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RESEARCH NEWSLETTER

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What Causes Upper Leaf Necrosis on Oriental Hybrid Lilies?

By Yao-Chien Chang and William B. Miller

Dedication. This project is dedicated to the memory of Mr. Piet Borst of Van Zanten, who passed away in Holland on July 23, 2003. Piet was a member of our Group 1 research committee, and a tireless promoter of lilies, especially on the west coast. We appreciated his thoughtful criticism, involvement, and support of the Flowerbulb Research Program at Cornell.

Growers of Oriental hybrid lilies, especially the cultivar 'Star Gazer' are familiar with an upper leaf "burn" that is commonly seen on 'Star Gazer' crops across North America and throughout the year. The disorder is characterized by necrosed (dead) upper leaves and by leaf curling, distortion or leaf tip burn (Fig. 1). The disorder is commonly found in greenhouse grown Oriental hybrid lilies worldwide. In Holland, this disorder is translated as "leaf scorch", but is a very different disorder than the fluoride-induced "leaf scorch" seen on 'Ace' Easter lilies in the 1960's and 1970's. To prevent confusion, we have named it "upper leaf necrosis", or ULN.

Fig. 1 A

Fig. 1 B

Fig. 1 C

Fig. 1. Upper leaf necrosis (ULN) affects many popular Oriental hybrid lilies. It reduces their aesthetic appeal, and economic value. (A)'Star Gazer' (B) 'Acapulco' and (C) 'Star Gazer' crop in Holland. Only leaves associated with flower buds and those immediately below the buds are susceptible.

After seeing this problem in many oriental hybrid lily crops in greenhouses in both the US and the Netherlands, we were convinced this was an interesting and important problem and began a systematic study of it in early 2000. The following is a brief introduction to the how, when, where and why of this disorder. The information presented here in has been obtained through 3 years of research at Cornell that has been supported by the USDA-ARS Floral and Nursery Crops Research Initiative, The Fred G. Gloeckner Foundation, The Royal Dutch Wholesalers' Association for Flowerbulbs and Nursery Stock, and the Kenneth Post/Herman Schenkel Memorial Council. IN the following newsletter, specific factors affecting the onset of the problem, and control measures will be given.

Background. Upper leaf necrosis-like disorders have been assumed to be caused by calcium deficiency. Similar disorders in Asiatic hybrid lilies were described by researchers nearly 20 years ago in Holland, but led to the (in our view, incorrect) thinking that ULN is caused by rapid changes in greenhouse environment, or by a series of cloudy, dark days followed by a bright sunny day. Industry observation has clearly indicated several features of this problem, the most important being that larger bulbs are more susceptible to this disorder than small ones, and our own research bears this out. Further, there is wide cultivar variation, with many cultivars being very susceptible (e.g., 'Star Gazer', 'Acapulco' and 'Muscadet'), and others quite resistant ('Alliance' and 'Helvetia').

How do the symptoms develop? Upper leaf necrosis is a difficult problem to study mainly because the obvious visible symptoms (brown upper leaves) develop many days after the actual injury occurs in the leaf cells. Therefore, growers typically notice this problem very late in its development, and in fact, a long time *after* the problem actually occurs. Very careful observation will reveal symptoms first appearing on young expanding upper leaves about 30-35 days after planting, when the plant is about 12-14 inches tall (Fig. 2). On a leaf that is lightly infected, one can see tiny depressed spots on the lower surface. On a severely affected leaf, the initial symptom is water-soaked tissue. These initial symptoms are most likely to start on the leaf margin, and may be missed unless growers observe their crop very carefully. These injured tissues cause the leaves to curl or distort as the leaf continues growing.

In bulbous plants, there are two sources of calcium: 1) calcium that is already contained in the young shoot inside the bulb and calcium that might be supplied by the bulb scales, and 2) calcium that is absorbed from the soil by the roots during active growth.

The calcium concentration in the bulb is very low, only about 0.04% by weight. Although the bulb can provide some calcium to the leaves, the amount is limited as a typical 16/18 cm 'Star Gazer' bulb only contains 8-10 mg calcium!). The calcium supplied from the bulb is only able to meet the need of lower leaves, there is not enough to supply the upper leaves. This is why necrosis only occurs on upper leaves. Upper leaf necrosis occurs at the stage the shoot enters its rapid growth phase, when the calcium supply from the bulb and the roots cannot meet the demand of the leaves.

Another important cause of upper leaf necrosis is leaf enclosure/overlap on the shoot apex. As plants grow, roots absorb calcium, and is moved passively upwards in the xylem or "transpiration stream", and deposited in leaves that are actively transpiring.
Since young, expanding leaves are physically enclosed by outer (older) leaves, transpiration of these young leaves is reduced. Since transpiration is required for plants to bring up calcium from the soil to the leaves, "leaf enclosure" reduces calcium translocation to young leaves, with calcium deficiency and ULN as the result.

