Technology & Product Reports

Release Rates of Controlled-Release and Soluble Magnesium Fertilizers

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ADDITIONAL INDEX WORDS. leaching, Mg

SUMMARY. Release rates at 21 °C were determined in sand columns for 12 commercially available soluble and controlled-release Mg fertilizers. Lutz Mg spikes, $K_2SO_4 \cdot 2MgSO_4$, $MgSO_4 \cdot H_2O$, and $MgSO_4 \cdot 7H_2O$ released their Mg within 2 to 3 weeks. Within the first 6 weeks, $MgO \cdot MgSO_4$ released its soluble Mg fraction, but little release occurred thereafter. Dolomite and MgO released <5% of their Mg over 2 years while MagAmp released <20% of its Mg. Florikan 1N-0P-26K-4Mg types 100 and 180 exhibited typical controlled-release fertilizer characteristics, with most of their Mg release occurring during the first 15 weeks.

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Florida Agricultural Expt. Station Journal Series no. R-05109.

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Magnesium deficiency is a common problem in plants growing in highly leached sandy soils such as those in parts of eastern United States (Tisdale and Nelson, 1975). Although Mg is considered a macronutrient for plants, it is not included in most "complete" fertilizers. Since most Mg losses from sandy soils are caused by leaching, applied soluble Mg fertilizers also are lost quickly to leaching and, thus, may be relatively ineffective in correcting serious Mg deficiencies in such soils. Controlled-release fertilizers have reduced leaching losses of N, P, and K (Broschat, 1995; Cox, 1993; Sharma, 1979). However, few controlled-release Mg fertilizers are produced commercially due to the difficulty of uniformly coating the angular and often hygroscopic or thermally unstable crystals of common Mg salts. Relatively insoluble Mg compounds, such as MgO, magnesium ammonium phosphate (MagAmp), and dolomite have been the only slow-release Mg sources available until recently, but their Mg release may be too slow to be useful in non-acidic soils. Nitrogen and K re-

lease rates of commercially available controlled-release fertilizers have been documented by Patel and Sharma (1977), Oertli and Lunt (1962), Prasad and Woods (1971), Allen et al. (1971), Holcomb (1981), and Broschat (1996), but to our knowledge, similar studies on Mg fertilizers have not been published. My purpose was to determine the release rates in sand of several commercially available soluble and controlled-release Mg fertilizers.

Materials and methods

Polyvinyl chloride (PVC) columns (30 cm long $\times$ 5.1 cm inside diameter) were mounted vertically into Buchner funnels (70 mm in diameter) that were supported by special funnel support racks. Columns were filled to a depth of 28 cm with medium grade HCl-washed silica sand and were maintained at 21 °C. Five grams of each of the 12 Mg-containing fertilizers listed in Table 1 were applied to the sand surface of three replicate columns and were mixed into the top 1 cm of sand. Columns were irrigated with 50 mL of deionized water three times weekly, and all leachates were collected in 500-mL polyethylene beakers. Once a week the leachate volumes were measured, and the samples were analyzed for Mg concentrations using atomic absorption spectrophotometry. Three replicate control columns containing no fertilizer also were included in this study, although control leachates contained negligible amounts of Mg. The amount of Mg in each sample was divided by the percentage of Mg in each fertilizer material to correct for differences in percentage of Mg in each product. Results were expressed as the cumulative percentage of applied Mg released over time.

Table 1. Magnesium fertilizer materials evaluated for release characteristics.

Product	Mg source	Mg (%)	Origin
$MgSO_4 \cdot 7H_2O$	$MgSO_4 \cdot 7H_2O$	9.8	Kali and Salz Ag., Kassel, Germany
$K_2SO_4 \cdot 2MgSO_4$	$K_2SO_4 \cdot 2MgSO_4$	9.2	AtlanticFECFertilizers, Homestead, Fla.
$MgSO_4 \cdot H_2O$	$MgSO_4 \cdot H_2O$	16.3	AtlanticFECFertilizers, Homestead, Fla.
Lutz Mg Spike	$MgSO_4 \cdot H_2O$	5.0	Lutz Corp., Oregon, Ill.
$MgO \cdot MgSO_4$	$MgO \cdot MgSO_4$	36.0	AtlanticFECFertilizers, Homestead, Fla.
Crop Mag 36	$MgO \cdot MgSO_4$	36.0	Martin-Marietta, Hunt Valley, Md.
MgO	MgO	51.5	American Minerals, Wilmington, Del.
Crop Mag 58	MgO	58.0	Martin-Marietta, Hunt Valley, Md.
MagAmp	$KMgPO_4 + NH_4MgPO_4$	12.0	The Scotts Co., Marysville, Ohio
Dolomite	$CaCO_3 \cdot MgCO_3$	10.4	Soil Doctor, Polk City, Fla.
Florikan 180	Resin-coated $MgSO_4 \cdot H_2O$	4.0	Chisso-Asahi Fert. Co., Tokyo
Florikan 100	Resin-coated $MgSO_4 \cdot H_2O$	4.0	Chisso Asahi Fert. Co., Tokyo

Results and discussion

Virtually all of the Mg in $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ was leached from the columns within the first 2 weeks, most of the leaching occurring during the first week (Fig. 1A). The release rates for $\text{K}_2\text{SO}_4 \cdot 2\text{MgSO}_4$ and $\text{MgSO}_4 \cdot \text{H}_2\text{O}$ were very similar, most Mg being leached within the first 3 to 4 weeks (Fig. 1A). Lutz Mg spikes are claimed by the manufacturer to release Mg for up to 1 year, but our

data suggest that little Mg is released after 3 weeks (Fig. 1A). This product performs similarly to $\text{MgSO}_4 \cdot \text{H}_2\text{O}$, the Mg source in these spikes.

