SLOW-RELEASE FERTILIZERS — PAST, PRESENT AND FUTURE

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Abstract. Methylene urea reaction products and certain experimental nitrogen sources varying in water solubility were evaluated under a wide range of environmental conditions using woody ornamentals as the indicator plant. Phytotoxicity was dramatically reduced by decreasing the water solubility of the nitrogen sources. Maximum safety and plant growth from methylene urea products was realized with 50 percent of the nitrogen in a cold water soluble form. In the midwest and northeast (Hardiness Zones 3, 4 and 5), a residual of 4 to 6 months was realized with a 3 to 4 month residual in more moderate climates (California). Experimental nitrogen sources exhibited better residual and safety than methylene urea products. This was particularly evident in moderate climates (California) with the trend still evident in the cooler climate of the midwest and northeast. A 12 to 18 month residual was realized with certain experimental nitrogen sources.

REVIEW OF LITERATURE

Nitrogen (N) levels in the root zone of plants is short-lived and must be constantly replenished to assure maximum plant growth and development. In contrast phosphorus and potassium, being a natural component in most soils, are not often limiting. If these elements are limiting, nutrient levels can be increased in the soil by a single application applied every 1 to 2 years. This is not the case with nitrogen; consequently, scientists have been concentrating their research on developing controlled-release N sources.

Research on controlling the release of N began in the mid-40's when urea formaldehyde reaction products (methylene ureas) proved to have controlled-release properties. Subsequent development of this technology was effective at controlling the release of N to meet the biological demands of different crops. The water solubility can be varied from essentially zero up to 100%. N is activated by water and microbial release. Rate of release is controlled by the degree of polymerization, particle size and microbial activity.

In the early 60's encapsulation and matrix modification of highly soluble N sources was investigated. This technology has a number of advantages over previous technology, for example, release of the N can be more nearly matched with biological demands resulting in much greater efficiency of utilization. The matrix concept has not been further developed for commercialization. Encapsulation of soluble nitrogen sources appears to be the most promising new technology. Coating materials and coating technology are changing very rapidly. New technology suggests residual characteristics of 1 to 2 years is feasible.

MATERIALS, METHODS, AND RESULTS

A number of studies on woody ornamentals grown under a wide range of cultural conditions were conducted at cooperating nurseries and private research stations for the past 3 years.

Rooted Liners in Ohio. Bare root liners were potted in 3" pots of 3-1-1 soil-peat-sand supplemented with P_2O_5 and K_2O. Fritted trace elements and dolomitic limestone were also applied to assure adequate levels of secondary and minor elements. Various N sources were incorporated at 1 lb of N/cu yd at potting time. No additional fertilizer was applied for the remainder of the test (11 months). The pots were plunged in sand and over-wintered under snow fence covered with plastic.

As shown in Table 1, completely soluble N sources caused extreme injury to cotoneaster and moderate injury to juniper. Modifying the nitrogen release rate by reacting urea with formaldehyde or encapsulating the N reduced the initial injury to an acceptable level (0 to 2%). Subsequent growth varied with the N release characteristics. Maximum growth and plant quality was realized with the encapsulated N. The best methylene urea product ranged from 50 to 66% CWSN, with the slower release (50% CWSN) inducing slightly better growth and quality.

Table 1. Response of *Juniperus chinensis* 'Pfitzerana' and *Cotoneaster apiculatus* rooted liners to methylene ureas (MU) varying in water solubility.

		Percent Injury		Fresh Wt. Tops (gms)		Plant Quality (1 > 10)	
Percent CWSN[3]	Nutrient[1] Source	Jun. 2 months*	Cot. 2 months*	Jun. 11 months*	Cot. 11 months*	Jun. 11 months*	Cot. 11 months*
100	Urea	25	90	1.7	1.2	7.0	8.0
75	MU	0	0	5.1	4.8	5.0	6.5
66	MU	0	0	6.8	8.3	3.0	5.5
50	MU	0	0	7.1	9.6	3.0	3.0
	Exp-N	0	0	10.0	12.4	2.0	2.0
	Growers Standard[2]	0	0	7.0	10.7	3.5	3.5
0	0	0	0	4.4	2.9	6.0	6.5

* Months after initial treatment

[1] Fertilizer was incorporated in the potting medium (1 lb N/cu yd) just prior to potting on July 20, 1973. No additional fertilizer was applied.

