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Response of Conifer Seedlings to Potting Medium Amendment with Meadowfoam Seed Meal

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Meadowfoam (*Limnanthes alba* L., Limnanthaceae) is an herbaceous winter-spring annual, grown as an oilseed crop in the Willamette Valley of Oregon, US and in New Zealand. The exceptionally high quality seed oil, consisting almost entirely of long-chain fatty acids, is used in cosmetics and lubricants. The seed meal (MSM) remaining after extraction of the oils with hexane solvent under elevated temperature is a granular by-product with little apparent commercial value, at present, except as an organic fertilizer or as an additive to livestock feed. However, MSM has some characteristics that suggest its potential utility in agriculture as a soil amendment to enhance plant growth and possibly suppress soil pests. For example, MSM contains the glucosinolate glucolimnanthin (Bartlett and Mikolajczak 1989; Vaughn et al. 1996) that, when hydrolyzed in the presence of the enzyme thioglucosidase glucohydrolase (myrosinase), can produce allelochemic compounds (aglycones), including isothiocyanates, thiocyanates, nitriles, and ionic thiocyanate (Van Etten and Tookey 1983), which have been shown to be potent biocides in soil (Bartlett and Mikolajczak 1989; Brown and Morra 1997; Deuel and Svensen 1999). Furthermore, MSM has been shown to have plant growth-enhancing properties of a phytohormonal nature (W.A. Deuel and S.E. Svensen, 1998, unpubl.; Deuel, US Patent No. 6,596,323 B1, 2003), but the nature of the responsible compound(s) remains unknown. At concentrations of MSM amendment to soil >2% by volume, inhibition of seed germination and other herbicidal properties occurs. Vaughn et al. (1996) demonstrated the herbicidal component in MSM to be 3-methoxyphenyl acetonitrile. Deuel and Svensen (1999) demonstrated that soil amendment with MSM reduced the incidence and severity of clubroot of cabbage and cauliflower in either soil or potting medium. The enzyme myrosinase needed to hydrolyze glucosinolates (Rosa et al. 1997) is present in the seed, and is produced by some soil microbes (Tani et al. 1974), but it and the glucosinolate are denatured during the hot hexane process of oil extraction, leaving only acetonitrile as a by-product in the MSM. Thus there is little or no potential to hydrolyze glucosinolate to S-containing volatile biocides in soil, such as isothiocyanates, as is known to occur with cruciferous crop residues (Vaughn 1999; Gamliel and Stapleton 1983).

The unusual growth-enhancing properties of MSM prompted an examination of it as an amendment to soilless potting medium on the growth of conifer seedlings commonly grown in container nurseries in the Pacific Northwestern US. The findings from those studies are reported here.

METHODOLOGY

Effects of MSM on Growth of Five Conifer Species

Seeds of five conifer species [Douglas-fir (*Pseudotsuga menzeisii* (Mirb.) Franco., Pinaceae]; western hemlock [*Tsuga heterophlla* (Raf.) Sarg., Pinaceae]; eastern white pine (*Pinus strobus* L., Pinaceae); noble fir [*Abies procera* (Dougl.) Lindl., Pinaceae]; and western redcedar (*Thuja plicata* Donn, Cupressaceae) were cold stratified for 6 weeks at 3.33°C, and planted into a pasteurized peat-based soilless medium containing a proprietary starter fertilizer prepared by the Weyerhaeuser Company, Rochester, Washington. Super-Cell Cone-Tainer tubes were filled with 140 cm^3 of medium and moistened by misting until gravitational drainage was apparent. Single conifer seeds were planted 0.32 cm deep in medium that was amended with the MSM at 0% (control), 1%, 2%, 3%, 4%, and 5% by volume 48 hr before planting. Germination occurred 7 to 10 days after sowing, varying with species. The experiment was laid out in a complete randomized block design, using replicates as blocking factor. Six replicates of each conifer were maintained under greenhouse conditions, where temperatures were 23/18°C day/night, and light was supplemented by high-pressure multi-vapor lamps for 14-hr daylengths, beginning after seedling germination. Water was applied as needed, usually thrice-weekly, using a low-pressure sprinkler nozzle. Plants were not fertilized during the entire experimental period of 12 weeks.

