There have been reports in the literature that nutrient deficiencies commonly occur in cuttings rooted under mist. These deficiencies could be due to two factors. First, mineral nutrients are leached from the cuttings as was the case with mature hardwood cuttings. Second, the cuttings grow through additions of carbohydrates from photosynthesis, and the nutrients retained in the cuttings are not sufficient for the new growth. In either case, additional nutrients supplied to the cuttings during rooting may be an important factor in rooting and in the subsequent growth and development of the rooted cutting.

Summary

Cuttings from numerous ornamental plants were surveyed in order to determine the extent of nutrient leaching when propagated under mist. Herbaceous and softwood cuttings proved very difficult to leach whereas hardwood cuttings were relatively easy to leach. Cuttings were capable of substantial growth during rooting due to the growth of new leaves and roots. Nutrients held in the older, fully expanded leaves of chrysanthemum were translocated to the growing new leaves and roots from where they were not readily leached. Nutrient deficiencies which commonly occur in cuttings rooted under mist could be due to (a) the leaching of nutrients, and (b) the diluting of mineral nutrients by additions of carbohydrates from photosynthesis.

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MODERATOR HESS: Now we will turn our attention to the area of new techniques. An obvious solution to solve the leaching problem would be to add nutrients to the mist. To tell us about his experiments with nutrient mist is Mr. John Wott.

PROPAGATION OF CUTTINGS UNDER NUTRIENT MIST

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Introduction

Many workers have reported that mineral nutrients can be leached from cuttings propagated under mist with the subsequent development of nutrient deficiency symptoms (Ang 1958, Evans 1951, Good and Tukey 1964, Sweet and Carlson

1955, Tukey 1962). Losses by leaching are related to the maturity of the cutting, being greatest for hardwood cuttings and much less for softwood and herbaceous cuttings.

Nutrient deficiencies in cuttings rooted under mist are due to a) leaching of nutrients and b) growth of the cuttings during rooting causing a dilution of the nutrients within the cuttings (Good and Tukey 1964, 1965). In either case it would seem that nutrients added to the cuttings during propagation might be of benefit.

Since it is well known that a broad spectrum of material can be absorbed by stems and foliage (Wittwer and Teubner 1959), application of nutrients through the mist would be an appropriate procedure. Thus Morton and Boodley (1962) observed that poinsettia and chrysanthemum cuttings propagated under a complete nutrient mist were superior to those propagated under a water mist.

This paper presents an evaluation of the use of nutrient mist in the propagation of several commercially important ornamental plants.

Materials and Methods

Uniform cuttings of twenty-nine ornamental species were collected from stock plants in November and early June. The complete list of plant material is given in Table 1.

Twenty to forty cuttings of each species were immediately dried, weighed and analyzed for nitrogen, phosphorus and potassium in the laboratory. Two hundred to 400 additional cuttings were divided into two groups and placed in greenhouse propagation benches equipped with mist and bottom heat in a rooting medium of peat and perlite (1:1 by volume). One group of each species was misted with tap water (water mist) at an interval of 12 seconds every 2½ to 10 minutes during the day. The

Table 1 List of Plant Materials Propagated Under Intermittent Nutrient Mist.

Berberis thunbergii[2]	*Philadelphus coronarius*[2]
Buxus sempervirens[2]	*Ribes alpinum*[1 2]
Chaenomeles speciosa[2]	*Rosa multiflora*[1 2]
Chrysanthemum morifolium[1]	*Rosa setigerum*[2]
Euonymus fortunei[1 2]	*Salix purpurea*[2]
Euonymus fortunei 'Vegetus'[1 2]	*Syringa vulgaris*[2]
Forsythia intermedia[2]	*Taxus baccata* 'Repandens'[1]
Forsythia suspensa[1 2]	*Taxus cuspidata*[1]
Hedera helix[1 2]	*Thuja occidentalis*[1]
Juniperus chinensis 'Hetzi'[1]	*Thuja plicata*[1]
Juniperus chinensis 'Sargentii'[1]	*Tsuga canadensis* 'Pendula'[1]
Ligustrum obtusifolium 'regelianum'[2]	*Viburnum lantana*[2]
Lonicera tatarica[2]	*Viburnum prunifolium*[2]
Lonicera morrowii[2]	*Vinca minor*[1 2]
Pachysandra terminalis[1 2]	

1) fall propagation
2) spring propagation

other group of cuttings was misted at the same interval with tap water to which a complete, all-soluble fertilizer (nutrient mist) with an analysis of 23-19-17 was added at the rate of six ounces per 100 gallons of water. The fertilizer was recommended for both foliar and soil applications.