[2] Three lbs N/1000 sq ft as 16-16-16 (100% CWSN) applied 8/21, 10/28, 4/1 and 6/1.

[3] Percent cold water soluble nitrogen (CWSN) based on the percent nitrogen solubilized in water at room temperature (22°C).

Potted Liners in Ohio. Potted liners (3" pots) were planted in 1 gal cans of 3:2 hardwood bark-sand mixture. Phosphorus, potassium and minor elements were supplied as above.

Soluble and slowly soluble N sources were incorporated at 1, 2 and 3 lbs N/cu yd. The 1 and 2 lb rates were retreated 7 and 13 months after potting, respectively, using 20lb N/1000 sq ft.

As shown in Table 2, cotoneaster treated with a completely soluble N source (100% CWSN) were damaged severely and/or failed to develop into quality plants. Reducing the N solubility by formaldehyde inactivation greatly increased the safety. This was particularly evident at CWSN levels of 50% or less. Three pounds of N/cu yd (> 66% CWSN) applied only at potting time was inferior to 2 lb N/cu yd followed by 20 lb N/1000 sq ft 13 months after potting.

Table 2. Response of *Contoneaster apiculatus* (potted liners) to incorporated and surface applications of methylene ureas (MU) varying in solubility.

Percent CWSN[2]	Lbs[1] N/cu yd	Nutrient Sources	Maintenance Fertilizer (months)	Percent Injury (4 mo)*	Fresh Wt. Tops (gms) (17 mo)*	Plant Color (10 > 1) (15 mo)*
100	1	Urea	7	9	43	4.5
100	2	Urea	13	100	0	1.0
100	3	Urea	0	100	0	1.0
75	1	MU	7	3	74	7.9
75	2	MU	13	0	90	10.0
75	3	MU	0	67	19	2.8
66	1	MU	7	3	87	9.0
66	2	MU	13	8	99	9.9
66	3	MU	0	17	42	5.3
50	1	MU	7	0	76	7.5
50	2	MU	13	0	98	10.0
50	3	MU	0	0	73	7.3
30	1	MU	7	3	85	9.2
30	2	MU	13	0	91	9.7
30	3	MU	0	0	73	8.4
	0	Control	0	23	19	3.0
L.S.D. .05				15	20	1.8

* Months after initial treatment.

[1] Fertilizer incorporated in the potting medium just prior to potting May 1, 1974. The one and two pound rates were retreated 7 and 13 months after potting, respectively using 20 lbs N/1000 sq ft.

[2] Percent CWSN based on percent nitrogen solubilized in water at room temperature (22°C).

As shown in Table 3, root, top and total plant weights of juniper were inhibited by soluble N source (100% CWSN). Maximum plant development (total weight of tops and roots) using a single application of 3 lbs of N/cubic yard was realized with methylene ureas in the range of 50-66% CWSN. Above or below this range results in too fast a release (75% CWSN) or too slow a release (30% CWSN) to satisfy the biological demands of the plant. A repeat application of 20 lbs N/1000 sq ft applied 7 months after potting to plants maintained on 1 lb N/cu yd since potting time resulted in the best overall development on a cost/performance basis.

Table 3. Root and top weights of *Juniperus chinensis* 'Pfitzerana' as affected by various methylene ureas incorporated in the potting medium.

Percent CWSN[1]	Nutrient Source	Lbs[2] N/cu yd	Maintenance Frequency (months)	Root Weights (gms) (17 months)*	Top Weights (gms)	Total Plant (gms)
100	Urea	1	7	12	9	21
100	Urea	2	13	11	21	32
100	Urea	3	0	5	5	10
75	MU	1	7	45	97	142
75	MU	2	13	34	94	128
75	MU	3	0	33	56	89
66	MU	1	7	46	100	146
66	MU	2	13	48	142	190
66	MU	3	0	46	114	160
50	MU	1	7	54	125	179
50	MU	2	13	51	141	192
50	MU	3	0	56	113	169
30	MU	1	7	51	147	198
30	MU	2	13	45	127	172
30	MU	3	0	42	75	117
	Control	0	0	20	19	39
L.S.D. .05				13	24	37

* Months after initial treatment.

