POSSIBLE KEY ROLE OF CALCIUM FOR THE FUTURE CULTIVATION OF CORN LILY (*VERATRUM CALIFORNICUM*)

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Introduction

Corn lily (*Veratrum californicum)* is a native plant and of interest because it has the potential to provide pharmaceutical precursors for use against cancer. Corn lily has been difficult to cultivate. There have been failures when transplanting corn lily rootstocks. Corn lily plants disturbed by transplanting or inadvertent transplanting by root and rhizome harvests display a range of symptoms in the field. This brief report should be considered an expanded hypothesis: that transplanted corn lily suffers from calcium (Ca) deficiency and possibly an unfavorable calcium/magnesium (Ca/Mg) ratio. Careful attention to calcium nutrition appears to be fundamental for healthy corn lily growth.

Corn lily develops large subterranean buds during the summer for the next year's growth. These buds are poised to grow quickly in a few weeks to provide a well-developed plant canopy. Carbohydrates and nutrients from the highly developed root system help sustain the rapidly growing plant. The working hypothesis is that once a corn lily plant is dug, the root system is severed, and the remaining plant encounters difficulty sustaining the calcium status of the plant top in the following growing season.

An extension of this hypothesis is that the very deep well-developed root system contains substantial Ca and is in close contact with very wet soil, enabling it to support a rapidly developing shoot system, and that much of the root system and its Ca supply or potential to deliver the supply is lost when the plant is transplanted. The growing transplants then develop Ca deficiencies and/or nutrient imbalances upon the resumption of rapid growth.

What follows are observations of a few soils where corn lilies grow, observation of apparent nutrient deficiency symptoms that developed on plants grown in a growth chamber in 2010 at the Oregon State University (OSU) Malheur Experiment Station, and chemical analyses of plants inadvertently transplanted in the harvesting of corn lily for pharmaceutical trials from Manti la Sal National Forest, Utah.

Soils Supporting Corn Lily

Starting in 2009, research was initiated to study the natural water regime in soils where corn lily naturally occurs, with the vision of later being able to try to optimize irrigation practices for commercial production. Soil samples from these sites were not unusual for moist mountain soils, except that some of the soils were particularly rich in calcium for wet mountain soils (Table 1).

Table 1. Soil from the monitoring sites to study the natural water regime of corn lily (*Veratrum californicum*).

Soil property[a]	Location and characterization of the *Veratrum californicum* stand			
	Manti la Sal National Forest, UT	Sawtooth Mountains, ID	Blue Mountains, OR	Central Mountains, ID
	Solid stand in aspen	Solid stand in aspen	Solid stand in forest clearing	Scattered clumps
Organic material, %	4.05	3.31	3.56	3.63
pH in water	6.1	5.9	6.1	6.5
CEC, meq/100g	11	10	11	10
base saturation	156	136	114	80
Ca, as % of base saturation	138	114	92	56
Ca, ppm	3,042	2,288	2,027	1,204
Mg, ppm	155	201	164	162
Ca/Mg ratio	19.6	11.4	12.4	7.4
Texture	Sandy loam	Loamy sand	Sandy loam	Sandy clay loam

[a]CEC = cation exchange capacity, Ca = calcium, Mg = magnesium.

First Observations of Apparent Ca Deficiency in Corn Lily

Corn lily plants were grown in a growth chamber to examine plant response to day length. At first the plants appeared to be normal, but after 30 days growth, some abnormalities started to appear (Fig. 1). The abnormalities appeared be consistent with Ca deficiency symptoms: leaf tips tended to stick to each other at the growing point, leaf tips burned and dried, and the lower parts of the leaves remained closer to normal leaf color, as have been observed on corn, sorghum, lettuce, and leek.

Figure 1. Corn lily (Veratrum californicum) in a growth chamber at the Oregon State University Malheur Experiment Station with apparent Ca deficiency symptoms.

In a few plants the abnormalities were extreme, and leaf and stem tissue became necrotic. Samples were sent to the University of Idaho plant disease clinic at Parma, Idaho and no bacterial or fungal pathogen was found. These results suggested that Ca deficiency or an abnormal Ca/Mg ratio may be the physiological cause. For example, Ca deficiency and a Ca/Mg ratio of less than 5 is known to cause the physiological defect of blossom end rot on tomato (Fig. 2).

Figure 2. Blossom end rot on tomato at the Oregon State University Malheur Experiment Station, September 28, 2010.

