Does Perlite Play a Role in Fluoride Toxicity of Floricultural Crops?

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Fluoride may be great for our teeth, but it can present problems for some of the crops we grow as floriculturists. Many of the sensitive plants belong to two families, Liliaceae and Marantaceae, but other species are affected (Table 1). Although most of the species sensitive to fluoride are grown as foliage plants, many of them such as spider plants and Tahitian bridal veil are common to most greenhouses.

The common symptoms of fluoride toxicity in plants include chlorosis of the tips and margins of older leaves followed by necrosis of these same areas. How much fluoride is enough to cause problems? As little a 1 ppm F in the water used for plant irrigation can result in toxicity symptoms on sensitive plants. Many municipal water sources will inject F as an additive to prevent tooth decay at 1 ppm, and F is also contained in many fertilizer sources and substrate components used in greenhouse and nursery production (Table 2).

We have known about the dangers of fluoride toxicity for years, and many growers follow recommended procedures to avoid / prevent fluoride toxicity in sensitive crops. For example, most Easter lily growers will try to maintain a substrate pH of 6.5 to 6.8 as it has been reported that fluoride becomes tied up in the substrate as calcium fluoride at this pH. Some growers will

Table 1. Commonly produced plants that exhibit sensitivity to fluoride.

Species	Common name	Family
Calathea spp.	Many species	Marantaceae
Chamaedorea elegans	Parlor Palm	Palmae
Chlorophytum comosum	Spider Plant	Liliaceae
Cordyline terminalis	Good Luck Plant	Agavaceae
Ctenanthe oppenheimiana	Never-Never Plant	Marantaceae
Dracaena spp.	Many species	Agavaceae
Gibasis pellucida	Tahitian Bridal Veil	Commelinaceae
Lilium spp.	Many species	Liliaceae
Maranta leuconeura	Prayer Plant	Marantaceae
Spathiphyllum spp.	Many species	Araceae
Yucca spp.	Many species	Agavaceae

avoid using products such as superphosphate (0-20-0; not readily available anymore) and perlite in production of plants known to be sensitive to F toxicity.

Although perlite does contain a significant level of fluoride, there is still some question as to whether the use of perlite in a substrate leads to fluoride toxicity. Earlier research has shown that F in perlite can be quickly reduced to very low levels simply by two or three heavy leachings. In many crop production systems, enough leaching occurs during the first few weeks to dramatically reduce F released from perlite into the substrate solution. Granted, subirrigation and other low-leach production systems do not allow for the rapid removal of F from the substrate, but perlite was targeted as a fluoride source long before such systems were widely used in our industry. Perhaps perlite has be given an undeserved label as a fluoride toxicity contributor. This would be unfortunate, because many highly effective and economical substrates contain perlite. The validity of the perlite-fluoride toxicity connection needed to be evaluated, and as such, set the stage for our study. Our objectives were ① to measure the initial release level and subsequent leaching pattern of fluoride from five major sources of perlite used in the North American ornamental industry; ② to assess the potential for fluoride toxicity from perlite on three sensitive crops; and ③ to measure the influence of substrate solution pH and calcium concentration on fluoride availability.

Experimental Procedures

Fluoride Leaching Study.

We contacted the Perlite Institute to develop a list of primary sources of perlite used in the North American agricultural market. Expanded, horticultural grade samples were obtained from three major sources, (one in Greece and the other two in New Mexico) along with one secondary source from California and one major brand of unknown origin.

The soluble fluoride content of each sample was evaluated using a leaching test. Perlite samples (100 cm^3 sample size) were leached with 100 ml of pH 5.2 sodium phosphate buffer over a 3 minute period. This procedure was repeated for a total of 5 leachings on each sample.

Perlite has a water holding capacity of 38% of its bulk volume when at container capacity. Since equal volumes of water and perlite were used in each leaching step, the leaching percentage was 62%. That is, 62% of the buffer applied passed through the perlite during the first leaching. This

Table 2. Levels of soluble fluoride measured in several substrate and fertilizer components expressed as parts per million (ppm) on a weight basis (mg/kg).