[1] Percent cold water soluble nitrogen (CWSN) based on percent nitrogen solubilized in water at room temperature.

[2] Fertilizer incorporated in the potting medium just prior to potting May 1, 1974. The 1 and 2 pound rates were retreated 7 and 13 months after potting using 20 lbs N/1000 sq ft.

Potted Liners in Connecticut. Potted liners of *Pieris japonica* were planted in 1 gal cans containing a 2-1-1 mix of bark-peat-sand. Phosphorus, potassium, dolomite, lime, sulfur, iron sulfate, and fritted trace elements were added to assure adequate levels of secondary and minor elements. N was incorporated in the potting medium just prior to potting at 1 and 2 lbs N/cu yd using methylene ureas and encapsulated N sources.

The plants were placed in 1 gal cans on May 29. Those plants treated with the low N rate (1 lb N/cu yd) were retreated October 24 (5 months) and those maintained on the high rate (2 lbs N/cu yd) were retreated May 9 (11 months) using 20 lb N/1000 sq ft.

As shown in Table 4, plants treated with a completely soluble N were severely damaged at both rates. When the N release rate was modified by combining ureas with formaldehyde or encapsulating a fast release source the safety was dramatically increased. This was particularly evident at CWSN levels of 50%.

The addition of 1 lb N/cu yd in late May followed by a fall feeding (October 24) of 20 lbs N/1000 sq ft using the experimental N source or methylene urea (50% CWSN) resulted in growth superior or comparable to the growers standard (fertigation applied 450 lbs N/acre/year).

Table 4. Response of *Pieris japonica* to incorporated and surface applications of methylene ureas varying in solubility.

Percent CWSN	Nutrient Source	Lbs[1] N/cu yd	Maintenance[2] Fertilizer (months)	Plant Quality 1 best < 10 dead (17 mo)*	Height (cms) (17 mo)*
100	Urea	1	5	10.0	0
100	Urea	2	11	9.5	3
75	MU	1	5	7.0	16
75	MU	2	11	7.5	17
66	MU	1	5	5.5	19
66	MU	2	11	3.5	33
50	MU	1	5	3.0	39
50	MU	2	11	4.5	30
—	Exp-N	1	5	2.5	48
—	Exp-N	2	11	2.0	49
	Control	0	0	8.0	25
		Growers Standard[3]		2.5	36
L.S.D. .05				1.7	13

* Months after initial treatment.

[1] Fertilizer incorporated in the potting medium just prior to potting on May 29, 1974.

[2] Plants topdressed with 20 lbs N/1000 sq ft on October 24, 1974 (5 months) and May 9, 1975 (11 months).

[3] 450 lbs N/acre/year (30 lbs N/acre applied 15 times during the growing season — fertigation).

Potted Liners in California. Potted liners of *Euonymus japonica* were planted in 1 gal cans containing 84% Douglas fir bark and 16% sand. Phosphorus, potassium, dolomite, lime, and fritted trace elements were added to assure adequate levels of secondary and minor elements. Various N sources were incorporated just prior to potting using 2 lbs of N/cu yd. The test was started November 11 with supplemental nutrients applied every 90 days to half of the plants and no supplemental feeding on the other half.

As shown in Table 5, when methylene urea was applied every 90 days the growth was superior to a single application at potting time. Plants treated with methylene urea (50% CWSN) were superior to plants treated with methylene urea (30% CWSN). A single application of experimental N sources varying in solubility compared favorably to a single application of methylene urea (50% CWSN) when a moderate release rate was evaluated (Exp. 3). As the release rate was reduced, a single application resulted in maximum growth when a very low soluble N source was used (Exp. 0.5). Growth was nearly doubled as compared to a fertigation program (1 lb N/1000 sq ft/week).

A repeat application of the experimental N sources 270 days after potting improved performance over single application at potting time when low to moderate soluble N sources were used (Exp. 1, Exp. 2, and Exp. 3). When the lowest soluble N source was used (Exp .05) a single application at potting time

Table 5. *Response of Euonymus japonica to methylene urea and certain experimental nitrogen sources incorporated in the potting medium*[1].

