needle rusts in the Japanese archipelago. Rept. Tottori Myc. Inst. Japan 19:1–159.

18. Nicholls, T.H., R.F. Patton, and E.P. Van Arsdel. 1968. Life cycle and seasonal development of *Coleosporium* pine needle rust in Wisconsin. Phytopathology 58:822–829.

19. Orishimo, Y. 1910. On the genetic connection between Coleosporium on *Aster scaber* and *Peridermium pini-densiflorae* P. Henn. Bot. Mag. Tokyo:24:1–5.

20. Raabe, R.D., A.H. McCain and P. Lert. 1961. Soil fumigation can control Fusarium wilt of aster. Pest Control Rev. May:7–9.

21. Savulescu, T. 1939. Contribution nouvelle a la connaissance des Uredinees de Roumanie. Bull. Sect. Sci. Acad. Roum. 22(2):1–18. (RAM 19:729–730.)

22. Schweinitz, L.D. 1822. Synopsis fungorum Carolinae superioris. Schr. Nat. Ges. Leipzig 1:70.

23. Sydow, P. and H. Sydow. 1914. Beitrag zur kenntnis der parasitischen Pilze der Insel Formosa. Ann. Mycologici 12:105–112.

24. Underwood, L.M. and F.S. Earle. 1896. Notes on the pine inhabiting species of Peridermium. Bull. Torrey Club 23:400–405.

25. von Thümen, F. 1878. New species of American uredineae. Bull. Torrey Club 6:215–216.

26. Weir, J.R. 1925. The genus Coleosporium in the northwestern United States. Mycologia 17:225–239.

27. Weir, J.R. and E.E. Hubert. 1916. Inoculation experiments with *Peridermium montanum*. Phytopathology 6:68–70.

Growth of Capillary-Irrigated Andorra Juniper and Sarcoxie Euonymus as Affected by Controlled Release Fertilizer Type and Placement[1]

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Abstract

Juniperus horizontalis Moench. 'Plumosa compacata' and *Euonymus fortunei* Turcz. 'Sarcoxie' were grown on a sand capillary bed with two types of controlled release fertilizer (3:1 Type 100:Type 40 Nutricote 16N-4.4P-8.1K (16-10-10), and Osmocote 18N-2.6P-9.7K (18-6-12) either medium-incorporated, surface-applied or dibbled below the roots. Throughout the growing season, neither leaf area, root or shoot dry weight of euonymus was affected by fertilizer type or placement. Branch length growth and dry weight of juniper was not affected by fertilizer type when fertilizer was surface-applied or medium incorporated. Dibbled Osmocote produced similar results, but dibbled Nutricote resulted in poor root and shoot development in juniper throughout the season. Medium soluble salt concentration (determined on container leachate) was 2800 dS/m in the dibbled Nutricote treatments in June (approximately 2.5 times higher than that in the other treatments). Soluble salts decreased between June 21 and August 16 in all treatments and then remained quite constant until the end of the season (September 13).

Index words: sand bed, containers, soluble salts

Significance to the Nursery Industry

As concerns over water consumption, quality and ground water contamination increase, capillary irrigation of nursery stock is likely to gain importance. Nutricote or Osmocote controlled release fertilizers which are either premixed or applied to the surface of the growing medium promote good growth of compact andorra juniper and sarcoxie euonymus on capillary systems. Dibbling should be used with caution especially when dealing with salt sensitive species, since rapid nutrient release can result in soluble salt accumulation in the early season.

Introduction

Capillary, or sub-irrigation is a popular irrigation method for container production in nurseries in various countries especially where water consumption and quality is a critical consideration (2, 7, 10). Considerably, less water is required with capillary, than with overhead irrigation. Moreover, water is more evenly distributed in the container thus reducing the potential for waterlogging and leading to improved plant growth (7, 11).

Fertilization via irrigation water is not practical with capillary systems, so their successful operation dictates the use of controlled release fertilizers applied to containers at the start of the season. Since water moves upward through the growing medium, it might be concluded that application of fertilizer to the medium surface would not be effective in sustaining nutrient supply in the root zone. Where fertilizers are medium-incorporated limited leaching might result in soluble salt accumulation leading to a reduction in growth. An alternative might be to dibble fertilizer in a zone just below the developing root system where an adequate water supply and the presence of developing roots should result in rapid uptake of nutrients (1). Previous research has compared the effects of fertilizer type and surface, incorporated

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or dibbled application on growth of containerized plants supplied with drip irrigation (12). There is much less information available for plants grown with capillary irrigation. This study was undertaken to investigate the effects of fertilizer type and placement on plant growth and soluble salt accumulation in capillary-irrigated containers as a first step in defining appropriate fertilization strategies for this irrigation method. The growth of two taxa (Andorra juniper and Sarcoxie euonymus) was studied in relation to surface, incorporated or dibbled application of Osmocote or Nutricote controlled release fertilizers.

