ppm would likely be adequate for thinning, these effects are not expected to be of importance.

Since fruit, vegetative growing points, and other plant organs are competing sinks for several energy requiring mechanisms, the effect of shading or photosynthetic inhibitors could alter several essential physiological and biochemical functions significantly. Previous work suggests the 1st step in the ethylene-releasing-compound induction of peach fruit abscission is a reduced translocation rate of ^{14}C photosynthate (6) and ^{14}C-sucrose (11, 15). Additional effects of limiting Pn could be production, transport, and function of plant hormones, carbohydrates, proteins and lipids, enzyme synthesis, RNA and DNA synthesis, phloem loading, maintenance of concentration gradients and several other energy requiring processes (5, 13).

Data presented here demonstrate that limiting photosynthesis by shading or by applying terbacil (a chemical photosynthetic inhibitor) caused fruit abscission in peach and nectarine. Further, the period when 'Redhaven' peach trees seemed most susceptible to shading was about 31–41 days after full bloom, and terbacil was an effective [fruit abscission] agent at this period. Terbacil and/or other photosynthetic inhibitors may have potential for post bloom thinning of stone fruit, and should be investigated to potentiate other chemical thinning agents such as carbaryl or NAA in apples.

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Soil and Foliar Application of Magnesium Compounds for the Control of Magnesium Deficiency in 'Shamouti' Orange Trees

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Abstract. **Band application of $MgCl_2 \cdot 6H_2O$ under the tree canopy of 'Shamouti' orange [*Citrus sinensis* (L.) Osbeck] trees significantly increased leaf Mg and Cl concentration. $MgSO_4$ and MgO were not effective. Fertigation with $MgCl_2 \cdot 6H_2O$ was less efficient than band application and was not superior to foliar application of $Mg(NO_3)_2 \cdot 6H_2O$ for increasing leaf Mg concentrations. In spite of high Cl concentration of the leaves, no visible toxicity symptoms were observed.**

Magnesium deficiency, well-known in Israel, is especially widespread in the Mediterranean coastal region characterized by light sandy soils. This problem has become of increasing concern to citrus growers and, in recent years, has been encountered in previously unaffected orchards. The causes vary, but among them may be the increasing use of potassium in both soil and foliar fertilization. Additionally, the widespread use of commercial fertilizer materials free of Mg and trace elements may be a factor contributing to the increasing occurrence of Mg deficiency in citrus trees (8).

No direct relationship has been found between moderate Mg application to orange trees and yield. Furthermore, yield increase was obtained only after the 5th successive year of Mg sprays in trees severely Mg deficient (11).

Using leaf Mg deficiency symptoms rather than yield as a guide to the Mg level may lead to the application of insufficient quantities of Mg. Pratt and Harding (13) theorized that in California, soils of low cation exchange capacity and the use of high Ca and low Mg irrigation water was most likely to produce Mg deficiency. This finding followed an earlier work by Heymann-Herschberg (9) showing that applications of $MgCl_2$ and $MgSO_4$ were not effective in correcting Mg deficiencies in sandy soils along the coastal plain of Israel. The latter salts were applied in quantities ranging from 0.25 to 2 kg per tree annually for 2 successive seasons. Jacoby (10) concluded that an exchangeable Ca/Mg ratio in the soil greater than 4:1 impaired Mg uptake by citrus seedlings. Lack of success in achieving adequate control of Mg deficiency by use of Mg fertilizer materials and only partial success with application of $MgSO_4$ sprays led to the use of $Mg(NO_3)_2 \cdot 6H_2$ as foliar spray material (2). Jones et al. (11) pointed out, however, that only a small fraction of the Mg from foliar sprays is translocated from old to young foliage, necessitating a program of annual sprays.

The site of the experiments was the major producing area of 'Shamouti' orange in the central coastal strip of Israel, which is characterized by light sandy soil of 7 to 8 pH. Four experiments were conducted at different growers' orchards. In all locations, 'Shamouti' orange trees, grafted on sweet

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Table 1. Effect of fertigation and spray application of Mg on 'Shamouti' orange on leaf mineral concentration.

