At the University of California (UC), Riverside, research is being conducted to evaluate water and nutrient requirements of ornamental and floriculture crops as influenced by plant type, fertilizer type, substrate components, irrigation methods and modifications of cropping systems. Primary goals of our research are to: 1) improve nutrient uptake efficiency; 2) optimize water use efficiency; and 3) mitigate nutrient runoff from nursery production systems.

Much of our research and outreach have been financed through grants from the California State Water Resources Control Board, The Thelma Hansen Fund and the California Association of Nurseries and Garden Centers (CANGC) (www.cangc.org). Our extension activities have been conducted through the University of California Nursery and Floriculture Alliance (UCNFA) (http://ucanr.edu/sites/UCNFA).

The success of the program can be attributed to the talents of several people who have or continue to work with the UC Riverside research team: Drs. Lea Corkida, Julie Newman, James Bethke, Steven Tjosvold (University of California Agriculture and Natural Resources), Joseph Albano (University of Florida), Eugene Blythe (Mississippi State University) and Salvatore Mangiafico (Rutgers, The State University of New Jersey).

With these continued collaborations on a multi-state level, our research and extension programs have a broader geographical impact since we are addressing production problems that most growers are facing — increased fertilizer costs, limited quality water availability, and more stringent regulations associated with nutrient runoff. Some of the highlights of our current research and extension include mitigation of nutrient runoff from production sites and improving fertilizer uptake efficiency in nursery and greenhouse cropping systems.

Mitigating Fertilizer Runoff from Nursery Production Systems

Federal guidelines to mitigate pollutants entering surface waters have been in place since 1972. Of the agricultural pollutants being regulated, nitrate and phosphate are the main nutrients of concern. Nitrate is the most likely to appear in runoff since it is applied in the greatest quantities relative to other nutrients. In addition, nitrate is a negatively charged compound (anion) so it does not readily bind to the negatively charged surfaces of soil and substrate.
particles. Similarly, because phosphate is also an anion, it can also readily leach from soil or growing media.

Many state water agencies have now implemented regulations to mitigate nitrate and phosphate runoff from agricultural sites. Fortunately for the agricultural industry, methods to reduce fertilizer runoff from production facilities are positively correlated with improved fertilizer use efficiency, which saves money since fertilizer costs have been going up steadily over the years.

Aside from improving fertilizer use efficiency through management of fertilizer programs, there are many infrastructure modifications that can be made to the nursery to reduce fertilizer runoff. The first and foremost method is to recycle irrigation water (Figure 1), so fertilizer that is leached from the containers can be recycled back into the production system. In some cases, this can save up to 50 percent of the fertilizer costs. In California, where runoff water quality regulations are in place, cost-effective recycling systems are being utilized by many nurseries, from small 2-acre nurseries to nurseries of over 200 acres. Converting from overhead irrigation to drip irrigation and using reclaimed water have also helped growers sustain production practices even during drought restrictions. Other infrastructure changes include the construction of drainage ditches, either concrete-lined (Figure 2a and b) or planted bioswales (Figure 2c). Further research is needed to understand fertilizer performance in nursery production systems, which is where we continue to focus our efforts.

**Improving Fertilizer Uptake Efficiency**

Fertilizer use and management continue to evolve as technology in this area improves. The scope of research is associated with fertilizer uptake efficiency, understanding the spatial and temporal aspects of fertilizer management. Initial studies investigated the performance of polymer-coated (prill) controlled-release fertilizers (CRFs), which slowly release fertilizer over time. The release characteristics of CRFs are positively correlated with increased temperature: as the temperature increases, the rate of fertilizer release from the prill increases (Figure 3). The spatial aspect of fertilizer research relates to the requirement of having the fertilizer where the actively growing roots are located. If granular fertilizers are not in proximity of actively growing roots, then nutrient release from CRFs or dissolving from uncoated fertilizer granules will leach out of containers rather than being taken up into the plants. Of course, irrigation practices (drip versus overhead, volume and frequency) will also impact the degree of nutrient leaching and plant uptake.

In our current research, we are analyzing allocation of nutrients from four different brands of CRFs. Remember, in crop production, it
is important to minimize nutrient loss (leaching) and optimize nutrient uptake into the plant. In our studies, we evaluated the fate of nutrient release from four different brands of CRFs blended into the media of 1-gallon containers. We planted 2-inch liners of rooted azalea or ligustrum. Nutrient leaching from containers was measured weekly and uptake into plants was measured monthly during a one-year production cycle.

Some of the questions we hope to answer in these studies are: 1) When is nutrient leaching greatest? and 2) Are there periods of time in production when nutrient uptake into plants is higher or lower? By answering these questions, we may be able to adjust fertilizer formulations or production practices to optimize nutrient uptake and minimize nutrient leaching.

Based on current data, we have found that the CRFs we tested performed quite well; initially, nitrogen release appeared quite low. This is an ideal scenario since roots from liners have not established into the larger containers during the initial stages of the crop production cycle. Over the production cycle, nutrient release from CRFs, nitrogen uptake into plants and nitrogen leaching from containers increased. Based on our observations, there are ways to improve nutrient uptake from CRFs.

Below is a list of best management practices that we have formulated from our preliminary analyses. As we analyze data for the other essential nutrients, we hope to develop more recommendations to improve fertilizer formulations, and adjust production practices to optimize fertilizer use and maximize profits and sustainability of the nursery and greenhouse industries.

**CRF selection.** Choose the right CRF for the crop. Most CRF brands have product blends for nutrient release over a three-month production cycle for faster growing herbaceous plants and up to 12-month release CRF blends for longer growing cycles required for woody perennials.

**Planting.** When possible, prepare growing media and plant crops in the cooler periods of the year. This will allow roots to develop throughout the container before sufficient fertilizer is released from the CRFs. As temperatures increase, nutrients released from CRFs will be taken up by the already present root system.

**Irrigation and weather.** Minimize water runoff from containers by avoiding excessive irrigation volumes during each irrigation event. This is especially important during warm or hot weather, when the rate of nutrient release from CRF prills is higher.

**Irrigation and new plantings.** Newly planted crops (plugs or liners transplanted into larger containers) have special water and fertilizer needs. Until root systems become established in containers, as we described in Figure 4, any water and nutrients in excess of what is needed by the plants will end up in runoff.

**Media storage.** If CRFs are blended into the growing media, prepare only enough media for immediate use. The CRF prills in any unused media will begin releasing nutrients, especially if the pile of planting mix is large and heats up (like a compost pile).

**Electrical conductivity (EC).** EC is not well correlated with nutrient concentrations. Use EC only as a general guideline for troubleshooting, not for direct estimation of specific nutrient concentrations.

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