Controlled-release Fertilizers and Nitrogen Leaching

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Introduction

Greenhouses have received increased attention in recent years as potential sources of nutrient and pesticide pollution of water. Most greenhouses are constructed with earthen floors which may allow fertilizer and pesticide runoff to leach and perhaps enter ground or surface bodies of water. Use of controlled-release fertilizer (CRF) in place of or as a supplement to liquid fertilizer is often recommended as a way of reducing nutrient leaching from containerized greenhouse crops. CRFs have the advantage of being an economical approach to the problem especially when compared to subirrigation systems which contain and recycle irrigation water resulting in "zero runoff," but are prohibitively expensive for most growers to install.

When CRFs are used, growers either mix a large dose of with the growth medium prior to planting or, as in the case of fall mums, topdress it on the surface shortly after planting. The objective is to minimize the labor required for fertilization by attempting to meet the total nutrient requirement of a crop in one application. This practice may result in damaging accumulations of soluble salts early in the crop and/or nutrient deficiency late in the growing period. Such results lead to the conclusion that the nutrient release pattern of CRFs does not match the nutrient requirements of most plants. Hershey and Paul (1983) working with chrysanthemums, and Rathier and Frink (1989) working with nursery crops, report that N loss by leaching from a CRF applied in this manner was highest during the early part of the growing period indicating that nutrient release during this time exceeded the needs of the plants.

In fact, the quantity of nitrate-nitrogen (NO_3-N) in the leachate from CRF-treated plants can be unacceptably high from an environmental standpoint. In two studies, Rathier and Frink (1989) and Jarrell et. al. (1983), found NO_3-N in container leachates at concentrations well in excess of current drinking water standards where a single application of CRF was made at planting. However, in the former study, NO_3-N concentration was significantly reduced by dividing the single CRF application into two smaller treatments spaced six weeks apart. These results indicate that the method of CRF application has a significant effect on N leaching.

Most research on the use of CRFs in the greenhouse has focused on the types of CRF and application levels needed to achieve optimum plant growth and quality. The work of Harbaugh and Wilfert (1980), Sharma and Patel (1978), and Kovacic and Holcomb (1981) are good examples. Very few studies (Cox, 1985, 1993; Stewart et. al. 1981), in addition to those discussed earlier, examine nutrient leaching and methods of fertilizing greenhouse crops. Therefore the objectives of this study were: 1) to determine to what degree N leaching from the fast-growing greenhouse crop can be controlled by CRFs compared to water-soluble fertilizer (WSF) and 2) to determine how N leaching is affected by incorporating CRF in the growth medium versus applying it to the surface and by one large application at planting versus two smaller applications, one at planting and a second several weeks later.

How the experiments were carried out

All experiments. 'First Lady' marigold was chosen for this study because a large number of uniform plants can be produced in a short period of time from seed at any time of the year. Marigolds also have a moderate growth rate (+\- 10 - 12 weeks from seed to marketable size) and distinct vegetative and flowering periods. In each experiment seedlings were 2 or 3 weeks old when they were transplanted to 4-inch pots of soilless mix. CRFs were incorporated in the growth medium (INC) or applied to the surface of the growth medium (SUR). Fertilizer treatments are discussed for the individual experiments. Nitrogen leaching was measured by suspending the pots in special containers to catch the drainage water. Leachate was analyzed for NH_4-N and NO_3-N at regular intervals to determine the total amount of N leached in each treatment during the experiments.

One important feature of the experiments was that the plants received the same quantity of N (+/- 500 mg/pot) regardless of fertilizer type of method and timing application. WSF was Peter's 20-10-20 Peat-lite Special at 208 ppm N and it served as the control in all experiments. CRFs were Osmocote 14-14-14 (OS) and Nutricote 14-14-14 Type 70 (NU) and they were applied at the rates shown in the tables (1 oz. = 28.3 gm). OS has a three to four month release time and NU has a 70 day release time according to manufacturers' specifications.

Another important feature was that the plants were watered with the same volume of water regardless of fertilizer treatment. This method of watering was used to eliminate the potential effects on N leaching of variations in the volume of water applied. Plants were watered at three or four day intervals according to a predetermined schedule beginning at planting. Either fertilizer solution or plain tapwater was applied depending on the fertilizer treatment. If additional water was needed between scheduled waterings, the same volume of water was applied to all treatments.

Experiment 1. The objectives of this experiment were to test the effects of CRF application method (incorporated at planting versus surface application) and split application (one application at planting versus two smaller applications; one at planting, the second 15 or 30 days later) on plant growth and N leaching (Table 1). Seedlings were planted 21 December 1990 and the experiment ran for 60 days.

Experiment 2. The purpose of this experiment was to study in more detail the effects of CRF application method and the timing of the second application in a split regime (Table 2). Seedlings were planted 7 March 1991 and the experiment was completed 75 days later.