Treatment	Application method	Amount	No. of applications	Leaf conc. (dry wt) Mg	Cl
Control				0.18 c[z]	0.26 a
$MgCl_2·6H_2O$	Fertigation	0.2 kg/tree	6[y]	0.21 ab	0.25 a
$MgCl_2·6H_2O$	Fertigation	0.3 kg/tree	6[y]	0.21 ab	0.33 a
$MgCl_2·6H_2O$	Fertigation	0.6 kg/tree	6[y]	0.23 a	0.31 a
$Mg(NO_3)_2·6H_2O$	Spray	1%	2[x]	0.23 a	0.27 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Applied from May to October.
[x]Applied in May and June.

Table 2. Effect of Mg application in a 35-cm band around 'Shamouti' orange trees on leaf mineral concentration and Ca/Mg ratio in the soil (50% applied in July 1979 and 50% one year later; leaf samples taken in November, 4 months after 2nd application).

Treatment	Amount (kg/tree)	Ca/Mg (ratio)[z]	Leaf mineral composition: NO_3 (ppm)	P (Dry matter %)	K	Ca	Na	Mg	Cl
Control		11.25	20	0.05 a[y]	0.36 b	3.24 a	0.15 a	0.18 b	0.35 c
$MgCl_2·6H_2O$	14	3.58	12	0.05 a	0.27 c	3.21 a	0.16 a	0.37 a	0.88 a
MgO	3	5.03	19	0.05 a	0.42 a	3.11 a	0.15 a	0.20 b	0.43 bc

[z]0- to 60-cm depth.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Effect of Mg application in 'Shamouti' orange leaf mineral concentration ($MgCl_2·6H_2O$ applied 50% in July 1981 and 50% one year later; leaf samples taken in November, 4 months after 2nd application).

Treatment	Application method	Amount	Leaf mineral composition: NO_3 (ppm)	P (Dry matter %)	K	Mg	Cl
Control			54	0.06 a[y]	0.61 a	0.21 c	0.28 b
$MgCl_2·6H_2O$	35-cm band[z]	14 kg/tree	32	0.06 a	0.54 a	0.42 a	1.68 a
$MgCl_2·6H_2O$	Fertigation	14 kg/tree	31	0.05 a	0.55 a	0.28 b	0.53 b
$Mg(NO_3)_2·6H_2O$	Spray	1.0% × 2	53	0.06 a	0.54 a	0.28 b	0.27 b

[z]Drilled into the top 5 to 7 cm of soil, under the canopy.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 4. Effect of band and spray application of Mg on 'Shamouti' orange leaf mineral concentration. (Application in band, half in July 1982 and 2nd half one year later. Leaf samples taken in November, 4 months after 2nd application).

Treatment	Application method	Amount	Leaf mineral composition: NO_3 (ppm)	Na (Dry matter %)	Mg	Cl
Control			51 a	0.11 a	0.16 c	0.28 b
$MgCl_2·6H_2O$	35-cm band	14 kg/tree	26 a	0.08 a	0.24 a	0.50 a
$MgSO_4$	35-cm band	9 kg/tree	41 a	0.11 a	0.18 b	0.29 b
MgO	35-cm band	3 kg/tree	52 a	0.10 a	0.20 ab	0.26 b
$Mg(NO_3)_2·6H_2O$	Spray	1.0% × 2	22 a	0.09 a	0.18 b	0.28 b
Mg-EDTA	Spray	0.2%	26 a	0.10 a	0.18 b	0.32 b
Mg-EDTA	Spray	0.5%	38 a	0.12 a	0.17 b	0.23 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

lime [*Citrus aurantifolia* (Christm.) Swing.] rootstock, inarched with sour orange (*C. aurantium* L.), were used. Trees were planted 6 × 4 m and varied from 18- to 24-years-old, depending on the orchard. Leaf analysis and visual observation showed the trees to be highly Mg-deficient.

Expt. 1. $MgCl_2·6H_2O$ was applied by injection into the irrigation system (fertigation) in 6 applications, from May to October. Three amounts, 0.2, 0.3, and 0.6 kg/tree were applied. A 1% aqueous solution of $Mg(NO_3)_2·6H_2O$ was applied as a foliar spray in May and June.