Materials and Methods

A growing medium prepared by mixing coarse sphagnum peat, perlite and sand (2:1:1 by vol) was amended with single superphosphate, 100 mesh-size dolomitic lime and Nutritrace[2] at 2.3, 2.3 and 0.5 kg/m^3 (3.9, 3.9 and 0.8 lbs/yd^3) respectively. A 3:1 (by vol) mixture of Nutricote[2] 16N-4.4P-8.1K (16-10-10) Type 100 and Type 40 was prepared. Nutricote Type 100 releases 80% of constituent N over 100 days at a mean soil temperature of 25°C (77°F) and Type 40 releases the same percentage N over 40 days under the same conditions. The growing medium was divided into 6 batches of equal volume, and the Nutricote mixture and Osmocote[3] 18N-2.6P-9.7K (18-6-12) were incorporated into the first and second batch at rates of 5 kg/m^3 (8.3 lbs/yd^3) and 4.4 kg/mg^3 (7.3 lbs/yd^3), respectively.

On May 24, 1988 rooted cuttings of compact Andorra juniper (Juniperus horizontalis Moench. 'Plumosa compacta') and Sarcoxie euonymus (Euonymus fortunei Turcz. 'Sarcoxie') were planted in 3.8 1 (#1) containers and assigned to the following factorial treatments: Nutricote, medium incorporated, Osmocote, medium incorporated, Nutricote surface-applied (15 g (0.53 oz)/container), Osmocote surface-applied (13.2 g (0.47 oz)/container), Nutricote dibbled (15 g (0.53 oz)), Osmocote dibbled (13.2 g (0.47 oz)). Dibbled fertilizer was placed at the bottom of 2 tapered cavities bored 16 cm (6.5 in) into the medium on either side of the plant. Fertilizer weights are calculated to provide the same nitrogen content in each container. Each plant was weighed before planting and, for Andorra juniper, a single branch was marked adjacent to the main stem to provide a reference for branch length measurement through the season. Containers were placed on permanently moist, sand capillary beds. Each bed measured 3.4 × 2.3 m (11 × 7.5 ft) and consisted of perforated 6 mil copolymer sheeting underlying a crushed rock base topped with 13 cm (5 in) of sharp sand. Water supply to the beds was via trickle irrigation tubing and was controlled by a modified bridge-type temperature controller operated in conjunction with stainless steel sensors embedded in the sand (4). On June 21, July 19, August 16 and September 13, 200 ml (7 fl oz) of distilled water were poured onto media surfaces of 8 containers in each treatment regimen. The resulting leachate was collected and analyzed at 25°C (77°F) for soluble salt content (expressed as electrical conductance) and pH (13). Since no significant differences in pH or soluble salt content were observed between juniper or euonymus containers, data for the two taxa were combined. pH was not affected by fertilizer type or placement but increased slightly (from a mean value of 5.71 to 5.96) over the growing season. Eight plants each of euonymus and juniper were harvested from each treatment regimen for measurement of root and shoot dry weight, leaf area (euonymus) and branch length increment (juniper). An error resulted in loss of data for the June juniper harvest.

The experimental design was a randomized complete block with 2 pots per experimental unit (monthly sample) and 4 replications. Data from individual pots in each block were averaged and transformed to logarithms for analysis of variance. Initial plant fresh weight was a significant covariate in analyses involving shoot dry weight of euonymus and juniper, and for leaf area of euonymus. Values for plant traits are reported as the back transformed least squares means adjusted for the covariate. Percentage standard errors of the mean were calculated where appropriate to facilitate comparisons between means on the original (non-logarithmic) scale.

Results and Discussion

Euonymus and juniper showed different growth patterns and responded differently to type and placement of controlled-release fertilizer (Tables 1 and 2). In juniper, plant dry weight increased between May 24 and August 16, but plants showed little further growth after this date. In contrast, euonymus plants gained weight continuously between May and September. Neither leaf area, shoot, or root dry weight was significantly influenced by fertilizer placement or type in euonymus. For juniper, minimum branch length increment and end-of season shoot and root weights were recorded in plants which received a dibbled application of Nutricote. When compared with the other treatments, growth of these plants was significantly reduced during the May to July period, and showed no recovery during the remainder of the season. Differences among the other treatments were not significant.

