HORTSCIENCE 27(3):225-227. 1992.

Reduction of Phytotoxicity in Polyurethane Foam-containing Potting Media

David Wees and Danielle Donnelly
Department of Plant Science, Macdonald Campus of *McGill University, 21,111 Lakeshore Road, Ste. Anne de Bellevue, Qué H9X 1C0, Canada*

Additional index words. container culture, radish, seed germination, soil amendment, tomato, *Raphanus sativus, Lycopersicon esculentum*

Abstract. **Leachates were produced by washing Hydra-fill, a polyurethane ester foam, with water. These leachates decreased radish *(Raphanus sativus* L.) and tomato *(Lycopersicon esculenturn* Mill.) seed germination and were phytotoxic to seedlings. Washing the foam for as little as 5 minutes (compared to not washing) before collecting the leachate significantly decreased the mean seed germination time by 0.6 to 1 day. Rinsing the foam with ethanol before collecting the leachate was detrimental to germination. When used as a potting medium component, the foam reduced radish shoot and root dry weights compared to potting media without foam. Washing the foam with tap water before use resulted in increased radish shoot and root dry weights. Hydra-fill generally reduced plant performance when included in potting media. However, radish grew well in fresh 25% Hydra-fill (raw or washed) mixed with loam.**

Various plastic foams, some of which are industrial waste products, may be desirable plant growth media addenda; they have high porosity, low bulk density, and water-release curves similar to perlite (Anstett, 1979; Benoit and Ceustermans, 1988; De Boodt and Verdonck, 1971; Verdonck et al., 1973). However, some phytotoxic effects have been associated with the use of these foams, the presence and severity of which are influenced by foam age; various heating, washing, or chemical pretreatments; and the proportion used in the potting medium (Anstett, 1979; De Boodt and Verdonck, 1971; Penningsfeld, 1973; Wheeler et al., 1985). In preliminary studies with potting media that contained Hydra-fill foam chips, phytotoxicity (including chlorosis and poor growth) occurred on 'Earlirouge' tomatoes **(***Lycopersicon esculentum* Mill.), geraniums *(Pelargonium* × *hortorum* 'Red Elite'), and Easter lilies *(Lilium longiflorum* 'Nellie White') (Wees and Donnelly, 1988). The objectives of this study were to reduce the phytotoxic effects of Hydra-fill foam in potting media by pretreating the foam and to evaluate the influence of age of foam, proportion of foam, and associated substrates in potting media.

Received for publication 18 Oct. 1991. Accepted for publication 12 Nov. 1991. We thank Györgyi Telbisz, Polyad Industries, North Lancaster, Ont., Canada, for providing the Hydra-fill foam chips. Financial support from the National Research Council's Industrial Research Assistance Program (I.R.A.P.) is gratefully acknowledged. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Hydra-fill (Polyad Industries, North Lancaster, Ont.) is composed of porous polyurethane ester foam chips 1 to 5 mm in diameter, produced from trimmings left from manufacturing household sponges. Foam was divided into two groups; "fresh" foam was less than 2 years old and "aged" foam was older and had been stored in a warehouse. 'Cherry Belle' radish and 'Earlirouge' tomato were used because of their rapid rates of germination and growth and moderate tolerance to soil acidity; radish is sensitive to soil salinity, but tomato is tolerant (Lorenz and Maynard, 1980).

Aged foam was pretreated in one of seven ways: spread onto trays and heated for 1 or

Table 1. Effect of Hydra-fill leachates, collected after various pretreatments, on the germination of 'Earlirouge' tomato seeds.

Pretreatment	Germination		
	Mean time (days)	Spread (days)	Percent[z]
Distilled water control	4.5	1.2	100.0
Heated 1 h at 70C	4.6	1.2	89.9
Heated 2 h at 70C	5.0	1.1	95.0
Heated 1 h at 100C	5.3**	1.1	84.8
Heated 2 h at 100C	5.0	0.9	90.0
Ethanol rinsed	7.2**	2.6**	45.9**
Water rinsed	4.9	1.0	90.0
Untreated	5.0	1.3	96.7

[z]Data arcsin-transformed for analysis, back-transformed data presented.
**Effect of treatment was significantly different from the control at $P = 0.01$ according to Dunnett's procedure (Steel and Torrie, 1980).