MSM and Fertilizer Interval Effects on Douglas-fir Seedling Growth

Pre-stratified Douglas-fir seedlings (provided by Weyerhaeuser) were grown in plastic trays designed specifically for seed germination and seedling growth in Weyerhaeuser nurseries. Two days before treatment, a volume of 2.95 dm^3 of each flat was filled with their proprietary seedling mix and moistened by misting until gravitational drainage was apparent. One pre-stratified seed per cell was sown at 0.32 cm depth. Half of all treatments were amended with 1% (by volume) MSM, and all treatments were fertilized with a proprietary "growth" fertilizer to determine the fertilizer intervals needed to yield the same size non-amended seedlings as MSM-amended ones after 12 weeks growth. The relative proportions of the fertilizer were N (75 ppm): P (30 ppm): K (38 ppm) applied to flow through. Based upon preliminary trials, growth fertilizer was applied at intervals of 1, 2, or 3 weeks. An initial proprietary "starter" fertilizer was applied 3 weeks after sowing, after which experimental intervals commenced. Control seedlings in both MSM-amended and non-amended treatments received no further fertilization. Four replications of each treatment were arranged in a randomized block design using replicates as blocking factors. Fertilizers were manually applied to media that were thoroughly watered 1 day prior to facilitate complete wetting of each growth cell.

MSM and Fertilizer Interval Effects on Transplanted Douglas-fir Seedling Growth

The same experimental design was also applied in another experiment where Douglas-fir starter plug seedlings were transferred into "Styro-60" containers filled with the medium amended or not with 1% MSM and again fertilized at intervals of 1, 2, or 3 weeks, compared to controls with no fertilizer added.

Parameters Measured and Data Analysis

After 12 weeks of growth, conifer seedlings in each experiment were harvested, the roots washed free of adhering medium, and root and shoot dry weights determined after drying for 48 hr at 70°C. Shoot tissue from each treatment was pooled by replication and analyzed for chemical properties by the Central Analytical Services at Oregon State University using a Perkin-Elmer Optima 3000DV inductively-coupled plasma optical emission spectrophotometer.

Data were analyzed separately for each experiment. Arcsin-transformed seedling survival data and log-transformed biomass data were analyzed by analysis of variance using Systat 11.0 (Systat Software, Inc., Richmond, California). Where appropriate, Fisher's protected L.S.D. tests ($P \leq 0.05$) were used to separate treatment means. Actual data are presented in all tables.

RESULTS AND DISCUSSION

Growth Response

Conifer seedlings responded positively to amendment of potting medium at rates up to 2% by volume for most plant species, up to 3% for some. The effect of rate was highly significant for each conifer species ($P \leq 0.001$). Rates above 4% generally were toxic to most plant species, compared to the 1% rate, and the 5% rate was toxic to all species (Fig. 1, 2). Plants of all species grew as though they were being fertilized frequently, even though they were not. The control seedlings exhibited distinct nutrient deficiency symptoms, especially P deficiency, and their growth was severely retarded. The MSM amendment appeared

Fig. 1. Growth enhancement of (A) western redcedar, (B) eastern white Pine, (C) Douglas-fir, (D) nobel fir, and (E) western hemlock grown for 12 weeks in peat-based soilless medium, with an initial starter fertilizer, amended (left to right) with 0 (control), 1, 2, 3, 4, and 5% meadowfoam seed meal (MSM) (western hemlock only to 4%). Seedlings in (F) are Douglas-fir grown in control medium (left) or with 1% MSM amendment.

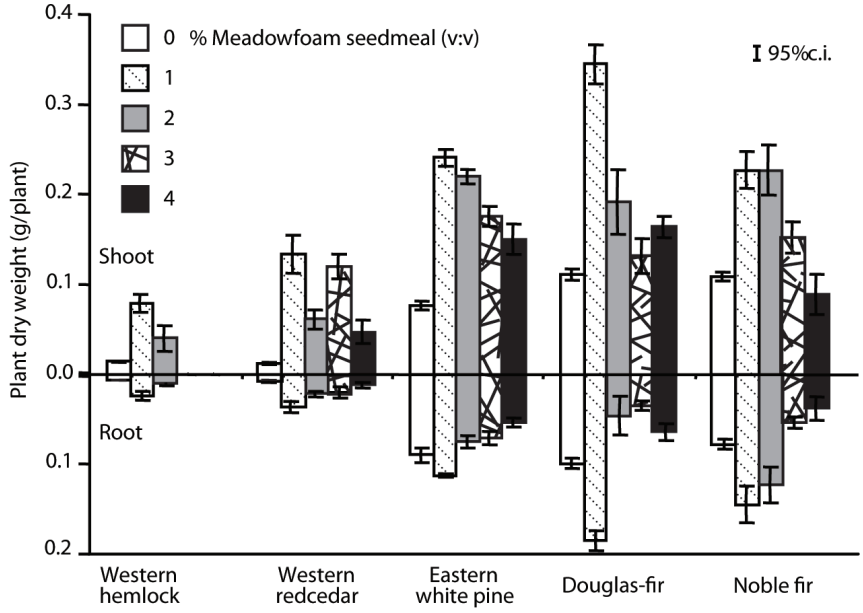

Fig. 2. Biomass of five conifer species seedlings grown for 12 weeks in peat-based soilless medium, fertilized only with an initial starter fertilizer, amended with different rates of meadowfoam seed meal (MSM) at 0 (control), 1, 2, 3, or 4% by volume.

