PROPAGATION OF CHRYSANTHEMUMS UNDER NUTRIENT MIST[1]

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Introduction

The most important method of propagating ornamental shrubs — deciduous as well as broad and narrow-leafed types of evergreens — is by cuttings (Hartmann and Kester, 1968). Likewise, many of the florist crops such as carnations, poinsettias, and chrysanthemums are propagated vegetatively by cuttings. Propagation by cuttings is simple, inexpensive, the techniques are easy to learn, many plants can be started in a limited amount of space, and genetic preservation of a desirable plant race is possible (Wott, 1966).

Water conservation is of prime importance to the cuttings during propagation and the development of mist propagation techniques greatly aided the propagation industry (Snyder, 1965). However, symptoms characteristic of nutrient deficiencies due to mineral nutrients leached from the cuttings or to nutrient dilution within the growing cuttings have been reported (Snyder, 1954; Sharpe, 1955; Good and Tukey, 1966). Nutrients can be applied to cuttings during propagation through intermittent mist (Dick, 1960; Morton and Boodley, 1962; Sorenson and Coorts, 1968; Wott and Tukey, 1967)

Earlier, Wott and Tukey (1965) reported that cuttings of several species of ornamental plants, including both softwood and herbaceous types, exhibited large increases in growth (linear stem length and dry weight), and in nutrient content when propagated under nutrient mist. In many species propagated under nutrient mist, cuttings developed a better quality root system, had more growth of lateral buds, and continued to grow at a faster rate after propagation than did cuttings propagated under water mist. Hardwood cuttings also responded favorably to nutrient mist, but the responses were not as great as with the fast-growing softwood and herbaceous cuttings (Wott, 1966).

Materials and Methods (General)

Cuttings of several cultivars of *Chrysanthemum morifolium* ('Giant Betsy Ross', 'Giant #4 Indianapolis White' 'Yellow Columbia' and 'Yellow Sceptor') were taken from stock plants grown in a greenhouse or secured as unrooted cuttings from Yoder Brothers, Barberton, Ohio. All cuttings were graded so as to be of a uniform size, length and leaf number. Cuttings for certain experiments were also selected on a fresh weight basis.

The cuttings were placed into propagation benches in a medium of vermiculite-perlite (1:1 by volume) under inter-

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mittent mist of tap water (water mist) with a mist cycle of 12 seconds of mist every 2½ to 10 minutes during the day. For comparison, a complete soluble fertilizer (Ra-Pid-Gro, analysis 23-19-17) was added to the mist at the rate of either 2, 4, 6, or 8 ounces per 100 gallons of water (nutrient mist) in a manner described by Wott and Tukey (1967).

When the cuttings were removed, they were dried, weighed, and analyzed for rooting, nitrogen, phosphorus, and potassium content. Some cuttings were potted up and grown to determine growth after propagation. The mineral content of the cuttings was compared with the content of the cuttings after rooting under the water or nutrient mist systems.

Concentration of Nutrient Mist

Cuttings of 'Giant Betsy Ross' were uniformly graded as to size and length, and rooted under a water mist treatment and nutrient mist treatments of 2, 4, 6, and 8 ounces of Ra-Pid-Gro per 100 gallons of water. The results of the dry weight and nutrient analyses are presented in Table 1. The dry weight of the cuttings increased considerably (60%) during propagation when compared to the dry weight of the cuttings before propagation. However, cuttings under the nutrient mist propagation increased more than those propagated under water mist.

The nitrogen content of the cuttings increased as the concentration of the nitrogen in the nutrient mist was increased. For example, the nitrogen content increased from 14.0 to 20.4 mlligrams per cutting as the concentration of nutrient mist was increased from 2 to 8 ounces per 100 gallons of water. In addition, the cuttings under nutrient mist had a higher nitrogen content than did those propagated under water mist or the cuttings before propagation.

Table 1 Influence of concentration of nutrient mist during propagation on the total dry weight and nutrient content of *Chrysanthemum morifolium* 'Giant Betsy Ross' cuttings.