When the cuttings were well rooted, they were removed from the benches and rooting percentages and root evaluations were determined. Root evaluations were made on the basis of size of roots, number, color, and brittleness. Some cuttings of each species were then potted up and grown on to determine growth rates after rooting. The remaining cuttings were then dried, weighed and analyzed for nitrogen, phosphorus and potassium. In some species, new shoot growth was produced during rooting and this was removed and analyzed. The mineral nutrient content of the cuttings of each species before rooting was compared with the content after rooting under the water or nutrient mist system.

Results

Hardwood Cuttings

The results of the fall propagation of three representative species are presented in Table 2. *Hedera helix* cuttings from under the nutrient mist had a higher dry weight at the end of the propagation period (919 mg) than did those from under the water mist (892 mg). Under the water mist there was a decrease of nitrogen, phosphorus and potassium content as compared with the content before rooting, indicating that leaching of the nutrients occurred during rooting. In contrast, the cuttings from under the nutrient mist show a substantial increase in content of these three nutrients when compared with both the cuttings from under the water mist system and the cuttings before rooting.

Cuttings from under the water mist had a higher rooting percentage than cuttings under nutrient mist and also a slightly higher root quality.

Hedera helix was one of the species in which the new growth of the cuttings made during rooting was removed and analyzed separately. As shown in Table 3, cuttings from under the nutrient mist made more growth (dry wt.) and had a greater uptake of nitrogen, phosphorus and potassium than did cuttings under the water mist.

Rosa multiflora and *Thuja plicata* gave similar results to those obtained with *Hedera helix* in that under the nutrient mist, the nutrient content and growth were considerably greater than under the water mists. For example with *Rosa multiflora*, rooted cuttings propagated with nutrient mist were 132% heavier (dry wt.) than cuttings propagated with water mist.

The results with *Vinca minor*, *Euonymus fortunei* and *Juniperus chinensis* 'Sargentii' were similar in some respects to *Hedera helix*. For example, like *Hedera helix*, nutrients were leached from the cuttings by the water mist. Similarly, the

Table 2 Influence of nutrient mist on the dry weight, nutrient content and root development of hardwood cuttings taken in November.

Species	Dry Wt	Nutrient Content			Rooting	Root quuality
		N	P	K		
	(mg/cutting)		(mg/cutting)		(%)	
Hedera helix						
Before rooting	938	16 56	1 88	9 59	—	—
After rooting — water mist	892	13 87	1 62	7.46	91 2	4 52
nutrient mist	919	20 63	2 67	14 05	83 2	4 32
Pachysandra terminalis						
Before rooting	501	14 91	1.92	9 38	—	—
After rooting — water mist	566	13 11	1 52	5 50	100 0	4 65
nutrient mist	517	16 49	1 83	6 58	100 0	4 67
Euonymus fortunei 'Vegetus'						
Before rooting	752	16 10	1 01	5 50	—	—
After rooting — water mist	887	17 21	2 32	2 55	91 2	4 80
nutrient mist	753	17 54	2 46	2 51	89 7	4 20

Table 3 Influence of nutrient mist on the dry weight and nutrient content of the new growth of *Hedera helix* cuttings produced during the rooting period

	Water mist	Nutrient mist
	(mg/cutting)	
Dry Wt.	92	116
N	2.05	4.15
P	0.33	0.56
K	2.43	4.30

nutrient content was higher under the nutrient mist and the dry weight was increased as compared to the water mist, as seen in *Juniperus chinensis* 'Sargentii' which had more growth under nutrient mist (487 mg) than with water mist (325 mg). However unlike *Hedera helix*, rooting percentages were somewhat higher under the water mist, whereas the root quality was higher under the nutrient mist.

After removal from the propagation bench, most of the rooted cuttings of the above mentioned species from under the nutrient mist grew faster (linear growth) and were heavier after six months than were cuttings from under the water mist.