Upper leaf necrosis is cultivar dependent. For example, 'Star Gazer' and 'Acapulco' are susceptible cultivars; 'Sissi,' 'Alliance,' 'Berlin,' and 'Tom Pouce' are not. The easiest way to deal with upper leaf necrosis is planting non-susceptible cultivars. However, due to market, production, or price concerns, this may not be possible. As with calcium deficiency disorders in other crops, raising soil calcium level (liming, for example) does not solve the problem, since it is caused by uneven calcium distribution within the plant rather than inadequate calcium uptake from the soil.

Tips for reducing upper leaf necrosis on Oriental hybrid lilies.
Using non-susceptible cultivars
Using small bulbs such as 12/14 and 14/16 cm
Increasing vertical airflow onto plants by overhead fans
Artificial lighting in the winter
Foliar calcium sprays
Keeping lily leaves dry
Keeping greenhouse dry
Reducing growth rate during the susceptible period (25-50 days after planting, or 12-inch tall to flower bud visible.
Avoiding high soluble salt levels in the substrate
Ensuring a good root system

In the next newsletter, we will discuss several methods that can be used to combat ULN in oriental hybrid lilies.

New project on storage and shipping conditions for perennials by PPO and Cornell University
Recently a new project started at PPO and Cornell University with the aim to find the optimal storage and shipping conditions for bare-root perennials. Until now storage and shipping temperature, humidity, digging time etc. are determined by trial and error.
In many cases the conditions are considered sufficient while they are far from optimal. First an inventory will be made of the experiences with storage and shipping conditions at different growers and exporter. Secondly the bottle-necks in the chain will be studied by taking samples of plants at different stages in the chain and storing and shipping these plants under 'ideal' conditions after which plant quality is determined at Cornell University. Finally experiments are carried out with different digging dates, storage temperatures and drying periods. These plants are also shipped to Cornell University, where the effects of the treatments are determined. Some important exporters are consulted on the experimental setup and the choice of conditions and problem species. Most experiments are carried out with the problem species Phlox paniculata, Lavatera, Echinacea, Helleborus and Papaver.
This project is financed by the Dutch Product Board for Horticulture. For more information: PPO, Pieter van Dalfsen (pieter.vandalfsen@wur.nl)

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Fig. 2 A

F i g

Fig. 2 B

Fig. 2 C

Fig. 2 D

Fig 2. Symptoms of upper leaf necrosis on 'Star Gazer' lilies. (A) Initial symptoms of water soaked tissue. (B) In most cases, symptoms start on leaf margin. (C) Symptoms actually develop early, when the leaf is enclosed and before it is unfolded. (D) Late symptoms, showing tipburn. Arrows on panels (A) and (D) indicate symptoms on the same leaf, on the first day symptoms were showing (A), and 20 days later, (D).

In more severe cases, necrosed areas develop inwards from both margins to the center, block translocation, and result in leaf tip death. Several days after the water soaked tissues are seen, necrosed areas turn brown. Leaves are occasionally purplish in color even without any significant necrosis.

When do necrotic symptoms occur? Although the *result* of calcium deficiency, that is, a necrosed upper leaf, persists for the remainder of the crop, the period the plant or an individual leaf is *susceptible to the actual calcium deficiency is relatively brief and occurs early in the crop.* Plants grown from 16/18 cm bulbs begin to *show symptoms* about 30 days after planting, but plants grown from larger bulbs might take as long as 45 days to show necrosis. In any case, once flower buds are visible, the danger of additional necrosis developing is minimal. Since early growth rate can vary depending on the length of cold storage, growing temperature, etc., another indicator is plant height. In our experiments, plants from 16/18 cm bulbs begin to show early necrosis symptoms when they are about 12 inches tall. Because the actual calcium deficiency develops much earlier than the symptoms are visible, we suggest that *the susceptible period is about 25-50 days after planting* (Fig. 3).

Fig. 3. 'Star Gazer' lilies become susceptible to ULN at this stage: when about 75% of the plants have begun to unfold their leaves, and plants are about 12" tall.

Where do necrotic symptoms occur? Upper leaf necrosis occurs only on the leaves associated with flower buds and the several leaves immediately below the flower buds (Figs. 1 and 2). No necrosis is observed on the lower leaves. In general, flower buds are not affected. Only in rare cases will symptoms be seen on flowers, and appear as tepal tip distortion. In very rare and extreme cases, flower buds can be abort from calcium deficiency.

ULN is a calcium deficiency disorder. By foliar analysis, we can show that a necrosed leaf has much less calcium than a healthy one. Table 1 indicates calcium concentration in necrosed leaf tissue is only about one sixth that of healthy tissue. On a whole-leaf basis, the lower the calcium concentration the greater the necrosed area on the leaf. For example, calcium levels in whole healthy leaves are about 0.8%, but only 0.2-0.5% in leaves showing necrosis. While there is a relationship, foliar analysis is not always a clear diagnostic tool if the whole leaf (mixing healthy and necrotic tissue) is analyzed.