	Before rooting	After rooting				
		water	2 oz[1]	4 oz	6 oz	8 oz
	(mg/cutting)	(mg/cutting)				
Dry wt.	214	366[2]	431[23]	438[23]	459[23]	448[23]
N	12.8	12.4	14.0	16.8[234]	18.8[234]	20.4[2356]
P	1.1	1.2	1.7[23]	1.8[23]	1.7[23]	1.6[23]
K	9.5	8.4	8.3[2]	9.3	10.0[4]	11.0[235]

[1]oz /100 gal. water

Significant difference at 5% level between:
[2]before and after propagation
[3]nutrient and water
[4]2 and 4 oz
[5]2 and 8 oz
[6]4 and 8 oz.

The phosphorus content of the cuttings was highest under the 4-ounce nutrient mist treatment, and did not show an increased phosphorus uptake under the 6- or 8-ounce treatments. However, the results of the change in potassium content were somewhat different. For example, the cuttings propagated under water mist and the 2-ounce nutrient mist treatments showed a decrease in potassium content when compared to the cuttings before propagation. This would indicate that leaching of potassium had occurred during rooting. Ra-Pid-Gro, applied at the rate of 4 or 6 ounces per 100 gallons of water was applied to the cuttings before the potassium content of the cuttings attained levels comparable to those of the cuttings before propagation (Table 1).

Ten representative cuttings from both the water and nutrient mist treatments were potted up at the time the cuttings were removed from the propagation benches and grown under identical greenhouse conditions until flowering. They were fertilized with a water soluble fertilizer being applied to the soil in the pots. An initial height measurement of the cuttings was taken immediately after potting, followed by weekly measurements thereafter.

As shown in Table 2, the cuttings propagated under nutrient mist were taller than those propagated under water mist when potted up, with the exception of the 2-ounce treatment. However, during the 63-day growth period after propagation, the cuttings propagated under the 2-ounce nutrient mist grew somewhat faster than those propagated under water mist. In contrast, those propagated under the 4-, 6-, and 8-ounce treatments grew considerably more than the water and the 2-ounce nutrient mist cuttings. Also there appeared to be

Table 2. Influence of nutrient mist during propagation on the growth of *Chrysanthemum morifolium* 'Giant Betsy Ross' cuttings after removal from the propagation bench.

Days after propagation	Water Mist	Growth-cm per cutting propagated under nutrient mist[1] 2 oz	4 oz	6 oz	8 oz.
0	3.2	2.8	4.3[23]	3.9[24]	3.3[567]
10	10.0	9.6	13.1[23]	12.6[24]	11.0[56]
21	25.2	25.3	30.5[23]	30.0[24]	29.3[25]
49	61.9	60.8	66.8[3]	67.9[24]	66.9[5]
63	64.7	65.5	69.5	71.6[2]	72.0[2]

[1]oz /100 gallon water.

Significant difference at 5% level between
[2]water and nutrient
[3]2 and 4 oz
[4]2 and 6 oz
[5]2 and 8 oz
[6]4 and 8 oz
[7]6 and 8 oz.

little difference in stem growth among plants originally propagated under the 4-, 6-, and 8-ounce nutrient mist treatments.

Dry Weight and Nutrient Change

Cuttings of *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' were cut from stock plants grown in the greenhouse, selected for uniform size and leaf number and a fresh weight of 1.5 grams each, and placed, 45 cuttings per flat, under water mist and nutrient mist (Ra-Pid-Gro at 6 ounces per 100 gallons of water). Thereafter, twenty cuttings were removed daily and root development was observed. The cuttings were then dried and analyzed for nutrient content.

The change in the dry weight and nitrogen content of the cuttings is shown in Table 3. The dry weight of the cuttings increased quite steadily throughout the propagation period from 187 milligrams per cutting to 580 milligrams per cutting at the end of the 20-day propagation period. The nitrogen content also showed a steady increase throughout the entire rooting period, from 8.6 milligrams per cutting to 18.2 milligrams per cutting. Larger increases were noted during the last 2 days of the propagation period when root growth was quite extensive. Rooting, which was noticeable on the eleventh day (30%) and reached 100% on the fifteenth day, had no measurable effect on the dry weight increase during the propagation period. Likewise, it had little effect on nitrogen uptake until the late stages of propagation. Phosphorus gave similar results to nitrogen, whereas the potassium content increased slightly during the early stages of the propagation period and remained steady throughout the remainder of the propagation.