Materials and Methods

Corn lily roots were harvested from approximately 8 acres (3 ha) in the Manti la Sal National Forest in 2009 for the manufacture of an experimental pharmaceutical. In the process of harvesting roots from the forest for pharmaceutical trials, some of the root stocks were disturbed but inadvertently left in the field. Both roots with buds that were heavily damaged and roots that were transplanted very shallowly did not grow into normal plants, but others were essentially transplanted through the harvesting process.

On 8 July 2010 12 areas of approximately 0.4 to 1+ acres (0.1 to 0.3 ha) each were chosen where plants had been inadvertently transplanted through the harvesting process in 2009. Ten or more plants within each harvested area were selected that had been inadvertently transplanted, but managed to completely open their leaves. Plants were dug with their roots attached (Fig. 3). Plants were cut at ground level and tops and roots were placed in separate paper bags. For each plant that had been inadvertently transplanted, a corresponding plant in the closest group of unharvested corn lily plants was also harvested (Fig. 4). A soil sample was collected along with the harvest of plants from each of the 12 areas. Plant tops, roots, and soil were transported to the OSU Malheur Experiment Station where tops and roots were washed in water and rinsed in deionized water. The height and diameter of each plant was measured. Tops and roots from each area were dried and grouped by whether or not they had been inadvertently transplanted. Tops were weighed at 50°C out of a sample drier.

Figure 3. Digging of corn lily (Veratrum californicum) at the Manti la Sal National Forest, UT on 8 July 2010. Plants had been inadvertently transplanted during harvest in 2009.

Figure 4. Digging of previously undisturbed corn lily (Veratrum californicum) at the Manti la Sal National Forest, UT on 8 July 2010, directly adjacent to the 2009 harvest area.

Tops were analyzed for plant nutrients and the soil was analyzed for pH, organic matter, soil texture, and nutrient content (Tables 4 and 5).

The experimental design was not randomized, because the harvested areas and the nonadjoining nonharvested areas were not chosen at random, but were predetermined in 2009 by the pattern of commercial harvest. Statistical comparison tests rely on random assignment of treatments so statistical comparisons would not be statistically valid.

Results

The disturbed and inadvertently transplanted corn lily plants had visual symptoms similar to those observed in the growth chamber. Disturbed plants had 40 percent as much dry weight, 68 percent as great a diameter at ground level, and 51 percent of the height of undisturbed plants (Table 2). Disturbed plants had lower total nitrogen, boron, and Ca content and higher levels of phosphorus, nitrate-N, manganese, zinc, and iron. Disturbed plants contained only 21 percent as much Ca as the undisturbed plants. The Mg content was also slightly higher in the disturbed plants, which could be troubling in view of the reduced Ca content. The ratio of Ca to Mg was less than 5 (reduced by 51 percent) in the disturbed plants (Table 3).

Table 2. Corn lily *(Veratrum californicum)* plant top growth, nutrient content, and total calcium (Ca) from disturbed and undisturbed plants sampled at the Manti la Sal National Forest, UT on 8 July 2010.

	Treatments	
Measurements of plant tops, plant nutrient contents of dry weight, and total Ca content per plant top	Disturbed plants, inadvertently transplanted	Undisturbed plants
Plant top dry weight, g	5.91	14.9
Plant diameter at ground level, cm	1.02	1.51
Plant height, cm	33.9	66.5
Nitrogen, %	3.60	4.55
Phosphorus, %	0.409	0.328
Potassium, %	3.53	3.69
Sulfur, %	0.180	0.176
Calcium, %	0.813	1.506
Magnesium, %	0.172	0.166
Sodium, %	0.011	0.008
Nitrate, ppm	34.7	14.7
Zinc, ppm	27.1	18.5
Manganese, ppm	45.7	26.8
Copper, ppm	11.2	10.9
Iron, ppm	1171	417
Boron, ppm	8.0	13.7
Plant top total Ca content, mg/plant	48.7	227.4

Table 3. Selected calcium (Ca) nutrient ratios from the plant tops of corn lily *(Veratrum californicum)* from disturbed and undisturbed plants sampled at the Manti la Sal National Forest, UT on 8 July 2010.