Amendment	ppm F
Single superphosphate	2,600
Diammonium phosphate	2,000
Triple superphosphate	1,600
Resin coated slow release fertilizer	376
Cotton hull ash	67
Dolomitic limestone	32
Ferrous sulfate	21
Cow manure	17
Perlite	17
Urea formaldehyde	14
Ammonium nitrate	7
German peat	4

is higher than the leaching percentage during a typical watering in the greenhouse but not unrealistic for a heavy watering.

Fluoride was analyzed in the leachates by an HPLC procedure. A Dionex model DX-300 chromatography system was used. Anions were separated in an ionPac AS4A column. A sodium tetraborate eluent was used.

Plant Tests. Three crops were grown in a greenhouse to assess the potential toxicity of fluoride in perlite. These included the Asiatic lilies 'Pixie Orange' and 'Sunray'; Tahitian bridal veil (*Gibasis pellucida*); and spider plant (*Chlorophytum comosum* 'Variegatum').

The pots used for these crops and the number of propagated units per pot were as follows. For lilies, one 12/14 cm circumference bulb was planted in each 13 cm standard plastic pot. Twenty five unrooted bridal veil cuttings were stuck in each 13 cm plastic azalea pot. And finally, 3 spider plant pups were planted in each 13 cm plastic azalea pot.

Temperature settings in the greenhouse were 62 °F (17 °C) at night and 75 °F (24 °C) during the day.

Fertilization for all crops consisted of a weekly application of complete fertilizer at 480 ppm nitrogen. An acid reaction fertilizer was alternated with an alkaline fertilizer to control substrate pH level.

Steam distilled water was used for watering and fertilization to avoid fluoride contained in our greenhouse tap water.

A randomized complete block experimental design with 12 treatments, 4 replications, and 4 pots per plot was used. In the case of lilies there were 2 pots of each cultivar within each plot.

The 12 treatments fell into 4 sets. In the first set, no perlite was used. Concrete grade sand was used in its place. In the second and third sets perlite was incorporated into the substrate at 25 and 50 percent by volume. The remaining substrate component was sphagnum peat moss. Within each of these 3 sets of treatments there were 3 substrate pH levels; 5.3, 5.9, and 6.5. The low pH was selected because it is the lowest safe level for culture of these crops and because fluoride availability increases with declining pH. The high pH was selected because it was reported in the literature to completely block fluoride toxicity. In the fourth set of treatments gypsum was incorporated into low pH substrate to determine if this pH-neutral calcium source could be used to avert fluoride toxicity without raising the pH. Only liming materials were incorporated into the substrate. Superphosphate was avoided due to its fluoride content.

Results and Discussion

Fluoride Leaching Study. Sample A contained the lowest amount of soluble fluoride (Figure 1). Fluoride declined from a high of 0.05 ppm in the first leachate to 0.01 in the fifth leachate. A second range of fluoride levels were found in perlite sources C, D, and E. Fluoride levels in these sources declined from 0.13 ppm in the first leachate to 0.07 in the fifth leachate. Perlite source B contained the highest levels of

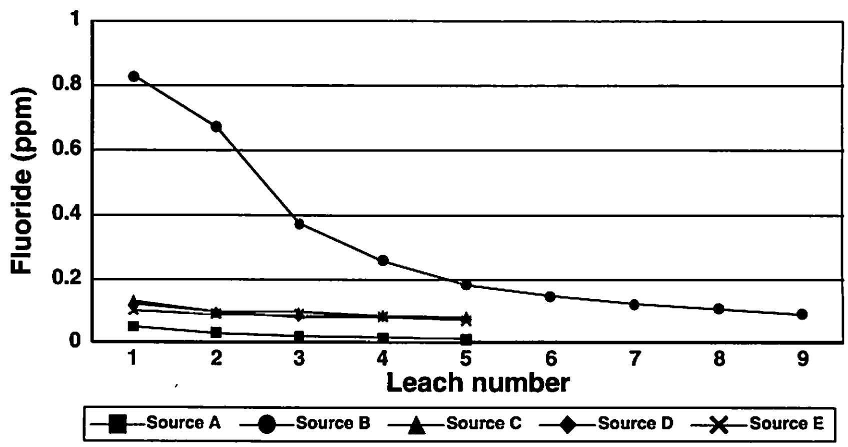

Figure 1. Concentrations of soluble fluoride in each leaching of five sources of perlite. Perlite Source B was used for growing spider plants and Tahitian bridal veil; Source E was used for the two lily cultivars.