Table 3. Influence of nutrient mist during propagation on the dry weight and nitrogen content of *Chrysanthemum morifolium* cuttings.

Days of propagation	Dry wt.	N
	(mg/cutting)	
0	187	8.6
2	242	9.1
4	251	9.7
6	285	9.5
8	318	10.9
10	347	11.3
12	384	11.8
14	429	13.5
16	442	14.0
18	502	15.2
20	580	18.2

Cultivar Rootability

Uniform cuttings of 'Giant Betsy Ross' and 'Yellow Columbia' were placed in flats, half under water mist and half under nutrient mist. Each day one group of cuttings was shifted from water to nutrient mist, or vice versa. The following day, a different flat was shifted and so on throughout the entire propagation period. 'Giant Betsy Ross', was in the propagation bench for 10 days, whereas 'Yellow Columbia' was in the bench for 13 days.

The total number of roots produced by 20 cuttings of 'Giant Betsy Ross' in each treatment is shown in Table 4. When propagated under water mist, the 20 cuttings produced a total of 239 roots. However, when nutrients were applied at some time during the propagation period, the total number of roots was increased, with only 1 exception. Also this cultivar rooted quite quickly with roots being first visible on the 7th day.

Table 4 Influence of cultivar rootability, time and length of nutrient mist application during propagation on the total root number of *Chrysanthemum morifolium* cuttings

Cultivar-Treatment	Root number[1]
Giant Betsy Ross	
10W[2]	239
2N — 8W[3]	262
4N — 6W	279
6N — 4N	262
8N — 2W	238
10N[4]	268
2W — 8N	259
4W — 6N	270
6W — 4N	257
8W — 2N	281
Yellow Columbia	
13W[2]	1119
2N —11W	153
4N — 9W	230
6N — 7N	300
8N — 5W	288
13N[4]	287
2W —11N	242
4W — 9N	228
6W — 7N	133
8W — 5N	106

[1]Total root number for 20 cuttings per treatment
[2]Water mist, 10 days for 'Giant Betsy Ross' and 13 days for 'Yellow Columbia'
[3]2 days under nutrient mist followed by 8 days under water mist
[4]Nutrient mist, 10 days for Giant Betsy Ross' and 13 days for 'Yellow Columbia'.

With the cultivar 'Yellow Columbia', the same treatments were followed except the propagation period was lengthened to 13 days since this cultivar rooted more slowly. As shown in Table 4, the cuttings rooted entirely under water mist had a total of 119 roots per 20 cuttings. Adding nutrients for the first 2 days increased the root number to 153 roots, whereas using 4 days of nutrients gave a further increase to 230 roots. If six or more days of nutrients were used, the total number of roots was increased to approximately 300 roots per 20 cuttings.

In contrast, when nutrients were omitted until the second day of propagation, the total number of roots was reduced to 242. Likewise, omitting nutrients for 4 days gave a further decrease and when nutrients were omitted for 6 days or more, the number of roots dropped to comparable numbers to those cuttings propagated only under water mist.

Differences in root quality also were evident in several cultivars when propagated under either water or nutrient mist. As shown in Table 5, 'Yellow Columbia' cuttings propagated under nutrient mist for the larger number of days, had more extensive lateral root systems. For example, only 5 cuttings which received 4 days of nutrients early in the propagation period (4N-9W) had extensive lateral roots, whereas 12 cuttings under nutrient mist for the entire 13 days (13N) had extensive lateral roots.

Table 5 Influence of cultivar rootability and time and length of nutrient mist applications during propagation on the number of cuttings displaying extensive lateral root growth

Treatment	Cutting number[1]
13W[2]	—
2N — 11W[3]	—
4N — 9W	5
6N — 7W	6
8N — 5W	9
13N[4]	12
2W — 11N	7
4W — 9N	7
6W — 7N	4
8W — 5N	1

[1]20 cuttings per treatment.
[2]Water mist for 13 days
[3]2 days under nutrient mist followed by 11 days under water mist
[4]Nutrient mist for 13 days

Cutting Size

To determine the affect of cutting size and type on rooting, cuttings of *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' were taken from stock plants, weighed and graded into groups with a fresh weight of 1½, 2, and 2½ grams each. Each weight group was further divided into 2 sections, one composed of cuttings which had a shorter stem length and larger stem diameter (short cuttings) and the other section composed of cuttings which had a greater stem length and smaller stem diameter (tall cuttings). The cuttings were placed into flats (40 per flat) and rooted under water and nutrient mist for 14 days.

