts of soilless media components for root fresh and dry weights and root vigor index[y] for *Anthurium andraeanum* 'Alii' and 'Midori' inoculated with *Radopholus similis*.

Cultivar	Contrasts	Fresh root weight	Dry root weight	Root vigor index
'Alii'	compost vs. others	ns[z]	*	ns
	cinder vs. others	*	**	**
	peat vs. others	ns	ns	ns
	rockwool vs. others	ns	*	ns
	organic matter vs. others	**	**	**
'Midori'	compost vs. others	ns	ns	ns
	cinder vs. others	ns	ns	ns
	peat vs. others	ns	ns	*
	rockwool vs. others	*	ns	*
	organic matter vs. others	ns	ns	ns

[y]Root vigor index = root vigor level × fresh root weight.
[z]*Differ significantly ($P \leq 0.05$); **Differ significantly ($P \leq 0.01$); ns = not significant.

tion period, would result in the lowest BN damage among the media.

The inconsistency in effects of medium between the two cultivars tested might be related to differences in root vigor accompanied by differential tolerance limits to BN infection. Detailed studies on the response of potato cultivars to potato cyst nematode (Evans and Franco, 1979; Trudgill, 1980; Van Gundy *et al.*, 1964) gave clear indications that root vigor and other factors were responsible for nematode tolerance. Later, Trudgill (1986) also demonstrated that the degree of tolerance was determined by the grafting stock in potato. Previous work from our laboratory has identified 'Midori' as a BN tolerant cultivar (Wang *et al.*, 1997). Therefore, even if nematode reproduction is higher in a medium with high organic matter content, 'Midori' is still able to tolerate nematode damage. This would account for a lack of pronounced (other than root vigor) medium effect in 'Midori'.

Orthogonal contrast analysis of the medium components suggested that reduction of nematode damage is related to absence of soil organic matter. However, previous studies showed that organic matter does not favor *R. similis* infection of citrus in sandy soil in Florida (Holdeman, 1986). The possible explanations for lower nematode infection in cinder in this experiment are decreasing secondary infection from other pathogens (compared to peat or compost), lower water retention of cinder resulting in a less conducive environment for secondary invasion, and most probably reducing nematode infection by ensuring good water drainage. Nematodes that have not infected plant roots or have exited the roots might be washed from the rhizosphere more readily in cinder than in other media. Further research is needed to clarify the mechanisms involved in the effects of cinder and organic matter on growth of *Anthurium* in the presence of BN.

Cinder is a commercially acceptable medium because it enables the greatest flower production, compared to *Anthurium* grown in other media in a BN infested environment. Although nematode contaminated *Anthurium* is worthless as a potted plant, the cut flower production of *Anthurium* remains the major production in Hawaii.

In summary, soilless media suitable for *Anthurium* growth are pine bark compost-perlite and rockwool-cinder-peat. However, cinder is a soilless medium less favorable to nematode damage in *R. similis* intolerant cultivars like 'Alii'. Therefore, cinder is recommended for BN intolerant *Anthurium* grown in the presence of nematode. The ability of cinder medium to significantly improve root vigor of a BN intolerant cultivar inoculated with BN suggests that selection of an appropriate growing medium can provide a supplemental means to manage anthurium decline problems of BN intolerant cultivars.

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