Table 2. Effect of Hydra-fill foam washing on leachate pH and leachate effect on germination of 'Cherry Belle' radish and 'Earlirouge' tomato seeds.

Treatment[z]		Radish germination			Tomato germination		
Washing (min)	Leachate pH[y]	Mean time (days)	Spread (days)	Percent[x]	Mean time (days)	Spread (days)	Percent[x]
Tap water (control)	6.98	1.4	2.8	100.0	4.6	1.0	89.9
0	4.14	2.2	2.3	79.9	5.5	1.8	74.7
5	4.43	1.6	2.6	92.3	4.5	0.9	88.5
30	6.21	1.6	2.6	96.2	4.7	1.1	92.4
60	6.39	1.5	2.7	97.5	4.7	1.0	92.4
Effect of washing (ANOVA)		**	**	**	**	**	**
Control vs. 0 min (orthogonal contrast)		**	**	**	**	**	**

[z]Foam age and age × washing were not significant, so data for fresh and aged foam were combined. Washing time exhibited both linear and quadratic effects on all variables tested.
[y]Means of four values.
[x]Data arcsin-transformed for analysis, back-transformed data presented.
**Effect was significant at $P = 0.01$.

2 h at 70C (soil pasteurization temperature) or at 100C (sterilization temperature) in an oven; held in a strainer and rinsed for 1 min with 95% ethanol or water; or left untreated. All foam samples were then soaked in twice their volume of distilled water for 24 h, filtered, and the filtrate collected. Ten milliliters of each filtrate or distilled water (control) was pipetted into each of three 10-cm petri dishes containing a filter paper disk on which 20 tomato seeds were distributed. The dishes were arranged in a randomized complete-block design with three blocks and incubated in darkness at 24 ± 2C. Seed germination was recorded daily for 9 days.

In a second experiment, fresh and aged foam were soaked in water for 12 h, drained (0-min wash), then continuously washed (leached) with tap water for 5, 30, or 60 min, at which time 500-ml samples were collected and the pH measured. Ten milliliters of each sample (filtered leachate or a tap water control) was pipetted into each of eight 10-cm petri dishes containing a filter paper disk and 10 seeds of tomato or radish. The petri dishes were arranged in a randomized complete-block design with four blocks and incubated in darkness at 19 ± 2C. Seed germination was recorded daily for 7 days.

For both experiments, mean germination time, spread (duration) of germination, and percent germination were calculated for each treatment (Orchard, 1977). Arcsin transformations were performed on percent germination data to ensure normality of distribution (Steel and Torrie, 1980).

On 1 Aug. 1988, 10 radish seeds were sown in polystyrene flats (external size 25 × 17.5 × 7.5 cm; internal volume 2400 cm^3) containing one of the following potting media combinations: 25% or 50% (v/v) fresh or aged foam (the balance being sphagnum peat or loam) that was untreated or previously soaked in water for 1 h (washed). Two commercial peat-lite media (Agromix, Fafard & Frères, St. Bonaventure, Québec; Promix-BX, Les Tourbières Premier, Riviere-du-Loup, Québec), a 50% peat and 50% vermiculite mixture (v/v) and a 50% loam and 50% vermiculite mixture (v/v) were used for comparison. Treatments were replicated three times in a randomized complete-block design. All media, except the two commercial mixtures, were amended with: 1.5 kg superphosphate, 1.75 kg KNO_3, 0.25 kg fritted trace elements, and 4 g chelated Fe/m^3 of medium. Dolomitic lime applications, to obtain a pH of 5.5 to 5.8, depended on the proportion of peat and foam (both of which were acidic) in the mixtures: 12 kg $lime/m^3$ of peat and 8 kg/m^3 of foam.