As shown in Table 6, within each fresh weight group, the short cuttings had a higher dry weight both before and after propagation than did the tall cuttings. For example, before propagation the tall cuttings with a fresh weight of 1.5 grams each, had a dry weight of 123 milligrams per cutting as compared with 130 milligrams per cutting in the case of the short cuttings. After propagation under water mist, the tall cuttings had a dry weight of 565 milligrams per cutting compared to 608 milligrams per cutting for the short cuttings. Also, the short cuttings within each fresh weight group produced a greater total number of roots than the tall cuttings. For example, the short 2½-gram cuttings had 25.3 roots per cutting compared to 24.4 roots per cutting for the tall 2½-gram cuttings when propagated under water mist.

The cuttings under nutrient mist followed the same trends. Also, the short cuttings of the same fresh weight group in-

Table 6 Influence of cutting size and nutrient mist on the dry weight and root number of *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings

Before rooting		After rooting				
			Dry wt		Root number	
Fresh wt		Dry wt	Water	Nutrient	Water	Nutrient
(g/cutting)		(mg/cutting)	(mg/cutting)		(roots/cutting)	
1.5	short	130	608	682[4]	20.6	22.8[4]
	tall	123	565	574[1]	18.9	21.2[4]
2.0	short	161	736	838[4]	22.3	25.1[4]
	tall	160	652[2]	720[2,4]	21.2	24.5[4]
2.5	short	202	852	932[4]	25.3	27.9[4]
	tall	200	788	890[4]	24.4	27.4[4]

Significant difference at 5% level between short and tall cuttings of:
[1]1.5 g
[2]2.0 g
[3]2.5 g and between
[4]water and nutrient mist

creased more in dry weight during propagation under nutrient mist than during propagation under water mist. The same was true for the tall cuttings of each fresh weight group. In addition, cuttings propagated under nutrient mist had more total roots than cuttings propagated under water mist. For example, the short 2.5-gram cuttings had 25.3 roots per cutting when propagated under nutrient mist, and 27.9 roots per cutting when propagated under nutrient mist. Also the short cuttings had more total roots than tall cuttings of the same fresh weight group when propagated under nutrient mist (Table 6).

Basal vs. Foliar Uptake

Four hundred *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings, each with the same leaf number, size and fresh weight were inserted through the lids of Freezete polyethylene containers (20 cuttings/container), approximately 1.5 inches into a rooting medium of quartz sand. The cuttings and containers were placed beneath a nutrient mist of Ra-Pid-Gro (4 ounces per 100 gallons of water). The nutrient mist was in contact with the foliage and the upper portion of the stems of the cuttings, but did not contact the stem bases and root medium within the containers.

The root medium was uniformly irrigated with a similar nutrient solution to which high specific radioactive phosphorus (^{32}P) was added at the rate of 5 mc per 80 cuttings. The radioactive nutrient solution was dispensed by gravity from 5-gallon plastic carboys, and after irrigation of the root medium, was collected for disposal. Thus, the above-ground parts of the cuttings, i.e. the foliage and upper portion of the stems. received non-radioactive nutrient mist. whereas the root medium, stem bases, and new roots as they developed, received ^{32}P-labeled nutrient solution.

On the second day after insertion of the cuttings into the rooting medium and every second day thereafter until the end of the propagation period, 2 containers of 20 cuttings each were removed. They were washed, dried, and analyzed for radioactive and non-radioactive phosphorus content for both the aerial and basal portions of the cuttings.

The change in the total phosphorus content. including both radioactive and non-radioactive, of the entire chrysanthemum cuttings is presented in Table 7. Before propagation, the cuttings contained 772 micrograms phosphorus per cutting which increased steadily throughout the entire propagation period to a total of 3196 micrograms per cutting. Of the total 3196 micrograms phosphorus contained by each cutting, 2494 micrograms per cutting was additional or "new" phosphorus which had been absorbed or taken up by the cuttings during the propagation period. As shown in Table 7, 2053 micrograms was absorbed from the foliar applications of unlabeled nutrient mist and 371 micrograms from the labeled nutrient solution being applied to the rooting medium. This

meant that 82% of the total additional phosphorus which the cuttings had absorbed during propagation was absorbed from the unlabeled nutrient mist applied to the foliage.