Pachysandra terminalis exhibited an indifferent response to nutrient mist. Table 2 shows that cuttings from under water mist had a higher dry weight than did either the original cuttings or cuttings from under nutrient mist. Some leaching of nutrients did occur and the potassium contents were higher under the nutrient mist, but the differences were small. In addition, there were no differences between treatments either in the rooting or the growth of the cuttings after rooting. *Taxus cuspidata* responded similarly to *Pachysandra*.

One species, *Euonymus fortunei* 'Vegetus' gave better rooting under water mist. Although the nutrient content of the cuttings was similar under both treatments, the cuttings under the water mist were considerably heavier and stronger and grew more after their removal from the propagating bench than did cuttings from under the nutrient mist.

Softwood Cuttings

The responses of representative softwood cuttings propagated in early June are presented in Table 4. All of the species, especially *Philadelphus coronarius* and *Forsythia intermedia* made large increases in dry weight during the rooting period. The growth of some species was favored by water mist and other species by nutrient mist.

Similarly, in all species, a considerable increase in the nitrogen, phosphorus and potassium content was noted in the cuttings propagated under nutrient mist as compared with the water mist and the content of cuttings before rooting. Leaching of nutrients by the water mist did occur especially with *Philadelphus coronarius* and *Salix purpurea*. Addition of nutrients to these rapidly growing cuttings not only replaced the leached nutrients

Table 4 Influence of nutrient mist on the dry weight, nutrient content, and root development of softwood cuttings taken in June

Species	Dry Wt	Nutrient Content			Rooting	Root quality
		N	P	K		
	(mg/cutting)		(mg/cutting)		(%)	
Philadelphus coronarius						
Before rooting	520	17 95	2 17	14 98	—	—
After rooting — water mist	850	12.27	2 15	9 87	54 2	1 67
nutrient mist	930	43 14	7.68	22 23	86 2	2 80
Euonymus fortunei 'Vegetus'						
Before rooting	560	12 42	1.66	4 99	—	—
After rooting — water mist	870	13 01	1 72	4 47	98 8	2 61
nutrient mist	770	22 27	2 82	6 08	100.0	2 75
Forsythia intermedia						
Before rooting	460	10 00	1 16	5 45	—	—
After rooting — water mist	1110	13 76	1 38	8 27	100 0	3 00
nutrient mist	1010	41 67	5 23	18 50	98 8	2 88
Salix purpurea						
Before rooting	405	12 95	1 14	5 36	—	—
After rooting — water mist	590	8 61	1 41	3 87	100 0	2 81
nutrient mist	546	23 87	5 68	8 32	94 0	2 81

but increased the nutrient content by three to four times as compared with cuttings under water mist.

In the case of *Philadelphus coronarius* and *Euonymus fortunei* 'Vegetus', cuttings under nutrient mist had a higher rooting percentage with a much more desirable root system than did cuttings under water mist.

In both species, rooted cuttings from under the nutrient mist grew faster (linear growth) and had a higher dry weight at harvest than did the cuttings from the water mist. In addition more side shoots developed on those *Euonymus* cuttings from under nutrient mist, whereas the mist cuttings from water mist made only terminal growth.

Comparison between softwood and hardwood cuttings of *Euonymus fortunei* 'Vegetus' can be seen in Table 2 and Table 4. While the hardwood cuttings did not respond favorably to nutrient mist, the softwood cuttings showed a higher nutrient content, better rooting percent and root quality under nutrient mist. The softwood cuttings from nutrient mist also developed more side shoots after their removal from the propagation bench than did the hardwood cuttings from nutrient mist.

Nutrient mist does influence the root quality of *Forsythia intermedia*. Cuttings under nutrient mist had thick, fleshy roots which were very brittle, whereas those propagated under water mist had a thin, fibrous root system. This same type of root difference was noted in cuttings of *Forsythia suspensa*, *Ligustrum obtusifolium* 'regelianum' and *Salix purpurea*. In fact, in the case of *Salix purpurea*, the roots were so brittle that 50% of the cuttings failed to survive transplanting.

The cuttings of *Forsythia intermedia* potted from under the nutrient mist were darker green when taken from the propagating bench, grew faster and had a higher dry weight after six months than did cuttings from under the water mist.