To further explore whether calcium was the real cause, we grew 14/16 cm 'Star Gazer' bulbs, a size that is not usually sensitive to ULN, in a sand culture experiment where we carefully controlled the calcium level.

Table 1. The difference of calcium concentration (% dry weight) between healthy and necrosed leaves. Leaf/tissue sampling was done 45 days after planting.

	Leaf tissue, after separating healthy from necrosed regions	Whole leaf without separating necrosed and healthy areas of the leaf
Healthy	0.6	0.8
Necrosed	0.1	0.5

Plants were grown in washed sand in 6" pots and irrigated with a nutrient solution with normal levels of all nutrients except calcium. Calcium levels supplied were 0, 8 ppm (very low), and 160 ppm (completely adequate), By the time of flowering, upper leaves of the calcium-free plants were severely necrosed, and in fact the buds on these plants were all aborted (Fig. 4). The control plants showed no necrosis at all, and plants in the low-calcium treatment had an intermediate level of necrosis. From these experiments, we can safely conclude that upper leaf necrosis is the result of calcium deficiency in developing leaves.

We did several trials on leaf calcium sprays to see if direct calcium application would reduce ULN. Calcium sprays were effective if done correctly, and our results indicated both calcium nitrate and calcium chloride were effective calcium sources (Fig. 5). The concentration suggested for calcium nitrate is 0.6% (0.8 oz calcium nitrate in 1 gallon water), or 0.4% for calcium chloride (0.5 oz calcium chloride in 1 gallon water). A major problem in adopting this as a commercial treatment is that *daily sprays were needed from the period of 30 to 43 days after planting.* This is very labor intensive and expensive. Daily sprays are needed because as each individual leaf grows, it needs direct contact with calcium solution before it develops its own calcium deficiency. Because individual leaves pass into their susceptible period on different days, daily, and not weekly or bi-weekly sprays would be required.

Fig. 4. 'Star Gazer' plants grown from 14/16 cm bubs in sand with nutrient solution containing all nutrients. Calcium was varied to provide (left to right) 0, 8, and 160 ppm calcium. Note that 14/16 bulbs are normally not susceptible to ULN when grown in a typical production situation.

Humidity. In plants, calcium is transported from roots to leaves by water loss from the leaves (transpiration). Plants with high transpiration rates have higher calcium levels in the leaves. High humidity is known to reduce transpiration, and commonly increases calcium deficiency problems in other crops. In one experiment, we misted 'Star Gazer' foliage, once or twice a day, and found necrosis was increased by the frequency of misting (Fig. 6). Some growers choose overhead watering as an irrigation method, and our results indicate this may increase the risk of upper leaf necrosis. We recommend keeping the leaves dry, and also to take steps to reduce humidity in the greenhouse.

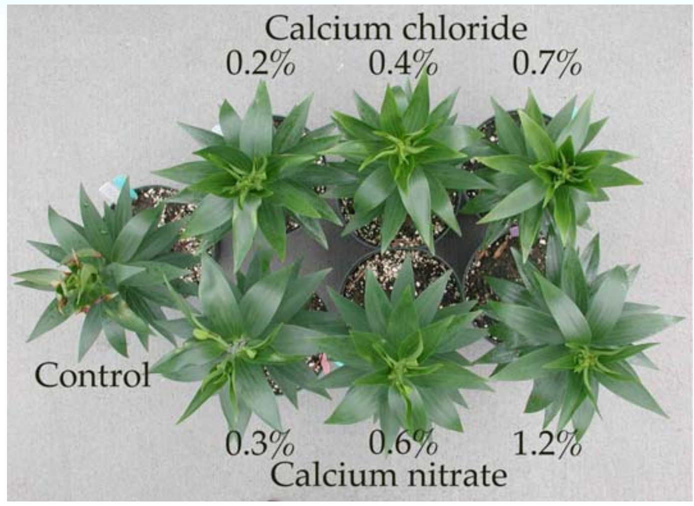

Fig. 5. Effect of fourteen daily foliar calcium sprays on reducing upper leaf necrosis on 'Star Gazer' lilies. Control on the left, calcium chloride treatments on the top, calcium nitrate treatments on the bottom. Control plants each had several severe necrosed upper leaves, while treated plants had very light symptoms that were mostly innocuous.

How does calcium deficiency occur? Physiologically, upper leaf necrosis is primarily caused by insufficient calcium supply.

Fig. 6. Misting (high humidity) increases upper leaf necrosis. Left to right: Control (no misting), misted once per day, or misted twice per day. The conclusion: keeping lily leaves dry and maintaining a dry greenhouse environment are important practices for reducing upper leaf necrosis.