Medium soluble salts were highest in all treatments in June and declined between June 21 and August 16 (Table 3). Salt content changed little between August and September. There were significant interactions between fertilizer method, sampling period and placement, due primarily to the high values for soluble salts in leachates from the dibbled Nutricote containers on June 21. High soluble salts are a probable cause of the reduced early growth of junipers in this treatment. Root damage caused by high salt concentrations is suggested by the relatively low root weights in the dibbled Nutricote treatment in July. Poor early root development may be responsible for sub-optimal growth throughout the season. A lack of similar sensitivity in euonymus indicates quite different degrees of salt tolerance in these two genera. Dibbled fertilizer application has previously been shown to limit root growth in some species (12), but to date evidence has been lacking that this method influences growth through elevated soluble salt concentrations. The present data suggest that this is the case for some, but not all, fertilizers. Reasons for the differential effects of dibbled Nutricote and Osmocote on medium soluble salt content are not clear. They may, however, be related to different nutrient release dependencies in each fertilizer. In Osmocote,

[2]Chisso-Ashai Fertilizer Co. Ltd., Tokyo.

[3]Sierra Chemical Co. Ltd., Milpitas, CA

Table 1. Leaf area, shoot dry weight and root dry weight of Sarcoxie Euonymus with incorporated, surface-applied or dibbled controlled-release fertilizer.

Placement (Fertilizer)[z]	Leaf area (cm−2) June	July	Aug	Sept	Shoot dry weight (g) June	July	Aug	Sept	Root dry weight (g) June	July	Aug	Sept
	(cm²)				(g)				(g)			
Incorporated (Nut)	94.17	228.87	372.02	375.38	1.71	3.08	6.23	8.70	0.38	0.74	1.59	2.18
Incorporated (Osm)	63.11	226.49	346.68	371.79	1.31	3.40	6.67	8.90	0.30	0.77	1.57	2.71
Surface Applied (Nut)	88.63	250.62	356.53	451.97	1.69	3.70	6.45	10.34	0.46	0.80	1.56	2.91
Surface Applied (Osm)	68.66	209.51	332.43	463.79	1.52	2.92	6.39	10.83	0.31	0.75	1.71	2.94
Dibbled (Nut)	76.04	188.92	357.70	444.72	1.72	3.04	6.58	10.38	0.27	0.67	1.44	2.84
Dibbled (Osm)	82.11	183.24	276.65	431.03	1.83	2.53	5.57	9.03	0.26	0.65	1.26	2.45
% SEM (n=4, df=69)[y]	(17.8%)				(16.3%)				(17.4%)			
F Value												
Placement (P)	NS				NS				NS			
Fertilizer (F)	NS				NS				NS			
Month	125.91**				161.88**				192.85**			
Linear	340.69**				480.09**				574.34**			
Quadratic	35.20**				NS				NS			
PxF	NS				NS				NS			
PxM	NS				NS				NS			
FxM	NS				NS				NS			
PxFxM	NS				NS				NS			

[z]Nutricote 16N-4.4P-8.1K (Nut) or Osmocote 18N-2.6P-9.7K (Osm).

[y]Data transformed to logarithms for analysis and the presented means are back transformed log means. Standard error for an individual mean = mean × % SEM/100%.

NS,*,**Nonsignificant (NS) or significant at 5% (*), 1% (**) level.

thickness of fertilizer coating determines the rate of nutrient release (8) whereas in Nutricote the process is mediated by the concentration of a release-controlling additive in the coating (9). Higher effective concentrations of this additive when the fertilizer is packed together (as in the dibble hole) is a possible explanation for elevated early-season soluble salt concentrations. Medium temperature affects nutrient release rate slightly dfifferently in Osmocote and Nutricote (6). The most rapid nutrient release at 25°C (77°F) occurs from Nutricote Type 40, but it is unlikely that temperature would influence release rate differently in dibbled and medium-incorporated fertilizers. High medium temperatures in

Table 2. Branch growth, shoot dry weight and root dry weight of Andorra Juniper with incorporated, surface applied or dibbled controlled-release fertilizers.

Placement (Fertilizer)[z]	Branch growth increment[y] (cm) July	Aug	Sept	Shoot dry weight (g) July	Aug	Sept	Root dry weight (g) July	Aug	Sept
	(cm)			(g)			(g)		
Incorporated (Nut)	3.37	7.34	7.99	1.68	3.17	4.48	0.22	0.40	0.78
Incorporated (Osm)	3.51	6.99	7.18	1.48	2.72	3.58	0.26	0.30	0.64
Surface applied (Nut)	3.92	6.89	7.17	1.55	3.43	3.77	0.21	0.41	0.68
Surface applied (Osm)	3.89	7.29	7.67	1.64	3.08	3.24	0.20	0.38	0.56
Dibbled (Nut)	1.84	3.81	3.47	1.13	2.00	1.89	0.12	0.22	0.21
Dibbled (Osm)	3.19	7.71	8.03	1.81	4.06	4.07	0.29	0.49	0.66
%SEM (n=4, df=69)[x]	(17.0%)			(22.6%)			(27.6%)		
F Value									
Placement (P)	6.91**			NS			NS		
Fertilizer (F)	10.50**			NS			4.71*		
Month	45.42**			28.34**			24.83**		
Linear	70.87**			48.98**			49.55**		
PxF	9.58**			6.90**			8.82**		
PxM	NS			NS			NS		
FxM	NS			NS			NS		
PxFxM	NS			NS			NS		

[z]Nutricote 16N-4.4P-8.1K (Nut) or Osmocote 18N-2.6P-9.7K (Osm).