Percent CWSN	Nutrient Source	Solubility	Maintenance[2] Fertilizer (days)	Height (cms) (11 mo)*	Top Fresh Weight (gms) (16 mo)*
50	MU	moderate	0	26	78
50	MU	moderate	90	31	231
30	MU	low	0	25	48
30		low	90	36	179
	Exp-3	moderate	0	32	94
	Exp-3	moderate	270	34	160
	Exp-2	intermediate	0	35	155
	Exp-2	intermediate	270	40	180
	Exp-1	low	0	36	150
	Exp-1	low	270	40	205
	Exp-0.5	very low	0	38	228
	Exp-0.5	very low	270	41	231
	Control		0	18	12
100[3]		high	7	26	124
L.S.D. .05				6	35

* Months after initial treatment.

[1] Fertilizer was incorporated in the potting media using 2 lbs N/cu yd just prior to potting November 11, 1974.

[2] Fertilizer applied every 0, 90 or 270 days using 20 lbs N/1000 sq ft.

[3] 25-0-25, 447 ppm N (200 ml/gallon can/week or 1 lb N/1000 sq ft/wk).

provided maximum performance. The addition of the topdress was of no value.

Bare Root Seedlings in Ohio. Bare root seedlings of catalpa were planted in a 3/1 composted hardwood bark/sand mixture containing superphosphate and potassium sulfate. The plants were grown in the greenhouse at air temperatures ranging from 60 to 80°F. The equivalent of 2 inches of water was applied per week. Various sources of encapsulated N were incorporated in the potting media using the equivalent of 3 lbs of N/cu yd. Eleven weeks after planting, the catalpa was harvested for fresh weight determination. A second crop was planted using seedling catalpa in the 1 to 2 leaf stage. The second harvest was made 12 weeks after planting. No additional fertilizer was applied.

As shown in Table 6, N encapsulation dramatically increased safety as compared to urea. Catalpa planted immediately after incorporating the N sources were very responsive to treatment. Those formulations with a moderate release rate (Exp 4.6, Exp 4.0 and Exp 3.3) cause a setback in plant growth. Plants harvested from the second planting exhibited excellent development, however. Those formulations exhibiting intermediate low and very low solubility were very safe when incorporated in the potting media at planting time.

Growth was excellent on all treatments with less growth occurring at the intermediate release rate (Exp 2.8) and the very low release rate (Exp 0.7) suggesting that these formulations were releasing N a little too fast and a little too slow, respectively, to induce maximum growth as realized with Exp 2.0

Table 6. Response of *Catalpa speciosa* to various experimental nitrogen sources varying in solubility.

Nutrient Source	Relative Solubility	Fresh Weights of Tops (gms) Harvest 1	Harvest 2	total
Urea	high	0	1	1
Exp-4.6	moderate	15	41	56
Exp-4.0	moderate	8	50	58
Exp-3.3	moderate	17	44	61
Exp-2.8	intermediate	27	41	68
Exp-2.0	low	56	39	95
Exp-1.7	low	46	33	79
Exp-1.1	low	40	38	78
Exp-0.9	very low	50	39	89
Exp-0.7	very low	21	52	73
Control		1	1	2
L.S.D. .05		8	7	15

[1] Fertilizer incorporated in the potting medium at 3 lbs N/cu yd.

[2] *Catalpa* harvested after 11 weeks (1st harvest). Pots replanted with *Catalpa* and harvested after 12 weeks (2nd harvest).

SUMMARY

Safety was dramatically increased by reducing the water soluble N level from 100% down to 75% or less. Maximum safety and growth from methylene urea was realized with 50% of the N in a cold water soluble form. In the midwest and northeast a residual of 4 to 6 months is realized while a 3 to 4 month residual is evident in more moderate climates (California).

Experimental N sources exhibited better residual and safety than methylene urea. This was particularly evident in moderate climates (California) with the trend still evident in the cooler climate of the midwest and northeast. A 12 to 18 month residual was realized with these experimental nitrogen sources.