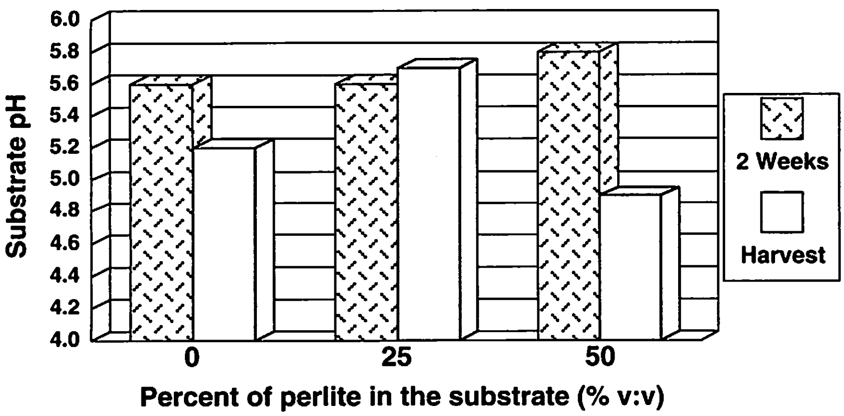

Figure 2. Substrate pH measured for the low pH treatment (targeted pH of 5.3) after 2 weeks and at harvest (6 weeks) for the Asiatic lilies.

soluble fluoride. This source was leached 9 times. Leachate fluoride concentrations were, in the first, fifth and ninth leachings, 0.83, 0.18, and 0.09 ppm.

The initial concentration of fluoride in source B would most likely be toxic to sensitive plants. However, the concentration quickly declines to what would appear to be a safe level. It would seem doubtful that the concentrations in the other sources would be toxic for pot culture of crops.

We used Source B perlite for the Tahitian bridal veil and the spider plant studies. Source E perlite was used for growing the lilies. Although we planned to use source B for all three studies, the large quantity needed for culture did not arrive on time.

Plant Tests. No fluoride toxicity symptoms developed in any of the test crops.

Lily. Substrate pH levels were sufficiently low in many of the lily treatments to maintain fluoride in an available state (Figure 2). The targeted pH treatments of 5.3, 5.9, and 6.5 were not precisely met, but the actual pHs very well covered the range from high availability to effective tie up of fluoride.

There was no way to tell whether the addition of calcium sulfate at low pH can prevent fluoride toxicity, since fluoride toxicity did not occur with any treatment on any species in our experiment. However, these last three treatments (target pH of 5.3 using 0, 25, and 50% perlite in the substrate) did provide extremely low substrate pH, as low as 4.6 (data not shown). Even at this low pH fluoride toxicity did not occur.

Pictures of the lilies were taken two weeks after initial bloom. Even by this late stage no fluoride scorch had developed. Sometimes there were symptoms of senescence on the lower one to three leaves. These symptoms were present across all treatments and took on the form of uniform chlorosis of the entire leaf blade followed gradually by necrosis. These were definitely not fluoride toxicity symptoms

Tahitian Bridal Veil. The measured pH data for bridal veil is similar to that for lilies (Figure 3). Substrate pH ranged from a high value of 7.0 to a low value of 4.6. If the level of fluoride in perlite Source B had been toxic it would have manifested itself at these low pH levels. No toxicity occurred. It is entirely conceivable that