Flats were kept in a greenhouse held at 26-30C/20-22C (14 h day/l0 h night) and fertilized weekly with a solution of 200 ppm N, 88 ppm P, and 166 ppm K, and chelated trace elements. Plants were harvested 31 days after seeding, and the dry weights of shoots and tap roots were measured. This experiment was repeated on 28 Oct.; treatments were identical but were replicated four times.

Symptoms of phytotoxicity were observed on plants in all treatments, except the controls. In the germination tests, tomato and radish seedlings were stunted and had poorly developed roots with brown tips. Radish plants grown in foam-containing mixtures also were stunted and showed chlorosis, leaf cupping, and poor root development.

In the first germination test, only heating the foam for 1 h at 100C and the ethanol rinse resulted in a mean germination time significantly longer than that of the control (Table 1). Only the ethanol rinse significantly differed from the control in terms of spread of germination and percent germination. The foam particles were partially dissolved or broken down by ethanol. The filtrate collected after the ethanol rinse slowed germination by ≈2 days, more than doubled the spread of germination, and decreased the percent germination by half compared with the control. The negative effect of this treatment on seed germination may have been due either to residual ethanol or other phytotoxic agent(s) in the leachate. Heating at 100C for 1 h or an ethanol rinse greatly reduced phytotoxicity symptoms in lettuce grown in polyurethane foam plugs (Wheeler et al., 1985).

In the second germination test, foam age did not affect germination, nor was there any interaction between foam age and washing treatment. Phytotoxicity symptoms were observed on radish and tomato seedlings in the unwashed (0 min) foam leachate, and germination was significantly reduced compared with the tap water control (Table 2). A 5-min wash was sufficient to improve the germination of radish and tomato seeds, with only mild toxicity symptoms visible on radish and none on tomato seedlings in this leachate. A 30-min wash was needed to reduce the acidity of the foam leachate, indicating that the foam had some buffering capacity. Adverse effects of the foam on radish and tomato seed germination were probably not related to pH or salinity. Indeed, a 5-min wash changed leachate pH only slightly but greatly improved germination. Furthermore, tomatoes are more tolerant of salinity than radish (Lorenz and Maynard, 1980); yet, in out experiment, tomato seed germinated more slowly than radish seed.

Results from both radish seedling performance experiments were very similar, so only the results from the first experiment are included in Table 3. Washing foam before use significantly improved radish growth based on shoot and root dry weights. Washing polystyrene before using it in potting media improved eggplant *(Solanum melongena* L.) and lettuce *(Lactuca sativa* L.) yields (Schwarz, 1967) by removing traces of formaldehyde (Penningsfield, 1973). Some phytotoxic chemical(s) were easily leached from Hydra-fill foam in our germination test (Table 2), but some remained in the medium and were released slowly over time, resulting in plants with symptoms of phytotoxicity and lower shoot and root weights than the controls (Table 3). As shown by the significant interaction effects (wash x age, wash

Table 3. Effect of Hydra-fill foam on the shoot and root dry weights (grams) of 'Cherry Belle' radish.