The amount of phosphorus absorbed by the cut stem bases and new roots was very small during the first ten days of the propagation period. After the first ten days when roots were first evident, basal absorption increased. However, at the end of the propagation period, less than 20% of the P absorbed during the propagation period had been absorbed by the cut stem bases and new roots.

Table 7 Absorption of phosphorus by *Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings propagated under nutrient mist

Days of propagation	Total P content	P Uptake during propagation				
		Total	Basal	Foliar	Foliar	Rooting
		(Micrograms/cutting)			(%)	(%)
0	772					
2	823	51	0	51	100	0
6	1174	402	4	398	99	0
10	1487	715	32	683	95	5
14	1636	864	38	826	95	55
18	2495	1723	93	1630	95	83
20	3196	2424	371	2053	82	100

Discussion

Herbaceous cuttings of *Chrysanthemum morifolium* grew considerably during propagation, and thus were able to utilize large amounts of additional nutrients. When nutrients were applied, the growth of the cuttings was increased more than when no nutrients were applied through water mist. The 2-ounce application of nutrient mist stimulated some increased growth during and after propagation, but the 4-or 6-ounce treatments stimulated more growth. As shown in Table 2, 'Giant Betsy Ross' cuttings which were propagated under the 4- or 6-ounce treatments, reached 12 centimeters in height 10 days after potting, whereas cuttings propagated under the water or 2-ounce treatment took an additional 4-5 days to reach the same height. This would be of practical importance to commercial chrysanthemum growers in decreasing the length of time necessary before beginning treatments to induce flowering.

The growth of the herbaceous cuttings of *Chrysanthemum morifolium* occurred throughout the entire rooting period (Table 3). These cuttings were able to photosynthesize at a rapid rate, and thus produce large amounts of photosynthate at a rapid rate, even before rooting. Thus the requirement for additional mineral nutrients was also increased. If additional

nutrients were available, these herbaceous cuttings could utilize them. This was shown in Table 1.

Whether nutrients were added early or late in the propagation period, had little influence on the total root number of the fast rooting cultivars of *Chrysanthemum morifolium* (Table 4). In contrast, the addition of nutrients early in the propagation period rather than for the same length of time at the end of the propagation period stimulated increased root production in the slow rooting cultivars. Thus, applications of nutrients during propagation were beneficial to all cultivars. The time of application was not critical for the fast rooting cultvars whereas, with the slow rooting cultivars, nutrients were beneficial when applied throughout the entire propagation period.

Cuttings with a greater fresh weight and dry weight prior to propagation produced greater increases in dry weight, a greater number of roots, and roots of greater length during propagation than did cuttings of less initial dry weight. Nutrient mist increased dry matter production and rooting in all cuttings, as compared with water mist, although nutrient mist was more effective with short cuttings than with tall cuttings of the same fresh weight. Thus, for increased rooting and dry matter production by chrysanthemum cuttings, the use of short, heavy cuttings propagated under nutrient mist would be advantageous.

Foliar absorption was most important in supplying the phosphorus requirements of the rapidly growing stems, foliage and new roots of *Chrysanthemum morifolium* cuttings during the propagation period. Even the stem bases and new roots received more than 80% of the absorbed phosphorus through foliar absorption and translocation to the basal portions (Table 7). This indicates that nutrients are much more efficiently absorbed by chrysanthemum cuttings from the nutrients mist than from the root medium, and that nutrient mist would appear to be the most effective method of applying nutrients to cuttings during propagation. Previcus experience with other nutrients and cuttings of many species indicates that the results with the phosphorus experiment are directly applicable to other foliar applied nutrients, especially with rapidly growing herbaceous and softwood cuttings.

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MODERATOR FORSTER: Thank you John, you have more than maintained the high quality of the papers this morning. Again we are still behind schedule and I'll have to ask you to hold all questions for the Question Box this evening.