Table 1. Chemical analysis per kg of five conifer species (shoots) grown for 12 weeks in a soilless peat-based medium amended or not with 1% to 3% (by volume) meadowfoam seed meal (MSM)

Treatment	P (g)	K (g)	Ca (mg)	Mg (mg)	B (mg)	Cu (mg)	Mn (mg)	Zn (mg)	Total C (g)	Total N (g)
Western hemlock										
None	na[z]	na	na	na	na	na	na	na	47.3	0.45
1%	na	na	na	na	na	na	na	na	46.4	1.48
2%	na	na	na	na	na	na	na	na	46.3	1.81
3%	na	na	na	na	na	na	na	na	46.6	1.49
Western redcedar										
None	na	na	na	na	na	na	na	na	46.0	0.66
1%	0.35	1.84	1.17	0.32	209.83	5.26	210	22.88	44.9	2.58
2%	na	na	na	na	na	na	na	na	44.6	3.25
3%	0.54	1.87	1.19	0.37	56.67	4.24	168	23.82	44.4	3.09
Eastern white pine										
None	0.11	0.63	0.38	0.17	42.34	6.23	68	16.62	46.4	0.60
1%	0.31	1.32	0.46	0.21	41.20	3.77	110	17.40	46.7	1.98
2%	0.44	1.35	0.46	0.22	46.24	3.22	157	29.02	46.5	2.61
3%	0.51	1.59	0.45	0.24	50.45	3.13	190	28.73	46.6	2.60
Douglas-fir										
None	0.07	0.58	0.39	0.11	84.87	14.40	105	20.00	46.6	0.45
1%	0.37	1.34	0.45	0.18	60.68	8.37	137	19.89	46.2	1.69
2%	0.90	1.92	0.51	0.25	73.17	5.42	525	29.93	45.1	2.84
3%	1.04	1.92	0.42	0.22	54.67	4.03	533	25.98	45.5	3.10
Noble fir										
None	0.10	0.62	0.31	0.15	52.18	11.40	62	14.59	47.2	0.56
1%	0.35	1.66	0.42	0.31	47.45	5.33	87	20.88	48.5	1.68
2%	0.55	2.01	0.60	0.37	53.06	5.44	111	30.38	44.8	2.17
3%	0.66	2.00	0.53	0.36	59.41	4.52	131	31.31	45.4	2.28

[z]na = insufficient plant sample for analysis.

to enhance nutrient uptake from the limited amount of starter fertilizer used (Tables 1, 2). Plants growing in the 1% MSM amendment treatment were darker green, had lateral branching typical of continued, normal growth under high fertility conditions (Fig. 1F).

Fertilizer-use Efficiency

Pre-trials with Douglas-fir grown in medium amended with MSM compared with fertilization of non-amended mix at different intervals up to 6 weeks, indicated that the amended treatment yielded seedling biomasses equivalent to application of fertilizer every 2–3 weeks over a 12 week period (data not shown). This improved fertilizer-use efficiency resulted in a savings of at least 6 weekly fertilizer applications to achieve the same seedling biomass (Fig. 3).

An additional experiment using 1% MSM and fertilizer applications every 1, 2, or 3 weeks in combination with 1% MSM indicated that shoot biomass of seedlings grown in medium amended with the combination of MSM and fertilizer were statistically larger than the treatment with MSM alone ($P \leq 0.001$) (Fig. 4, 5).

Starter plug seedlings that were transplanted into larger "Styro-60" containers filled with the same medium and experimental treatments and grown for 12 weeks did not exhibit as strong growth responses in their shoot fresh biomass. The effect of MSM was only marginally significant ($P \leq 0.05$) while the application interval effect was not significant.

Table 2. Chemical analysis per kg of Douglas-fir seedlings (shoots) grown for 12 weeks in a soilless peat-based medium amended or not with 1% (by volume) meadowfoam seed meal (MSM) with or without additional fertilizer applied every 1, 2, or 3 weeks.