Potting mixture					
Foam					
Pretreatment	Age	Proportion (%)	Other	Shoot dry wt (g/plant)	Root dry wt (g/plant)
Raw	Fresh	25	Peat	0.167	0.069
Washed	Fresh	25	Peat	0.296	0.103
Raw	Fresh	25	Loam	0.384	0.200
Washed	Fresh	25	Loam	0.344	0.264
Raw	Fresh	50	Peat	0.038	0.005
Washed	Fresh	50	Peat	0.171	0.109
Raw	Fresh	50	Loam	0.121	0.021
Washed	Fresh	50	Loam	0.253	0.194
Raw	Aged	25	Peat	0.058	0.009
Washed	Aged	25	Peat	0.307	0.123
Raw	Aged	25	Loam	0.228	0.166
Washed	Aged	25	Loam	0.253	0.168
Raw	Aged	50	Peat	---[z]	---
Washed	Aged	50	Peat	---	---
Raw	Aged	50	Loam	0.067	0.046
Washed	Aged	50	Loam	0.256	0.090
			Agro-mix	0.359	0.195
			Pro-mix	0.275	0.176
			50% peat/50% vermiculite	0.374	0.200
			50% loam/50% vermiculite	0.468	0.218
Wash				**	**
Wash × age				**	NS
Wash × proportion				**	NS
Wash × substrate				**	NS
Wash × proportion × substrate				*	NS
Age				**	NS
Age × proportion				**	NS
Age × substrate				*	NS
Proportion				**	**
Proportion × substrate				NS	*
Substrate				**	**
Orthogonal contrast significance					
Media with foam vs. without foam				**	**
Commercial media vs. loam/vermiculite and peat/vermiculture				**	NS
Loam/vermiculite vs. peat/vermiculite				*	NS

[z]Plants dead or too small to be weighed.

*,**,NSEffect was significant at $P = 0.05$ or 0.01 or not significant, respectively. Interactions with no significant effect on either variable were not reported.

× proportion, and wash × substrate), washing had a greater beneficial effect on aged vs. new Hydra-fill, on media with 50% as opposed to 25% Hydra-fill, and on media with peat rather than loam (Table 3).

Radish shoot dry weight was higher in fresh (0.222 g/plant) than in aged (0.146 g/plant) foam, although foam age did not affect germination. This contradicts other findings where a reduction in toxicity of older foams was noted (Schwarz, 1967; Wheeler et al., 1985). Polyurethanes produced toxins after extended periods of use as potting substrates (Penningsfeld, 1973), possibly due to photolysis (Anstett, 1979). Variability in phytotoxicity among samples of polyurethane, which we also observed (data not shown), was reported by Wheeler et al. (1985). Conflicting reports on foam age and phytotoxicity may be related to foam chemistry; polyurehane esters such as Hydra-fill are more susceptible to degradation than polyurethane ethers (Anstett, 1979; Benoit and Ceustermans, 1988). The influence of other factors varied according to foam age (age x proportion, age × substrate). Increasing Hydra-fill proportion from 25% to 50% had a greater negative effect on shoot dry weight in aged than fresh foam. Substituting loam for peat had a greater positive effect on shoot dry weight in aged than in fresh foam.

The proportion of foam used (25% or 50%) and the other substrate in the medium (peat or loam) significantly affected all growth characteristics (Table 3). Decreasing the proportion of foam probably diluted the substance(s) responsible for phytotoxicity and decreased the likelihood of root contact with the foam. Decreasing the proportion of Hydra-fill had a greater positive effect on root dry weight in peat-based media than in loam-based media. Radish seedling performance was best in mixtures with 50% vermiculite and 50% peat or loam and almost as good in 25% fresh foam (untreated or washed) mixed with loam. When media contained 25% washed foam, peat-based media performed as well as loam-based media and better than Pro-mix (shoot dry-weight basis). However, when media contained raw foam or 50% foam, loam gave a shoot dry weight 2 to 4 times higher than peat. Loam-vermiculite gave better results than peat-vermiculite. It was unlikely that substrate fertility was a factor, but the loam may have neutralized or bound the toxin(s) contained in Hydra-fill foam.

In conclusion, plant performance was generally reduced in all media containing Hydra-fill foam, relative to other substrates. Pretreating foam by washing reduced, but did not eliminate, phytotoxicity; the effect of foam age was variable. Of the foam-containing media, the best had 25% fresh foam (untreated or washed) mixed with loam. The toxins found in some polyurethanes are tertiary amines or isocyanates (Wheeler et al., 1985), but further work is needed to identify the compounds and improve methods of eliminating them from Hydra-fill foam. Longer washing periods, the use of detergents, or the addition of detoxification materials, such as calcium compounds, may be necessary. The cost-efficiency of such procedures needs to be evaluated.

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