ably in all stages of cell division. The degree of contraction depends a good deal on the concentration of the solution used and duration of treatment prior to killing the root tips for staining. The effects produced by some of these chemicals on root tip chromosomes of three common plants at metaphase (the stage of division at which they are most condensed under natural conditions) are shown in the photo. The plants are: onion (*Allium cepa*, 2n = 16), broad bean (*Vicia faba*, 2n = 12), and spider plant (*Chlorophytum elatum*, 2n = 28).

The carbamates are white, crystalline solids of low solubility in water. Saturated solutions vary widely in concentration; they must be diluted for chromosome studies. Satisfactory dilutions lie between 5 and 40 ppm. Time of treatment is important, as the effective period for satisfactory results lies between 1 and 3 hours. Destruction of chromosomes occurs rapidly at concentrations exceeding 50 ppm, and ultimately at low concentrations if treatment time exceeds 4 to 5 hours. A suggested starting point from which one may vary concentration and treatment time either way is 10 ppm for 1 hour for excised root tips of most species of plants.

Two important precautions must be taken in using carbamates to pre-treat material for cytological studies. First, bottles, vials, and other glassware to be used must be scrupulously clean. Second, the chemical should be mixed directly with distilled water to make a saturated stock solution. Not even a trace of alcohol or other organic solvent should be used to dissolve the chemical before adding it to the water because the chromosomes may be destroyed rapidly even at high dilutions. The reason for this destruction is not known, but may involve either extremely rapid penetration of the chemical into the cell, or synergistic activity of the chemical and solvent. A stock solution in a well stoppered bottle was found to have lost none of its potency after two years at room temperatures in the laboratory.

Two advantages in the use of carbamates such as IPC and CIPC are their relative safety and economy. They have failed consistently to produce tumors of any sort on laboratory animals in exhaustive clinical experiments, and are regarded as noncarcinogenic. The purified chemicals cost about $3.00 per pound. The solubility of purified IPC is roughly 250 ppm. One gram, costing less than one cent, is sufficient to make up about 400 liters of saturated stock solution, or 10,000 liters of 10 ppm solution.

The carbamates investigated provide cytologists with a new tool for chromosome studies. Additional carbamates, as well as other presently unexplored groups of selective herbicidal chemicals, may produce comparable or different effects and become equally useful.

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Magnesium deficiency in cut-flower chrysanthemums

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A severe leaf yellowing, or chlorosis problem, has occurred in chrysanthemums at several commercial greenhouses in the San Francisco Bay Area. The disorder was found to be magnesium deficiency caused by high annual applications of potassium. Magnesium fertilization, even at high rates, was not effective in correcting the problem. Elimination of potassium fertilization gave immediate control.

THE CHLOROSIS discussed in this study appeared on rooted cuttings of chrysanthemums shortly after they were planted in ground beds. On young plants the symptoms were confined to the older leaves. These exhibited an interveinal yellowing, accompanied in advanced stages by a reddish-purple pigmentation of the leaf margins. Near bloom time the chlorosis progressed rapidly up the stem in severe cases, affecting most of the foliage and reducing the marketability of the cut flowers. Many varieties of standard chrysanthemums have been affected, including white and yellow Albatross, Indianapolis, Lavender Queen, Donolope, White Spider, Copperhead, Bunbu, and Iceberg.

The magnesium and potassium contents of leaves representing different stages of symptom development on White Albatross are shown in table 1. Chlorotic leaves contained less than 0.1 per cent magnesium. The percentage of magnesium found in the leaves with mild symptoms (0.06 per cent) is in good agreement with the magnesium critical level established by research on chrysanthemums at University of California, Los Angeles. The leaf analyses, leaf symptoms, and the progessive pattern of symptoms, from lower to upper leaves, all indicated a magnesium-deficiency problem.

The grower's fertilization program included annual applications of potassium at a very high rate. Continuous application of potassium to soils in amounts greatly exceeding crop requirements can lead in time to an imbalance of potassum and magnesium in the soil. Under such conditions, magnesium uptake by plants is restricted and magnesium deficiency can develop, even if the soil contains a normal amount of available magnesium.

Normal chrysanthemum leaf to left, as compared with magnesium deficient leaf to right.

In the case of these chrysanthemums, potassium had been applied since 1948 preplant to each crop—every 15 weeks at the rate of 1 to 1½ lbs of potassium sulfate per 100 sq ft. At this rate the annual application of potassium sulfate amounted to 3½ to 5¼ lbs per 100 sq ft. In addition, appreciable amounts of potassium were added in the form of barley

straw and rice hulls used as soil amendments.

Soil samples taken from the top six inches of beds producing magnesium-deficient plants were analyzed to determine the potassium-magnesium balance in the soil. The soil analysis substantiated the leaf analysis in defining the problem as magnesium deficiency. The data, presented in table 2, show that the ratio of exchangeable potassium to exchangeable magnesium in the chrysanthemum beds was 0.7. Soil potassium/magnesium ratios are normally less than 0.5. Ratios greater than 0.5 have been reported to be associated with potassium-induced magnesium deficiency in a number of crops.

Based on the soil and plant data, it appeared that the magnesium deficiency might be corrected by an increase in magnesium fertilization or by a decrease in potassium fertilization. Either should tend to reduce the soil potassium/magnesium ratio, thereby improving the balance of these two elements and favoring increased magnesium uptake.