Treatment [z] (time)	P (g)	K (g)	Ca (mg)	Mg (mg)	B (mg)	Cu (mg)	Mn (mg)	Fe (mg)	Zn (mg)	Total C (g)	Total N (g)
No MSM											
None	0.27	1.05	0.16	0.10	37.80	7.81	319.96	26.50	20.33	45.04	0.54
1 wk	0.24	1.19	0.17	0.11	54.13	4.13	178.69	30.66	32.12	45.59	1.00
2 wk	0.23	1.12	0.17	0.10	44.51	3.99	251.81	30.21	32.72	45.34	0.75
3 wk	0.23	1.12	0.16	0.12	43.08	3.28	212.25	29.10	24.91	45.28	0.65
MSM											
None	0.20	0.97	0.13	0.11	39.41	3.43	268.35	22.76	27.89	46.14	0.97
1 wk	0.31	1.21	0.20	0.12	51.04	4.34	159.34	32.56	35.11	46.52	1.38
2 wk	0.22	1.03	0.16	0.10	42.20	3.10	321.18	24.76	23.47	46.28	0.95
3 wk	0.23	1.08	0.15	0.10	41.52	3.04	166.70	27.18	28.20	46.27	0.99

[z]None = no additional fertilizer application; additional fertilizer application at 1, 2, or 3 week intervals.

Fig. 3. Douglas-fir seedlings grown for 12 weeks in a soilless peat-based medium amended, with weekly fertilization (A), without fertilization (B), or with 1% meadowfoam seed meal (MSM) (C).

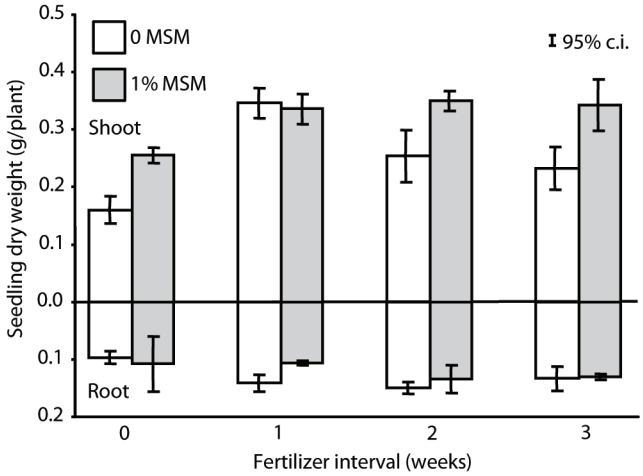

Fig. 4. Douglas-fir seedlings growth for 12 weeks in a soilless peat-based medium amended or non-amended with 1% meadowfoam seed meal (MSM) (by volume) without or with additional fertilizer applied every 1, 2, or 3 weeks.

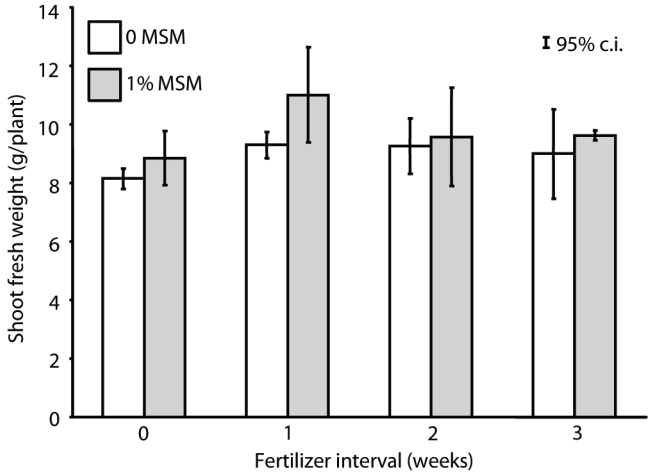

Fig. 5. Douglas-fir seedlings transplanted into and grown for 12 weeks in soilless peat-based medium amended or non-amended with 1% MSM (by volume) alone or in combination with fertilizations every 1, 2, or 3 weeks.

CONCLUSIONS

Meadowfoam seed meal has economic potential as a soilless growth medium amendment for the production of conifer seedlings. Low levels of amendment (1%–2% by volume) stimulated striking seedling growth of all conifer species tested, without fertilization beyond the initial starter fertilizer in the peat-based soilless medium; however, at higher rates, the seed meal was toxic. The apparent enhanced fertilizer-use efficiency could result in significant savings with fewer applications needed to grow seedlings. The specific nature of the presumed hormonal effect remains unknown.

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