

Management of Water Status of a Gravel Substrate by Ech₂O probes to Reduce *Rhizopus* Incidence in Container Production of *Kalanchoe blossfeldiana*

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Significance to the Industry: Cultural and management practices in a growing operation can greatly affect the productivity and quality of any plant species. What is less easy to identify is when those factors change over time and how they may conspire to influence the plant growth environment, reducing plant productivity, quality, and maybe increasing the incidence of disease. We investigated the cultural and environmental variables that appear to influence the incidence of the shoot fungal pathogen *Rhizopus stolonifer* (Ehrenb. ex Fr.) Lind on the growth and development of *Kalanchoe blossfeldiana* v. Poelln. under intensive greenhouse conditions.

Nature of Work: *Kalanchoe blossfeldiana* is succulent species, native to Madagascar and regions of Africa, which has been selected and bred since 1930 as a floral ornamental crop (1). It is an extremely popular indoor plant species in Europe and the Americas, with long-lived showy inflorescences. Many cultivars have been bred with different floral colors and it flowers under short-day conditions. Propagation is usually from shoot-tip cuttings, which are harvested from blocks of mother plants grown under intensive greenhouse conditions in Central America and other regions of the world. Shoot-tip cuttings are air-freighted to wholesale growers in other countries, to be grown for the retail trade. *Rhizopus stolonifer* is usually a post-harvest pathogen (8) with a worldwide distribution (6), which commonly infects fruit in storage and transport. The literature indicates that the presence of water and high relative humidity contribute to the development of this pathogen; however, *Rhizopus* can also infect the stem and leaves of *K. blossfeldiana* in greenhouse production. Since there appear to be no references in the literature on either the growth of *Kalanchoe* or on the incidence of *Rhizopus* on living vegetative plants, we initially hypothesized that the development of *Rhizopus* was due mainly to the overabundance of moisture from irrigation and high relative humidity at certain times of the year in the greenhouse. *Rhizopus* appears to be an opportunistic (weak) pathogen, since spores are ubiquitous in the environment and many plants exhibit no visible symptoms of the pathogen during production. The incidence of *Rhizopus* infection increases when wetter conditions prevail during

times of production, i.e., under conditions of high relative humidity, lower radiation load, and when irrigation is excessive.

An understanding of the ecophysiology of the species and its native environment (1) is important, to better control environmental and cultural conditions and maximize plant productivity. Although *K. blossfeldiana* is a facultative CAM species, it is known to switch to a C3 metabolism when environmental conditions (e.g., high light, long days, adequate water) are optimal to maximize photosynthesis (9). However, it is known to revert to a CAM metabolism under conditions of stress (9). *Kalanchoe* is adapted to low-moisture conditions both in the aerial and root environment, and thus normal greenhouse cultural conditions might in fact provide too much moisture for this species. Plant available water in a substrate is known to be affected by both substrate physical properties and container height (3, 4, 5). The particle size distribution in a substrate has the most significant effect on the total water-holding capacity and aeration of a substrate (10, 5). Thus for precise irrigation scheduling, a knowledge of the interaction of all of these variables is important to provide an environment that is firstly conducive to plant root growth, and secondly more antagonistic to fungal pathogens.

After an initial evaluation of substrate particle size distribution, irrigation frequency, and greenhouse relative humidity records, we initiated a study where we increased the air-filled porosity of the gravel substrate used to produce *Kalanchoe* mother plants, by reducing the percentage of fine particles in a modified substrate. We compared the growth and production of three *Kalanchoe* cultivars with known sensitivity to *Rhizopus* infection ('Pink', 'Tenorio', and 'Fuego') in two substrates (the local 'unmodified' gravel and a 'modified' source of this gravel) in a complete randomized design with three replicates (n = 18). Each replicate block consisted of 660 plants in flat containers (2) with six 6 plants per container. The three cultivars were transplanted on 4 November, 2005 and the experiment ran for a total of 43 weeks (until 15 August, 2006), a normal production period. Irrigation water was supplied using drip tape, with two emitters per container. A pressure regulator was installed to maintain water pressure at 12 psi. Drip emitter uniformity was evaluated over the entire experimental area (6 rows) and had a chi-squared value of 90.8. The available water in each replicate block was continuously monitored (data were measured every minute and an average (n = 10) logged every 10 minutes) using 10-cm Ech₂0 sensors (2) and two CR10X dataloggers (Campbell Scientific, Logan, Utah) for the duration of the experiment. Data from the Ech₂0 sensors were downloaded and graphed on a weekly basis and the average output of the sensors (by substrate; n = 9) was used by the irrigation manager to schedule irrigations, to better suit actual plant water requirements in each substrate. Data on the weekly number of plants infected by *Rhizopus* were kept by treatment as they were culled from the blocks every few days. All other production factors were maintained by the grower (e.g., fertilization regime and frequency, automatic shading and ventilation, pesticide and growth regulators, etc.).