	Treatments	
Selected Ca nutrient ratios in the plant tops	Disturbed plants, inadvertently transplanted	Undisturbed plants
Ca/phosphorus ratio	2.04	4.89
Ca/magnesium ratio	4.77	9.31
Ca/nitrate ratio	30.5	1,055.0
Ca/manganese ratio	184	688.0
Ca/iron ratio	7.64	40.8

Discussion

The ratio of Ca/Mg is recognized as a critical criterion in plants. When the ratio of Ca to Mg in the middle lamella of cell walls is 5 or below, cell wall integrity is not adequately supported by Ca and Mg pectate in tomato, resulting in blossom end rot, a physiological disorder of tomato fruit. A similar process may be occurring in corn lily shoots.

Calcium translocation to developing tissues is dependent on water transport, which in turn is depends on a vigorous root system and the lack of water stress. In the case of transplanted corn lily, the deep root system has been disturbed and the remaining root system is close to the top of the soil surface where it is much more subject to variations in soil water content.

Future Research

The preliminary results presented here point out several research needs:

1. Carefully study the nutrient relationships of corn lily throughout development cycles, with special care to examine the lower part of the root system and recycling of nutrients.
2. Determine the degree to which the new tissue growth has already been predetermined in the buds on plants during the previous season.
3. Carefully examine the role of Ca and Ca/Mg ratios in transplanted and undisturbed corn lily and in cell wall integrity.
4. Determine whether additional Ca can enhance success and growth of transplants.

Table 4. Selected soil properties at the Manti la Sal National Forest, UT, on 8 July 2010, from locations that support natural populations of corn lily *(Veratrum californicum).*

Field ID	pH in water	Organic matter %	CEC[a] meq/100g	Ca/Mg	Sand %	Silt %	Clay %	Texture class
A	6.7	3.68	21	23	57.5	17.5	25.0	sandy clay loam
B	6.6	3.16	16	15	52.5	17.5	30.0	sandy clay loam
C	6.7	2.63	21	16	57.5	10.0	32.5	sandy clay loam
D	7.0	3.44	17	23	67.5	7.5	25.0	sandy clay loam
E	6.7	3.25	21	31	80.0	7.5	12.5	sandy loam
F	6.8	3.55	18	39	57.5	17.5	25.0	sandy clay loam
G	6.7	3.36	17	23	70.0	7.5	22.5	sandy clay loam
H	6.7	3.27	22	30	62.5	17.5	20.0	sandy clay loam
I	6.6	2.91	17	21	70.0	7.5	22.5	sandy clay loam
J	6.3	3.30	17	18	62.5	12.5	25.0	sandy clay loam
K	6.7	3.43	16	30	57.5	17.5	25.0	sandy clay loam
L	6.6	3.51	16	28	65.0	12.5	22.5	sandy clay loam

[a]CEC = cation exchange capacity

Table 5. Selected soil nutrients (ppm) at the Manti la Sal National Forest, UT, on 8 July 2010 from locations that support natural populations of corn lily *(Veratrum californicum).*

Field ID	P bi.[a]	NO_3	NH^4	Ca	Na	B	K	S	Mg	Zn	Cu	Mn	Fe
A	17	42	3	2702	14	0.4	215	19	116	2.0	1.2	15	57
B	19	65	2	1855	18	0.5	338	14	120	2.5	0.9	16	66
C	19	21	3	1819	14	0.4	226	12	115	1.2	0.9	9	58
D	15	46	5	2308	17	0.4	141	14	99	1.3	0.9	12	51
E	9	39	5	2359	16	0.3	136	15	75	1.4	0.8	12	44
F	11	30	5	2607	15	0.3	130	16	67	1.3	0.8	15	42
G	13	7	7	2154	23	0.5	211	17	93	1.5	0.8	10	43
H	11	7	9	2802	27	0.6	253	17	94	1.4	0.9	10	45
I	16	8	10	2761	26	0.5	298	17	131	1.5	0.8	8	50
J	19	6	4	2153	22	0.5	329	14	118	3.2	0.9	11	70
K	12	5	4	2670	29	0.5	229	17	89	1.3	1.3	11	46
L	13	5	4	2465	16	0.5	236	16	87	1.6	1.1	9	46

[a]P bi = phosphorus bicarbonate extracted, NO_3 = nitrate, NH_4 = ammonium, Ca = calcium, Na = Sodium, B = boron, K = potassium, S = sulfur, Mg = magnesium, Zn = zinc, Cu = copper, Mn = manganese, Fe = iron.