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Foliar-applied Molybdenum for Preventing or Correcting Molybdenum Deficiency of Poinsettia

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Abstract. **'Annette Hegg Brilliant Diamond' poinsettia *(Euphorbia pulcherrima* Willd. ex Kl.) was grown in an unlimed growth medium consisting of equal volumes of sphagnum peat and perlite and received a fertilizer solution supplying all micronutrients except Mo. Plants were untreated or foliage was sprayed with solutions of 1, 10, or 100 mg Mo/liter 5, 8, or 11 weeks after pinching. Untreated plants developed foliar symptoms of Mo deficiency (marginal and interveinal chlorosis, marginal necrosis, and downward curling), and leaf tissue contained Mo below the critical level of 0.5 µg·g^{-1} and NO_3-N > 1.0%. Treatment at 5 or 8 weeks largely prevented deficiency symptoms, increased tissue Mo, and reduced tissue NO_3-N. Molybdenum deficiency symptoms were in the early stages of development on the day of treatment when plants were sprayed at 11 weeks. Molybdenum sprays at this time increased tissue Mo and reduced tissue NO_3-N but did not eliminate the symptoms. However, when the experiment was completed 15 weeks after pinching, the number of leaves showing symptoms was about one-half that of untreated plants. Increasing the concentration of Mo in the spray solution increased the concentration of Mo in the leaves but had no effect on NO_3-N.**

Molybdenum deficiency of poinsettia is characterized by marginal and interveinal chlorosis, marginal necrosis, and downward curling of recently matured and middle-aged leaves. Deficiency occurs on susceptible cultivars in growth media of low pH (<5.5) when the Mo supply is low (Cox, 1988, 1990; Jungk et al., 1970). The concentration of Mo found in the recently matured leaves of poinsettia is very low; the currently accepted Mo critical level for poinsettia is 0.5 µg·g^{-1} and the normal range is l-5 µg·g^{-1} (Ecke et al., 1990). Molybdenum deficiency results in the inhibition of nitrate reductase enzyme activity and the accumulation of NO_3-N in the leaves of most plants, including poinsettia (Cox, 1988). Poinsettias are most likely to develop Mo deficiency when growing in soilless growth media, and foliar symptoms generally become apparent within 5 to 6 weeks of marketing. Normally Mo is supplied by micronutrient fertilizers incorporated in the growth medium and/or by MO-containing water-soluble fertilizers applied after planting, but foliar applications are possible. Larson et al. (1978) recommend that Mo be applied to poinsettia by foliar spray at the rate of 100 mg·liter^{-1}. It is not clear, however, whether foliar application of Mo is a treatment that can be used with equal success to both prevent and correct Mo deficiency, nor has the effect of timing of application been considered. The objective of this work is to clarify these points.

Rooted terminal cuttings of 'Annette Hegg Brilliant Diamond' poinsettia were obtained from a commercial propagator and potted on 4 Aug. 1988 in 1.5-liter (15-cm diameter) pots containing a growth medium of equal volumes of sphagnum neat and perlite and containing 4.7 kg single superphosphate/m^3 and 21 g chelated iron/m^3. To create conditions favorable for the development of Mo deficiency, no limestone or trace element fertilizer was added to the growth medium. The pH of the medium at planting was 3.3; at the termination of the experiment pH was 4.2. Plants were fertilized at every watering with (mg·liter^{-1}) 300 N, 300 K, and 24 Mg from calcium nitrate, potassium nitrate, and magnesium sulfate, respectively. Fertilizer solution supplied micronutrients, except Mo, according to Hoagland and Arnon (1950). Plants were grown in a glasshouse at ≈21/17C (day/night) under natural light conditions. Plants were pinched to four to five nodes 23 Aug. No growth-retarding chemicals were applied.

Mo was applied as a single foliar spray treatment 5, 8, and 11 weeks after pinching, when the uppermost lateral shoot developing from the pinch was 4.9 ± 0.8, 9.2 ± 1.3, and 12.7 ± 2.1 cm long, respectively. Spray rates were 1, 10, and 100 mg Mo/liter. Spray solutions were prepared using ammonium molybdate, deionized water, and Tween 20 (0.1% v/v). Molybdenum spray volumes were 8.0 ± 1.2, 12.8 ± 2.0, and 14.2 ± 2.4 ml/plant at 5, 8, and 11 weeks, respectively. The growth medium was covered during spray application to protect it from drip. Treatments were applied in factorial combination of application time and Mo concentration. An untreated, nonsprayed control was also included. There were five single-plant replicates per treatment, completely randomized.

The experiment was completed on 12 Dec., 15 weeks after pinching. To determine the effectiveness of treatments in preventing or correcting Mo deficiency, the number of leaves on the lateral shoots showing Mo deficiency was counted and expressed as a percentage of the total leaf count per plant. Leaves subtending the lateral shoots and colored bracts were not counted; neither leaf type showed Mo deficiency. To be counted as showing Mo deficiency, a leaf must have exhibited marginal chlorosis and distinct in-

Table 1. Effect of application time and Mo concentration of foliar sprays on the percentage of leaves showing Mo deficiency symptoms and the concentrations of Mo and NO_3-N in poinsettia leaves.