Experiment 3. Nutricote CRF was applied in split application and the experiment was designed to study how the level of the first application and the timing of the second application affected plant growth and N leaching. Seedlings were planted 20 August 1991 and the experiment ran for 70 days.

Results of experiments

Experiment 1. A single large application of CRF at planting, whether INC or SUR, resulted in as much or more N leaching than WSF (Table 1). In general, dividing CRFs into two small doses resulted in significantly less N leaching than WSF and the single large dose made at planting. Some split treatments reduced N leaching to a level less than 50% of WSF. In most cases N leaching was reduced more when the CRF fertilizer was applied to the surface rather than mixed with the growth medium at planting, but the differences between application methods were not always large enough to be significant.

Shoot dry weight was reduced somewhat by all CRF treatments compared to WSF, but only where the reduction was more than 10% of WSF were the differences statistically significant. Plants were otherwise equal in appearance and development -- no nutrient deficiency symptoms were apparent and flowering was normal and occurred at the same time in all treatments.

Experiment 2. This experiment was designed to confirm the results of Expt. 1 and, in general, the outcome of both experiments was very similar. Here, as in Expt. 1, one application of CRF at planting resulted in more N leaching than the WSF control and N leaching was greatly reduced when the amount of CRF was applied in two smaller doses (Table 2).

In general, N leaching was reduced most by applying both doses of CRF to the surface and by making the second application 30 rather than 15 days after planting. Nitrogen leaching was similar with both OS and NU. Plants in all CRF treatments were slightly smaller (less dry weight) than those grown with WSF, but otherwise the appearance and development of the plants was the same in all treatments.

Experiment 3. In Expts. 1 and 2 CRFs were more effective in reducing N leaching when they were applied in two small doses instead of a single large dose at planting. Results also suggested that N leaching with two applications of CRF might be affected by two factors: 1) the level of the first application and 2) the timing of the second application. This experiment was designed to study these two factors independently using NU as the test CRF.

Considering all treatments in Expt. 3, the most N recovered in the leachate was from plants receiving a single large application of CRF at planting (Table 3). All treatments where CRF was divided into two smaller doses resulted in significantly less N leaching than WSF or the single large dose of CRF at planting.

The first factor, level of the first application, had little effect on N leaching and dry weight. Slightly less N leaching and dry weight occurred at the lowest levels of CRF applied at planting, but differences were not large. Perhaps the lack of differences in N leaching between treatments was due to the effects of the second larger CRF application made on day 30. The second factor, timing of the second CRF application, had no effect on the amount of N leaching either. However, the dry weight decreased as the time interval between the first and second application became longer. So waiting too long to apply the second CRF dose resulted in less growth at the end of the crop and little extra reduction in N leaching.

Discussion

The experiments reported here studied N leaching from a marigold pot crop. Plants received the same amount of N from CRFs or WSF and the same volume of irrigation water during each experiment. Under these conditions a single large application of CRF made at planting resulted in as much or more N loss by leaching as regular waterings with WSF. The effectiveness of CRFs in reducing N leaching was greatly improved when they were divided and applied in two smaller doses, the first at planting and the second at least 15 days later. In the third experiment a very small first application or a second application made more than 15 days after planting had little additional benefit in reducing N leaching. However, growth was depressed as the level of the first application became smaller or the time interval between the first and second application became longer.

In all three experiments the largest amount of N leaching occurred early in the growth period -- within the first 20 to 30 days following planting. Generally speaking, fertilizer type (WSF or CRF), timing, or application method had no great effect on this pattern. Clearly the methods and rates of fertilizer application used in this study, which were not greatly different from those used in commercial practice, provided N in excess of the crop's requirement during the early part of the growth period. Most greenhouse fertility programs probably do as well.

Generally, application of CRF to the surface of the growth medium resulted in less N leaching than when the same quantity of fertilizer was mixed with the growth medium. Most growers choose surface application because it is a convenient way to applying precise amounts of CRF, but it also appears to have the advantage of reducing N leaching. Presumably drying between waterings and the tendency of nutrients to accumulate in the upper layer of the growth medium with the evaporation of moisture from the surface, reduces the amount of N available for leaching.

No treatment in this study caused foliar symptoms of nutrient deficiency or had adverse effects on flowering, but most CRF treatments led to reduced shoot dry weight compared to WSF. However, in most cases, growth was reduced less than 15% compared to WSF and, with marigold, these reductions would be difficult to observe in commercial practice and would not lessen marketability. These results suggest that in order to significantly reduce N leaching using the techniques studied here optimum growth may be compromised to some degree.

Practical Implications

This research demonstrates that the use of CRFs does not always ensure a reduction in N leaching from potted crops compared to WSF. The common practice of making a single large application of CRF at planting may result in as much or more N loss by leaching as the regular use of WSF. Dividing the large application into two smaller doses spaced several weeks apart proved to be the best way of using CRFs to control N leaching.