Expt. 2. $MgCl_2·6H_2O$ at 14.0 kg/tree, and MgO (95%) at 3.0 kg/tree were each spread on the soil in a 35-cm band under the tree canopy. The magnesium salts were hoed into the soil to a depth of 5 to 7 cm.

Expt. 3. $MgCl_2·6H_2O$ was applied either as described in Expt. 2 or as an equivalent amount (14 kg/tree) in the irrigation system. Half of the amount was applied in July 1981 and half one year later. $Mg(NO_3)_2·6H_2O$ was applied as in Expt. 1.

Expt. 4. $MgCl_2·6H_2O$ was applied as in Expts. 2 and 3. $MgSO_4$ (95%), 9 kg/tree, and MgO (95%), 3 kg/tree, were applied in a similar manner. These quantities are equivalent to 1.7 kg of elemental Mg per tree. A 1.0% aqueous solution of $Mg(NO_3)_2·6H_2O$ was applied as a foliar spray in May and June, and Mg-EDTA was applied only in May as 0.2% and 0.5% aqueous solutions.

Leaf samples from fruiting terminals were taken in November after the last application of Mg. The leaf samples were analyzed for Mg, Cl, NO_3, P, K, Na, and Ca by aqueous extraction (1). In one of the $Mg(NO_3)_2·6H_2O$ spraying experiments, Mg content of fruiting and nonfruiting terminal leaves, following aqueous extraction vs. wet digestion, was studied. Soil samples from Expt. 2 were taken from a depth of 0 to 60 cm, immediately before application of the Mg fertilizers, in July and again 1 year later, after the completion of the application. The samples were analyzed for Ca, Mg, and Cl, using the extract from 1.0 N buffered ammonium acetate extraction at pH 7.0 by titrimetric (versenate) methods for combined Ca and Mg, and for determination of Ca alone (14). The quantity of chlorides was determined in aqueous extracts of soil, using a Buchler-Cotlove chloridometer.

In each experiment, 4 replicates, chosen at random with 4 trees-per-replicate, were used per treatment. Data were subjected to analysis of variance and mean values compared, using Duncan's multiple range test, 5% level.

Fertigation and foliar spray showed a significant increase in leaf Mg content, without a significant increase in leaf Cl, compared to the control sample content (Table 1). Band application of $MgCl_2·6H_2O$, under the tree canopy, brought about a significant increase in leaf Mg and Cl and decrease in leaf K concentrations and, as expected, a major reduction in the exchangeable Ca/Mg ratio in the soil (Table 2). Because of its relative insolubility, MgO was ineffective in raising leaf Mg concentration. Exchangeable Mg and Cl quantities in the soil were calculated as 3.06 and 5.32 meq/100 g soil, respectively. These calculations include Mg quantities found prior to $MgCl_2·6H_2O$ addition. One year later, 35% of Mg and only 2% of the Cl remained in the soil. Apparently, significant quantities of Cl were lost by leaching, assuming approximately equivalent uptake rates for Mg and Cl. Negligible amounts of Cl are known to be absorbed in clay.

The results of the 3rd experiment, using 3 methods of Mg application, are compared in Table. 3. The superiority of the $MgCl_2·6H_2O$ band application, over the 2 other methods of Mg application, is apparent. No visible damage to the leaves was caused by the high Cl concentration that resulted from the $MgCl_2·6H_2O$ band application. Trees with high leaf Mg concentration

Table 5. Magnesium concentration (percentage of dry matter) of 'Shamouti' orange leaves. Leaf analysis done on 7-month-old, spring-cycle leaves from fruiting and nonfruiting terminals.

Leaf Sample	Aqueous extract	Wet digestion
Fruiting terminals	0.15 a[z]	0.18 a
Nonfruiting terminals	0.11 b	0.13 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

showed improved growth, reduced leaf abscission in autumn, produced darker green leaves, and showed less dieback of branchlets. Magnesium sulfate band application or Mg-EDTA-chelate sprays were relatively ineffective in correcting leaf Mg deficiency in comparison with $MgCl_2 \cdot 6H_2O$ band application (Table 4).