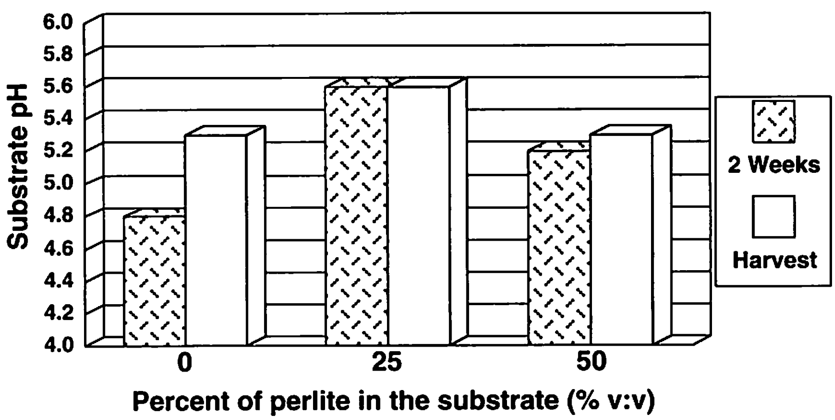

Figure 3. Substrate pH measured for the low pH treatment (targeted pH of 5.3) after 2 weeks and at harvest (8 weeks) for Tahitian bridal veil plants.

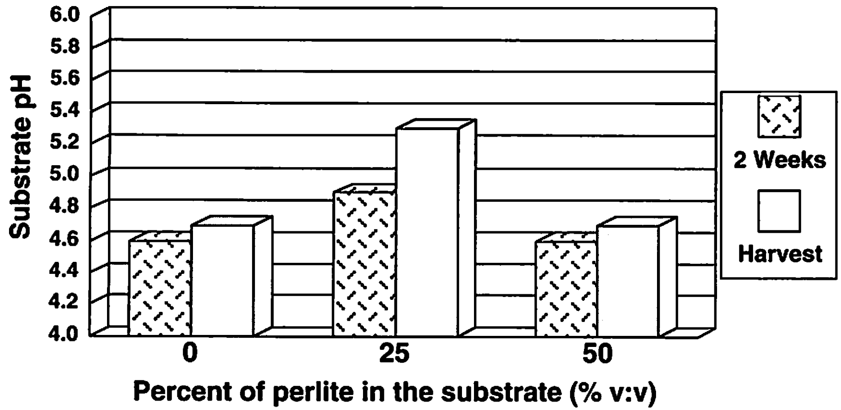

Figure 4. Substrate pH measured for the low pH treatment (targeted pH of 5.3) after 2 weeks and at harvest (7 weeks) for the spider plants.

the initial leach concentration of fluoride was potentially toxic but that it did not persist long enough in the substrate to cause a toxicity.

Spider Plant. Substrate pH for the spider plants also ranged from 4.6 to 7.0 (Figure 4). In general, there are more low pH values than in the previous two crops, yet, no fluoride toxicity occurred. The high fluoride Source B perlite was used in this crop.

Conclusions

We can draw the following conclusions from this study:

① Perlite sources vary in their soluble levels of fluoride. The initial concentration of fluoride in leachate from the five sources of perlite used in this study ranged from 0.05 to 0.83 ppm. The higher value was potentially toxic but it did not persist. Soluble fluoride rapidly decreased in subsequent leachings to very low concentrations. If perlite was a cause of fluoride toxicity, the problem would be experienced in the initial weeks of culture. This has not been reported to be the case. Toxicity is more prevalent in later stages of the crop. Follow-up studies (data not shown) with additional perlite sources found that perlite with an initial F concentration of 1.7 ppm could be used at 50% volume of substrate to produce 'Corsica' Asiatic lilies without fluoride toxicity; even when pH reached 4.2!

② Fluoride toxicity did not occur in three fluoride sensitive crops, Asiatic lily, Tahitian bridal veil, and spider plant, when grown in substrate containing up to 50% perlite at substrate pH levels below 5. Typically the substrate pH level would be 5.5 of higher and perlite would not exceed 25% by volume. Clearly, fluoride toxicity does not stem from these sources of perlite.