Spray application time (weeks after pinch)	Spray concn (mg Mo/liter)	Leaves with symptoms[z] (%)	Tissue Mo[y] (µg·g^{-1})	Tissue NO_3-N[x] (%)
Control	---	33	0.43	1.06
5	1	4	0.56	0.68
	10	0	1.02	0.50
	100	0	1.99	0.46
8	1	3	1.00	0.55
	10	1	1.62	0.50
	100	2	7.33	0.55
11	1	13	0.85	0.78
	10	21	1.48	0.65
	100	16	4.07	0.63
Application time		L**Q**	Q*	NS
Mo spray concn		NS	L**Q*	NS
Application time × spray concn		NS	**	NS

[z]All spray treatments resulted in a significant reduction of the percentage of leaves showing symptoms when compared with the untreated control (Dunnett's procedure, $P = 0.05$).
[y]Underlined means are significantly different from the untreated control by Dunnett's procedure, $P = 0.05$.
[x]All spray treatments resulted in a significant reduction of tissue NO_3-N when compared with the untreated control (Dunnett's procedure, $P = 0.05$).
[NS],*,**Effects of spray application time or spray concentration are nonsignificant or significant at $P = 0.05$ or 0.01, respectively, and are linear (L) or quadratic (Q).

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terveinal chlorosis on at least one-third of the leaf blade. Upper, recently matured leaves were sampled and washed to remove residual Mo from the surface in preparation for Mo and NO_3-N analysis. Leaves were gently washed in a 0.6% (w/v) solution of laboratory detergent (Sparkleen, Fisher Scientific, Pittsburgh), rinsed twice with tap water, rinsed twice with deionized water, then blotted to remove excess water before drying in a forced-air oven at 54C. Following drying, tissue was ground to pass through a screen with 425-µm openings (40-mesh). Molybdenum was determined by the thiocyanate colorimetric procedure described by Greweling (1976). Tissue NO_3-N analysis was conducted to determine if Mo sprays stimulated the assimilation of NO_3-N and its subsequent reduction in leaf concentration. NO_3-N was determined potentiometrically (Mills, 1980). Data were subjected to analysis of variance, and regression analyses were used to determine significant responses to Mo spray concentration and time of application.

Moderate to severe foliar symptoms of Mo deficiency were present at the conclusion of the experiment on untreated control plants. Symptoms included: marginal chlorosis; interveinal chlorosis; and, on some leaves, marginal necrosis. Molybdenum deficiency symptoms became apparent during the 9th and 10th weeks following pinching, so plants sprayed at 11 weeks were symptomatic at the time of treatment. Molybdenum sprays applied 5 or 8 weeks after pinching greatly reduced the percentage of leaves showing deficiency symptoms at the end of the experiment compared with the control but did not completely prevent symptom expression (Table 1). Plants treated at 11 weeks (after deficiency symptoms began to appear) had many more symptomatic leaves than plants treated at 5 or 8 weeks, but the number of symptomatic leaves was reduced to about one-half that of the untreated control. While time of Mo spray application had a significant effect on the percentage of leaves showing symptoms, Mo concentration in the spray solution had no effect on symptom expression. Shoot dry weight, plant height, and bract diameter were not affected by the treatments imposed in this study (data not shown).

Concentration of Mo in the upper, recently matured leaves of untreated control plants was below the critical level of 0.5 $\mu g \cdot g^{-1}$ (Table 1). Molybdenum sprays increased tissue Mo compared with the untreated control on all treatment dates, but the differences were significant only with 10 mg Mo/liter 8 and 11 weeks after pinching and 100 $mg \cdot liter^{-1}$ applied at all times. Tissue Mo was increased by each increase in the Mo spray concentration; leaves contained the most Mo when plants were sprayed at 8 weeks. Some of the data suggest that tissue Mo alone may not be a completely reliable indicator of Mo deficiency. For example, plants were largely symptomless when 1 mg Mo/liter spray was applied at 5 and 8 weeks, but tissue Mo concentration was not, significantly higher than that in the symptomatic control. Further, tissue Mo was well above the critical level, but symptoms were still evident 4 weeks after treatment, when plants were treated at 11 weeks with foliar sprays of 10 and 100 mg Mo/liter. Cox (1988) also reported that tissue Mo status does not always correlate with the appearance of Mo deficiency symptoms on some poinsettia cultivars.

All Mo spray treatments resulted in less accumulation of NO_3-N in the leaves compared with the untreated control (Table 1). The concentration of NO_3-N in the leaves from plants treated with Mo spray was not affected by application time or Mo spray concentration. The NO_3-N content of leaves sampled from all treatments was >0.3%, the level said to reflect Mo deficiency in poinsettia (Ecke et al., 1990). Undoubtedly, the large accumulation of NO_3-N in the leaves was due, at least in part, to the frequent application (two or three times per week) of fertilizer solution that contained nitrate as the sole source of N.

Results of this experiment show that foliar sprays of Mo applied before the appearance of Mo deficiency symptoms can largely prevent the development of symptoms. The occurrence of a very small percentage of symptomatic leaves in some treatments, even when the Mo content of the upper recently matured leaves was well above the critical level of 0.5 $\mu g \cdot g^{-1}$, may indicate that Mo does not translocate well from the point of application. Data from a study of foliar-applied Mo to primary leaves of bean *(Phaseolus vulgaris* L.) indicate that Mo is only intermediate in mobility (Bukovac and Wittwer, 1957). These results and those of this study suggest that thorough coverage of the leaves with spray solution may be necessary to ensure complete prevention of Mo deficiency symptoms.

In summary, foliar application of Mo is effective as a treatment to prevent Mo deficiency. Although there was no difference among Mo spray concentrations in their ability to prevent Mo deficiency symptoms, 100 mg Mo/liter resulted in tissue Mo concentrations well within the normal range (l-5 $\mu g \cdot g^{-1}$) for poinsettia. Foliar application of Mo after symptoms start to appear may alleviate the symptoms but cannot be relied upon to completely correct symptoms by marketing time.

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