A significantly higher leaf Mg concentration was found in 'Shamouti' orange leaves picked from fruiting terminals than from nonfruiting terminals (Table 5). This difference in 7-month-old spring-cycle leaves was evident whether the analysis was done by aqueous extraction or by the wet digestion technique. The aqueous extraction method gave substantially lower values than the wet digestion method.

Our results provide some answers to the persistent problems associated with Mg deficiency in 'Shamouti' orange. Foliar application of $Mg(NO_3)_2 \cdot 6H_2O$ has been neglected because it is no longer considered effective by many growers. This neglect stems from the inability to discern visual improvement in leaves of sprayed trees. Furthermore, no direct relationship between fruit yield and elimination of Mg deficiency can be established in a short-term experiment (11). There is evidence, however, that trees weakened by Mg deficiencies are increasingly suspectible to adverse environmental conditions such as cold (4), leaf abscission, dieback of branches, and decreased yield (3).

Perhaps the primary consideration in choosing a soil application of Mg is that this technique provides long-lasting effects from a single (or once repeated) treatment. Results of experiments reported here show clearly that significant improvement in leaf Mg concentration can be achieved by application of relatively large quantities of $MgCl_2 \cdot 6H_2O$ in a narrow band of soil under the tree canopy. On the other hand, $Mg(NO_3)_2 \cdot 6H_2O$ foliar spray resulted in increases of only 0.02% to 0.07% in leaf Mg content, requiring repeated spraying at least once annually, depending on the severity of the Mg deficiency.

Addition of 1.7 kg of elemental Mg and 4.8 kg of elemental Cl per tree (as a band application of 14.0 kg of $MgCl_2 \cdot 6H_2O$) caused an increase of 0.19% and 0.53% in leaf Mg and Cl concentrations, respectively. The corresponding increases in terms of milligram equivalents were 0.016 Mg and 0.015 Cl. On an equivalent weight basis, Mg and Cl were taken up in nearly equal quantities. Similar results were obtained in the experiments summarized in Table 4. However, the equivalent Cl concentration in the leaves (Table 3) was 2.35 times higher than that of Mg. High values of leaf Cl shown in Table 3 (1.68%) are not unusual in citrus. Chapman et al. (5) reported leaf Cl values of up to 1.83% in 'Washington Navel' orange leaves; yet, at leaf levels of 0.3% Cl, they observed some yield reduction, and at over 0.75% there was serious growth retardation. Leaf tip burn did not occur, although Embleton et al. (7) found in certain cases that high Cl concentration may cause foliar damage in citrus. The absence of a deleterious effect of high Cl levels in our experiments may be explained by the differences in orange cultivar and accompanying cations in the 2 experiments, i.e., Na vs. Mg. Growth retardation could not be observed because these trees were 20-years-old; on the contrary, the trees recovered from leaf Mg deficiency, and leaf abscission was reduced. Magnesium sulfate and MgO soil application was used in order to prevent increases of leaf Cl concentration, and failed to bring about significant increases in leaf Mg concentrations in our soils (pH 7.0 to 8.0). Most of the added Cl was leached by irrigation (750 mm) and rains (550 mm) one year after application, indicating that large amounts of $MgCl_2 \cdot 6H_2O$ added to the soil were not harmful.

Differences were found in Mg composition of leaves from fruiting and nonfruiting terminals, in agreement with Smith's (15) results. In our case, the Mg concentration was at least 0.04% greater in the fruiting terminals than in the nonfruiting. This difference was larger than the gain likely to be achieved by $Mg(NO_3)_2 \cdot 6H_2O$ foliar spray. Lowering the exchangeable Ca/Mg ratio in the soil from 11.3:1 to 3.6:1 (Table 2) was associated with a significant increase in leaf Mg concentration, agreeing with the result of potted seedlings done by Jacoby (10). This finding should assist in detemining the quantities of Mg fertilizer that should be applied to the soil. Data from both soil tests and leaf analyses were found to be a more reliable guide than those from only one of them for determining quantities of Mg to be added to the soil (6, 12).

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