[y]Increment from May 24 to sampling dates in July, August and September.

[x]Data transformed to logarithms for analysis and the presented means are back transformed log means. Standard error for an individual mean = mean × % SEM/100%.

NS,*,**Nonsignificant (NS) or significant at 5% (*), 1% (**) level.

Table 3. Electrical conductance of leachate collected following addition of 200 ml distilled water to media surfaces.

Placement (Fertilizer)[z]	EC_{25}[y] (ds/m)			
	June 21	July 19	Aug 16	Sept 13
Incorporated (Nut)	1300	780	260	250
Incorporated (Osm)	1000	470	370	490
Surface applied (Nut)	1120	580	230	300
Surface applied (Osm)	1220	550	280	370
Dibbled (Nut)	2800	550	300	280
Dibbled (Osm)	940	480	380	260
SEM (n=4, df=69)[x]	(112)			
F Value				
Placement (P)	4.3*			
Fertilizer (F)	10.8**			
Month	107.8**			
Linear	247.6**			
Quadratic	74.0**			
PxF	NS			
PxM	6.49**			
FxM	13.57**			
PxFxM	9.17**			

[z]Nutricote 16N-4.4P-8.1K (Nut) or Osmocote 18N-2.6P-9.7K (Osm).

[y]Electrical conductance of medium leachate measured at 25°C.

[x]Data transformed to logarithms for analysis and the presented means are back transformed log means.

NS,*,** Nonsignificant (NS) or significant at 5% (*), 1% (**) level.

the early season are, therefore, not a plausible explanation for the differences in soluble salt content observed in this study.

There were no significant differences in leachate soluble salts obtained from containers with surface-applied or incorporated fertilizers suggesting that soluble nutrients are released from granules irrespective of their location in capillary-irrigated containers. Determination of soluble salts in container leachates does not, of course, indicate the distribution of salts within the container. It is likely that salt concentration is highest in the uppermost 4 cm (1.5 in) of the medium where fertilizers are applied to the surface of capillary-irrigated containers (3) but this localization did not significantly affect plant growth in the present experiments. While several factors including seasonal rainfall and rate-pattern of fertilizer release may determine the effectiveness of surface-applied controlled release fertilizers (5), it is notable that this placement has been reported to promote good growth in previous trials with capillary systems (3).

Literature Cited

1. Cobb, G.S. 1985. Comparison of fertilizer application methods for a single component medium. Proc. Southern Nurserymans Assoc. Res. Conf. 30:60–72.

2. Edmonds, J. 1980. Container Plant Manual. Grower Books, London.

3. Havis, J. 1982. Applying slow-release fertilizers in container nurseries with capillary watering. Amer. Nurseryman. 156(4):24–32.

4. Hicklenton, P.R. and K.G. Cairns. 1984. Capillary irrigation of woody ornamental nursery stock. Canadex 560. 275 pp.2.

5. Hicklenton, P.R. and K.B. McRae. 1989. Mineral status and growth of containerized compact andorra juniper under different irrigation and fertilizer regimens. Can. J. Plant Sci. 69:1295–1300.

6. Lamont, G.P., R.J. Worral and M.A. O'Connell. 1987. The effects of temperature and time on the solubility of resin-coated controlled release fertilizers under laboratory and field conditions. Scientia Hort. 32:265–273.

7. Richards, M., P. Desborough and I. Duncalf. 1980. Design of drained sand capillary beds. New Zealand Nursery Research Centre Annual Rept. p. 105–111.

8. Rutten, T. 1980. Osmocote controlled-release fertilizer. Acta Hort. 99:187–188.

9. Shibata, A. S. Fufita and S. Maeda. 1980. Nutricote-coated fertilizers processed with polyolefin resins. Acta Hort. 99:179–186.

10. Smith, E.M. and S.A. Treaster. 1979. Studies of capillary watering of container grown nursery stock. New Horizons. Horticultural Res. Institute, Washington, D.C. p. 25–27.

11. van de Werken, H. 1989. A new way with containers. Amer. Nurseryman 170(2):43–51.

12. Yeager, T.H. and D.L. Ingram. 1987. Response of azalea and Ligustrum to fertilizer placement and application rate. Proc. Southern Nurserymans Assoc. Res. Conf. 32:88–90.

13. Yeager, T.H., R.D. Wright and S.J. Donohue. 1983. Comparison of pour-through and saturated pine bark extract N, P, and K, and pH levels. J. Amer. Soc. Hort. Sci. 108:112–114.