Another problem was noted in cuttings of *Salix purpurea* under nutrient mist in that the terminal growth died and blackened, resulting in cuttings with a bushy appearance. Whether this was related to high salt concentrations in the nutrient mist was not determined.

Discussion

The results of these experiments verify that mineral nutrients are leached from both hardwood and softwood cuttings propagated under mist. Of the three nutrients studied, potassium is the most easily leached, followed by nitrogen and phosphorus. These results are in agreement with many other reports in the literature (Tukey, 1962).

Cuttings in these experiments, especially softwood cuttings, increased in dry weight during the rooting period. For example, softwood cuttings of *Forsythia intermedia* more than doubled in dry weight during rooting (Table 4). This also is in agreement with reports in the literature (Hess and Snyder 1957, Good and Tuksy 1965).

Mineral nutrients applied to cuttings through the mist lines

were readily absorbed by the cutting and greatly increased the nitrogen, phosphorus and potassium content of both hardwood and softwood cuttings as compared to cuttings propagated under water mist. This was particularly true with the fast growing softwood cuttings as shown in Table 4. The amount of nutrient uptake is influenced by the plant species and the nutrient itself. For example, all three nutrients were readily absorbed by hardwood cuttings of *Hedera helix*, but not to the same extent by *Pachysandra terminalis* (Table 3).

The response of cuttings to nutrient mist is specific for each species. For example, hardwood cuttings of *Hedera helix* and softwood cuttings of *Philadelphus coronarius* absorbed large quantities of nutrients from the mist, rooted well and made better growth after rooting than did cuttings which did not receive nutrients. In contrast, *Euonymus fortunei* 'Vegetus' propagated as a hardwood, made better response under water mist. Still other species, such as hardwood cuttings of *Pachysandra terminalis* and *Taxus cuspidata* were indifferent to nutrient mist.

Rooting and root quality is also influenced by nutrient mist. Some cuttings such as *Hedera helix* and *Salix purpurea* had a slightly higher rooting percentage under water mist than nutrient mist whereas others such as *Philadelphus coronarius* rooted better under nutrient mist. Under nutrient mist *Forsythia intermedia* produced a thick, brittle root system which was somewhat difficult to transplant.

The problem of the die-back in *Salix purpurea* points out that perhaps the concentration of nutrients in the mist may be important. Salix, which is fast rooting and fast growing, may not require high concentrations of nutrients during the entire misting period for maximum benefit.

Plants which produce new growth in the propagating bench and have an adequate supply of nutrients during rooting will grow faster after their removal from the bench. For example, *Philadelphus coronarius* nutrient mist cuttings produced twice as much growth (dry weight) as the water mist cuttings. Others which do not make as much growth during rooting, such as the hardwood cuttings of *Pachysandra terminalis* and *Euonymus fortunei* 'Vegetus' were not beneficially affected by nutrient mist in their growth after removal from the propagating bench.

Summary

Nutrients applied through the mist lines were readily absorbed by both hardwood and softwood cuttings. However, cuttings which were actively growing during rooting, particularly the softwood cuttings, were more favorably influenced by nutrient mist than were slow growing cuttings. Uptake of nutrients from the mist is specific both for the plant and the nutrient, while rooting also varies with the plant. Rooting percentage and root quality were better under nutrient mist with some species, while others were more favorably influenced by water

mist. Those cuttings which show a definite uptake of nutrients and growth while in the propagation bench continue to grow at a faster rate after their removal from the propagation bench than do cuttings which do not receive nutrients.

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MODERATOR HESS: Another technique which has had a tremendous impact upon horticultural industries is the control of plant growth and development by regulation of day length. Dr. Sidney Waxman was among the first to combine the techniques of mist propagation and day length control. He will now tell us about some of the results and implications of this combination.

PHOTOPERIODIC TREATMENT AND ITS INFLUENCE ON ROOTING AND SURVIVAL OF CUTTINGS "LIGHTING UNDER MIST"

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My talk will be confined to the use of light given during the night for the purpose of extending the daylength to which the cuttings are exposed. As you know, many trees and shrubs that are given long days will not become dormant in late summer or fall, as they normally do, but will continue to grow for an extended period of time. This can be accomplished by illuminating the cuttings every night until they have rooted.