Results and Discussion: Substrate Particle Size. We initially evaluated the original ('old') gravel that had been used for approximately three years, with steam pasteurization between crop production cycles. We found that the smallest particle size fractions (Table 1) constituted a large proportion (46.3%) of the total

volume; visual observations noted that this gravel retained water for relatively long periods after an irrigation, and that it became very compact (set like concrete) when the substrate dried out. Root system development was relatively shallow (7) in this old gravel and irrigation frequencies were high (almost daily) because of small root:shoot ratios, especially after plants reached maturity [when secondary thickening was observed (7)]. When the particle size distribution of a new batch of gravel was analyzed, we found that this 'unmodified' gravel had a significantly lower proportion of fine particles (Table 1). This gravel was sourced from a quarry near Alajuela, Costa Rica. The gravel is volcanic in origin, but not extrusive (i.e., pumice expelled as magma and containing gaseous pores), but classified as intrusive (without gaseous matrices) and dark grey in color. Even though this gravel material is initially very hard, we suspect that it breaks down rapidly under conditions of high moisture and relatively high (greenhouse) temperatures. Also the use of soluble fertilizers in production may provide ionic factors that may accelerate this process. We then modified the particle size distribution of this new gravel by washing out as many of the fine particle sizes as possible, reducing the small and residual fractions to 16.2 % of the total volume (column 3; Table 1). By doing this, we produced a substrate that did not compact when it dried out and provided a higher air-filled porosity, but which had a low water-holding capacity. For this reason, we monitored the water status of both substrates on a continuous basis (2) and used this information (Fig. 1) to provide the irrigation manager with data each week during the experiment.

Irrigation Management. As stated, the Ech₂0 sensor data was downloaded, graphed, and provided to the irrigation manager on a weekly basis. Although this was retroactive information, it allowed us to discuss irrigation strategies with him in an effort to reduce the frequency of irrigation and to better match the requirements of the plants in each substrate. Although this information was very useful, we agreed that the irrigation manager could decide to irrigate at any time, based on his knowledge of the species and his integration of immediate environmental conditions. Despite this latitude, we found that irrigation frequencies were reduced on average to 2 to 3 times per week (Fig. 1), compared to the previous situation where plants were irrigated more frequently (as often as once a day). Irrigation durations were also reduced since the substrate was more porous and it leached more rapidly. The net effect of these management changes was a significant reduction in the overall amount of irrigation water applied to both substrates compared to the previous practice.

Incidence of Rhizopus. We used *Rhizopus* incidence data (from 2005) in the old gravel substrate to compare with the incidence of infection in the new (unmodified) and modified gravel substrate, by cultivar. Pathogen incidence data (Table 2) were normalized by calculating an index value (= number of diseased plants / plant age in weeks). This provided a weighed average over time for the incidence of *Rhizopus* in areas planted at different times (since production areas are replanted continuously during the year). As can be seen from Table 2, the progression of the disease was delayed by using new (unmodified) and modified gravel. In the old gravel substrate, the total incidence of *Rhizopus* was 17%, 28% and 22% for Pink, Tenorio, and Fuego cultivars respectively, over the production period. In contrast, the total incidence of *Rhizopus* was 5.1%, 7.9% and 32.1% in the unmodified substrate, and 4.6%, 9.3% and 14.1% (for Pink, Tenorio, and

Fuego, respectively) in the modified substrate. Except for the Fuego/Unmodified substrate combination (Table 2), the incidence of *Rhizopus* was significantly lower in all three susceptible varieties, especially in the modified substrate. The most notable decrease in *Rhizopus* infection was with Pink (irrespective of substrate).

Providing a substrate with better aeration and careful control of irrigation management therefore appears to help reduce the incidence of *Rhizopus* infection of *Kalanchoe* in greenhouse production. This knowledge will allow us to further develop a non-chemical control strategy for reducing the incidence of the disease in the greenhouse. Further decreases in infection rate would probably occur with a more comprehensive disease management program. In terms of profitability, *Kalanchoe* mother plants return a net profit from approximately week 25 onwards. Therefore, any reduction in the development of this disease with an increase in the number of shoot-tip cuttings per plant will have a direct effect on the net return from this crop for producers.

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Table 1. Particle size analysis of three gravel substrates used in the commercial production of *Kalanchoe blossfeldiana* in mean percent with standard deviation_(s).

| Particle size fraction (diameter, mm) | Old gravel ¹ | | Unmodified gravel ² | | Modified gravel ³ | |
|--|----------------------------|-------|-----------------------------------|-------|---------------------------------|-------|
| | Mean % | s | Mean % | s | Mean % | s |
| Large (> 5 mm) | 24.3 | ± 3.2 | 22.2 | ± 0.9 | 24.6 | ± 3.5 |
| Medium (3 to 5 mm) | 29.5 | ± 2.8 | 49.9 | ± 1.8 | 59.2 | ± 3.1 |
| Small (1 to 3 mm) | 11.0 | ± 0.8 | 16.4 | ± 2.3 | 13.7 | ± 1.0 |
| Residual (< 1 mm) | 35.2 | ± 4.2 | 11.6 | ± 2.4 | 2.5 | ± 0.4 |
| Large + Medium | 53.7 | ± 4.3 | 72.1 | ± 2.3 | 83.8 | ± 0.9 |
| Small + Residual | 46.3 | ± 4.3 | 27.9 | ± 2.3 | 16.2 | ± 0.9 |

¹Three-year-old gravel.

²New, unwashed gravel.

³New, washed gravel.

Figure 1. Typical irrigation frequency for modified substrate during production week 25. Average value is the mean of nine Ech₂0 sensor readings.