Although this research was conducted with marigolds, the general findings of this work can be applied to most other crops. Of course the extra labor required to make two applications of CRF makes this practice problematic from an economic standpoint, particularly where large numbers of plants are being grown. However, split application is about the only way that N leaching can be greatly reduced using CRFs. Split application also reduces the chance that young plants will be injured by soluble salts from a single large dose at planting or that nutrients will "run out" late in the crop.

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Table 1. Nitrogen leaching and growth of 'First Lady' marigold. Expt. 1.

–Controlled-release– At planting (gm/pot)	Second application (gm/pot)	Total N leached (mg/pot)	Shoot dry wt. (gm/plant)
Peter's Peat-lite 20-10-20			
–	–	60.2	11.9
Osmocote 14-14-14 (3-4 month release)			
3.6 INC[z]	None	79.9a	11.1ab
3.6 SUR	None	50.4b	11.5a
1.8 INC	Day 30, 1.8 SUR	37.7bc	10.3b
1.8 SUR	Day 30, 1.8 SUR	28.0c	10.0b
Nutricote 14-14-14 (70 day release)			
3.6 INC	None	107.3a	11.1ns
3.6 SUR	None	92.5a	10.7
1.8 INC	Day 30, 1.8 SUR	49.2b	10.5
1.8 SUR	Day 30, 1.8 SUR	34.8bc	11.0
0.9 INC	Day 15, 2.7 SUR	38.1bc	11.2
0.9 SUR	Day 15, 2.7 SUR	29.6c	11.0

[z]INC= incorporated in growth medium; SUR= applied to the surface of the growth medium.

[y]Underlined means are significantly different from means of Peter's fertilizer (Dunnett's procedure, $P = 0.05$).

[x]Means followed by different letters within columns and brand of controlled-release fertilizer are significantly different (Duncan's Multiple Range Test, $P = 0.05$) (ns= not significant).

Table 2. Nitrogen leaching and growth of 'First Lady' marigold. Expt. 2.

–Controlled-release– At planting (gm/pot)	Second application (gm/pot)	Total N leached (mg/pot)	Shoot dry wt. (gm/plant)
Peter's Peat-lite 20-10-20			
–	–	126.4	10.1
Osmocote 14-14-14 (3-4 month release)			
4.0 INC[z]	None	147.8a	8.9ns
0.8 INC	Day 15, 3.2 SUR	99.5b	8.8
0.8 SUR	Day 15, 3.2 SUR	69.1c	9.1
1.6 INC	Day 30, 2.4 SUR	69.8c	9.0
1.6 SUR	Day 30, 2.4 SUR	47.2d	9.1
Nutricote 14-14-14 (70 day release)			
4.0 INC	None	164.2a	9.6a
0.8 INC	Day 15, 3.2 SUR	116.7b	8.8b
0.8 SUR	Day 15, 3.2 SUR	71.7c	8.5b
1.6 INC	Day 30, 2.4 SUR	67.7c	9.5a
1.6 SUR	Day 30, 2.4 SUR	45.6d	9.4a

[z]INC= incorporated in growth medium; SUR= applied to the surface of the growth medium.

[y]Underlined means are significantly different from means of Peter's fertilizer (Dunnett's procedure, $P = 0.05$).

[x]Means followed by different letters within columns and brand of controlled-release fertilizer are significantly different (Duncan's Multiple Range Test, $P = 0.05$) (ns= not significant).

Table 3. Nitrogen leaching and growth of 'First Lady' marigold. Expt. 3.

–Controlled-release– At planting (gm/pot)	Second application (gm/pot)	Total N leached (mg/pot)	Shoot dry wt. (gm/plant)
Peter's Peat-lite 20-10-20		56.7	14.4
Nutricote 14-14-14 (70 day release)			
4.0	None	96.5▲	13.2
Level of first application			
1.6	Day 30, 2.4	27.5▲	12.3▲
1.4	Day 30, 2.6	22.9▲	11.3▲
1.2	Day 30, 2.8	26.5▲	11.9▲
1.0	Day 30, 3.0	21.4▲	11.2▲
0.8	Day 30, 3.2	19.1▲	11.2▲
Time of second application			
0.8	Day 15, 3.2	20.5▲	13.7
0.8	Day 20, 3.2	20.8▲	13.3
0.8	Day 25, 3.2	16.7▲	12.3▲
0.8	Day 30, 3.2	20.0▲	11.3▲
0.8	Day 35, 3.2	22.6▲	10.3▲

[z]Underlined means are significantly different from means of Peter's fertilizer (Dunnett's procedure, $P = 0.05$).

[y]Means followed by (▲) are significantly different from means of 4 gm Nutricote/pot applied at planting (Dunnett's procedure, $P = 0.05$).