The two magnesium oxysulfate products tested ($\text{MgO} \cdot \text{MgSO}_4$ and Crop Mag 36) had similar release curves, most Mg being leached within the first 4 weeks (Fig. 1B). During the first 4 weeks, their Mg release rates were similar to that of $\text{MgSO}_4 \cdot \text{H}_2\text{O}$, but after 8 to 10 weeks, the curves

were virtually identical to MgO . Magnesium oxysulfate is a mixture of MgO and MgSO_4 , and like MgO , its Mg release after 8 weeks is too slow to be of practical use as Mg fertilizer. Crop Mag 58 is also MgO , and its release was similar to the other MgO product tested (Fig. 1B and C). Dolomite and MagAmp released Mg at constant but very slow rates over 2 years (Fig. 1C).

In non-acidic media, there seems to be little solubilization of Mg from

Fig. 1. (A-D) Cumulative percentage of Mg released from soluble and controlled-release Mg fertilizers incubated in sand at 21 °C.

MgO, dolomite, or MagAmp. Presumably, Mg release would be significantly more rapid for these materials under acidic media conditions. The sand used in these columns had an initial pH of 5.9 and little buffering capacity. Sand in columns containing MgO, MgO·MgSO₄, and dolomite had final pH values of 8.6, 8.1, and 8.1, respectively, which undoubtedly affected the solubilization of Mg from these products.

The two Florikan products were the only materials tested that exhibited typical controlled-release characteristics. The 100- and 180-d formulations released Mg at similar rates, however (Fig. 1D). These products appeared to have significant Mg release for ≈12 to 14 weeks, or about twice as long as MgO·MgSO₄. Unfortunately, these Florikan products contain only 4% Mg (Table 1) and are intended primarily for correction of K deficiency without upsetting the K : Mg balance.

The percentage of applied Mg released over 2 years varied widely among products. MgSO₄·H₂O released ≈60% of its Mg, and MgSO₄·7H₂O released ≈80% of its Mg within 4 to 5 weeks (Fig. 1A). K₂SO₄·2MgSO₄, Lutz Mg spikes, and the two Florikan products released between 60% and 80% of their Mg within 16 weeks (Fig. 1A and D). The two MgO·MgSO₄ products ultimately released ≤10% of their Mg over 40 weeks (Fig. 1B), whereas the MgO products and dolomite released <5% of their Mg over 2 years (Fig. 1B and C). MagAmp released ≈20% of its Mg over 2 years (Fig. 1C).

Although plant response to Mg fertilizers is beyond the scope of this study, it is reasonable to assume that the soluble MgSO₄-containing products release much more Mg during the first 2 weeks than plants are likely to use. In soils with high cation exchange capacities, such soluble fertilizers may provide adequate Mg over long periods of time, but in highly leached

sandy soils with poor nutrient retention, soil Mg levels will quickly drop back to inadequate levels. The insoluble Mg fertilizers such as MgO, dolomite, and MagAmp probably would never provide adequate Mg for plant growth in a neutral to alkaline Mg-deficient soil, but they may be suitable under acidic soil conditions.

In conclusion, no good, high Mg analysis, controlled-release fertilizer exists at this time, and frequently applying MgSO₄·H₂O or MgO·MgSO₄ remains the best solution for treating or preventing Mg deficiencies. The two Florikan 1N-0P-26K-4Mg products have excellent Mg and K (data not shown) release characteristics, but the Mg analysis of these products may be too low to correct Mg deficiencies.

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Preliminary Evaluation of the Effects of Fluridone in Irrigation Water on Container-grown Azaleas

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ADDITIONAL INDEX WORDS. aquatic herbicide, *Rhododendron indicum* 'George Tabor', 1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone, nontarget effects

SUMMARY. In 1992, we initiated a study to determine the effects of fluridone in irrigation water applied to container-grown azaleas. Azaleas (*Rhododendron indicum* L. 'George Tabor') were grown in containers with a 3 pine bark : 1 sand mixture and were irrigated daily for 5 weeks (except weekends) with solutions containing fluridone concentrations ≤2000 g·L⁻¹. The threshold for appearance of visible injury symptoms (bleaching of new growth) was 250 g·L⁻¹ at 5 and 12 weeks after treatment initiation. Visible symptoms did not appear until at least 35 days after treatments began. No statistically significant injury occurred to azaleas treated with solutions containing fluridone concentrations <250 g·L⁻¹. This treatment rate was

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This project was funded by the National Pesticide Impact Assessment Program, Southern Region, under Contract SR92-53-0-NC. Fluridone for these studies was provided by DowElanco (Indianapolis). We are grateful to S.T. Hoyle, R.I. Hunt, R.J. Mills, and J.L. Boyd for providing technical assistance and to M.A. Gumpertz for statistical consultation. Additional assistance with this project was provided by C.R. Coley, A.G. Poovey, and A. Bryan. We thank Stuart Warren and Walter Skroch for reviewing and providing comments on this manuscript.

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