An experiment was conducted to study the effects of both types of treatments. Albatross cuttings were grown to bloom stage in 6-inch clay pots containing soil from a commercial greenhouse where magnesium deficiency occurred. The soil was differentially fertilized with magnesium from two different sources—magnesium sulfate and dolomite. Half of the pots were fertilized with potassium sulfate at the grower's usual rate of 1 to 1½ lbs per 100 sq ft; the other half received no potassium fertilizer. Magnesium fertilization, even at very high rates, was not effective in raising leaf magnesium into a normal range when potassium fertilization was continued at the grower's usual rate. This is illustrated by the data in table 3 showing the percentage of magnesium in the lower leaves of Albatross chrysanthemums at bloom stage.

Even at the highest rate of magnesium sulfate, leaf magnesium was only 0.11 per cent—barely enough to prevent magnesium deficiency symptoms from appearing. Symptoms were present on the lower leaves of plants in all the other magnesium sulfate treatments and also on plants treated with dolomite at all rates.

In contrast, no magnesium-deficiency symptoms appeared on any of the plants grown without potassium fertilization, whether or not magnesium was applied. Leaf magnesium for the zero magnesium and zero potassium treatment was 0.16 per cent. Magnesium fertilization with either magnesium sulfate or dolomite did not increase the leaf-magnesium level further.

The effect of eliminating potassium fertilization was also studied in a trial at a commercial greenhouse where the potassium-induced magnesium deficiency problem was encountered. Albatross chrysanthemum cuttings were planted in ground-bed plots that received no potassium but which were differentially fertilized with magnesium sulfate. Magnesium deficiency symptoms did not develop on plants in any of the treatments. The leaf magnesium and potassium levels at midperiod and at bloom stage are shown in table 4.

At neither sampling time was there a leaf-magnesium deficiency, whether or not the plants had been fertilized with magnesium. Magnesium sulfate fertilization at the higher rates increased the percentage of magnesium in leaves sampled at the midperiod of growth. By bloom time these differences in leaf magnesium no longer existed.

Leaf potassium decreased from midperiod to bloom stage. However, even at the latter stage the potassium levels were adequate, according to the critical level for lower leaves of chrysanthemums (2.15 per cent) established at UCLA.

These studies illustrate the importance of controlling potassium fertilization of soils to maintain adequate magnesium nutrition for chrysanthemums. Annual fertilization of the same soil with potassium in amounts well above crop requirements can eventually result in a magnesium deficiency. In chrysanthemums, such a problem is difficult to correct by magnesium fertilization. However, elimination of potasssium fertilization can bring about rapid correction of the problem. The length of time that potassum fertilization can be discontinued to correct potassium-induced magnesium deficiency, without encountering potassium deficiency, cannot be predicted; the time will vary with different soils and past fertilization practices. In commercial chrysanthemum-growing operations, where elimination of potassium fertilization may be necessary to correct potassium-induced magnesium deficiency, the interruption of potassum use should be temporary only. Plant and soil analyses can be useful guides in determining when potassium fertilization should be resumed in order to avoid potassium deficiency. The problem discussed herein can be prevented by use of moderate amounts of potassium in fertilization programs.

TABLE 1. MAGNESIUM AND POTASSIUM CONTENT OF LOWER LEAVES OF WHITE ALBATROSS CHRYSANTHEMUMS AT VARIOUS STAGES OF GROWTH AND SYMPTOM DEVELOPMENT

State of growth	Leaf symptom	Leaf magnesium	Leaf potassium
		%	%
8 weeks before bloom	None	0.10	4.8
3 weeks before bloom	Slight interveinal chlorosis	0.06	6.0
7–10 days before bloom	Severe interveinal chlorosis	0.04	5.3

TABLE 2. ANALYSIS OF SOIL FROM ROOT ZONE OF MAGNESIUM DEFICIENT CHRYSANTHEMUMS

CEC me/100 gm	Exchangeable cations me/100 gm				K
	Ca	Mg	K	Na	Mg
30.4	27.6	1.1	0.8	0.2	0.7

TABLE 3. LEAF MAGNESIUM AND POTASSIUM AT BLOOM STAGE IN POT-GROWN ALBATROSS CHRYSANTHEMUMS DIFFERENTIALLY FERTILIZED WITH MAGNESIUM; POTASSIUM APPLIED AT GROWER'S USUAL RATE

Magnesium source	Rate of application	Leaf magnesium*	Leaf potassium
	lbs/100 sq ft	%	%
Mg sulfate	0	0.06	2.3
Mg sulfate	⅛	0.09	2.3
Mg sulfate	½	0.08	2.3
Mg sulfate	2	0.11	2.3
Dolomite	Equivalent	0.06	2.3
Dolomite	to above	0.07	2.4
Dolomite	rates of	0.07	2.4
Dolomite	Mg sulfate	0.09	2.0

* Lower leaves, average of 3 replications.

TABLE 4. LEAF MAGNESIUM AND POTASSIUM LEVELS IN GROUND-BED-GROWN ALBATROSS CHRYSANTHEMUMS DIFFERENTIALLY FERTILIZED WITH MAGNESIUM; POTASSIUM WITHHELD

Fertilization rate magnesium sulfate	Leaf magnesium*		Leaf potassium*	
	Mid period	Bloom stage	Mid period	Bloom stage
lbs/100 sq ft	%	%	%	%
0	0.21	0.23	4.8	3.1
⅛	0.21	0.18	5.5	2.4
½	0.24	0.22	5.0	3.0
2	0.28	0.23	4.6	2.3

* Composite of 4 replications.

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