

## **Final Report on the Rose Cut-flower modeling work**

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The focus of this report is to describe the status of the UC Davis cut-flower rose modeling work as of December 2005.

### **Objective**

This project has the overall objective of development of a computer simulation model to describe the ecophysiology of various aspects of the rose production system with special emphasis on variables that are important for crop production. This approach is taken to provide us with a basis for creating applications and problem solving.

In addition to describing the basic crop physiology through mathematical models, we are also developing tools derived from this work for the specific purpose of helping greenhouse growers with production management issues. The rationale for this approach is to carry out the research in such a way that we can deliver important complex information to the end-user in a way that can be readily used.

### **Background**

Mathematical models have long been used to characterize both simple and complex systems. Typically such models serve to either summarize the information, or to quantify it in a way that allows the result to be used in optimization. When implemented in simulation models, the information can be dynamic, allowing one to visualize the system as variables change over time.

This is a particularly useful approach for agricultural systems because we typically have a set of variables that we can control. In greenhouse production we can control nearly all environmental variables to some extent. Our early work on the cut-flower rose production system focused on light, above-ground temperature, and carbon dioxide concentration and how this translated in to plant growth, biomass partitioning and accumulation, and crop development.

The fundamental modeling approach has been to quantify the growth and development of individual shoots with the idea of creating a crop model from this by simulating the growth and development of various shoot classes (classified by position in the canopy and time of initiation). Furthermore, the shoot model was designed to describe the formation of each internode, each corresponding leaf, as well as the formation of the flower on the terminal point. The model assumes this basic plant morphology, so that it is not applicable at this time to spray roses (multiple flower heads). The basic approach focuses on long-stemmed, large-flower, hybrid-tea roses rather than smaller types or types that don't flower all year round.

The shoot growth model combines information from several physiological plant processes to simulate development of flower stems. To summarize: the model uses temperature as the

driving force for developmental events to represent the fact that the rate of leaf unfolding occurs quicker under warmer temperatures and takes longer under cooler temperatures. As leaves unfold on a shoot the model simulates growth of the leaf (increase in leaf surface area) over time. Biomass accumulation of shoots is determined by using light, carbon dioxide, and temperature to predict rates of photosynthesis. Carbohydrates from photosynthesis are then distributed to leaves, stem, and flowers. Finally, the model calculates respiration by the shoot (for example, during the night time some carbohydrates are consumed by the shoot which will decrease biomass).

It should be noted that the basic modeling approach is independent of where the plant might be grown. By conducting our research on the underlying components under a wide range of conditions, we have made the shoot simulation robust in that it can accurately simulate shoot growth across very different environments. The international collaborations have been a very powerful attribute of this work.

Early work in this project resulted in a model for the various developmental events of rose shoots as they grow in a typical production setting (described below under user tools). This led to the development of a software tool that was suitable for predicting and simulating how various temperature conditions caused the timing of flushes of flowers to become available for particular target dates (holiday flower production). The initial version of this tool assumed that the start of a flush was induced by pinching or pruning and that growing conditions were typical conditions used in California.

## **Recent work**

The focus of this project in recent years has been to work simultaneously on several fronts. One area consists of the scientific work of developing mathematical models based on scientific experimentation with the plants. The second area focused on development of software tools designed to help growers make production decisions. Both these areas will be described below as they are linked very tightly.

### Modeling work

Recent modeling work has focused on the uptake of nutrients in relation to root zone variables such as temperature, nutrient availability (concentrations), and dissolved oxygen concentration. Our modeling focus is to quantify how these variables drive biomass production in both the root zone and in the aerial environment.

One facet of this research was to use the concept of modeling actual growth as a function of the “potential growth” as driven by various driving variables. The driving variables we specifically focused on were root zone temperature, moisture conditions, and dissolved oxygen concentration. We explored the use of microcalorimetry to explore the notion of “potential growth”. Prior to this work, this concept was generally an abstract notion without the ability to explicitly measure it. The methodology, however provides a calculation for variables (such as specific growth rate) which have been hypothesized to represent such potential growth information. Thus our quest was to use this technology to try to develop mathematical models as

to the potential growth of rose tissue in relation to root zone variables. We were frustrated by many set-backs especially with regard to precision control of root zone temperature and oxygen concentration. Even with regard to moisture tension where we had earlier developed reliable control technologies, we had trouble as recent work seemed to contradict work we had done in earlier years describing the relationship between root activity and moisture tension. The main difference between earlier studies and the current one were the use of a “draw-down” of water rather than constant high-tension conditions, suggesting that the information we get from calorimetric data is representative more of acclimated conditions, rather than instantaneous conditions. While this may seem a fairly minor point, it has a major impact on the model development because our interest has been in modeling instantaneous response, rather than long-term acclimation conditions.

Recent work has also involved the development of a model describing the plant’s response to dissolved oxygen concentration. Our early work showed that dissolved oxygen dropped dramatically in intensive hydroponic production. In a period of 2 hours a healthy rose plant was able to consume all the oxygen and the diffusion of oxygen in the rooting medium was not adequate to resupply oxygen to the roots. This was an amazing discovery and set a number of projects in motion to identify how plants respond to the availability to the roots of oxygen. Plant physiologists know that oxygen must be present, but the exact dynamics have not been understood well enough to create mathematical models. When we set out to build a model that would tell us the critical oxygen pressure (the low-oxygen condition that triggers suboptimal plant performance or “stress”) we quickly found that we got conflicting results with some plants showing virtually no physiological response while other plants showed dramatic responses to the same conditions. The most recent results suggest that roses are fundamentally different from many other plants in relation to this response. Chrysanthemum, for instance, responds very dramatically with reduced nutrient uptake under oxygen deficiency, while roses appear to be able to use internal nutrient storage pools to buffer against instances of oxygen deficiency. We are currently exploring several flowering plants to see if we can develop a model that can be tuned to any plant, regardless of whether it is sensitive to oxygen starvation or not.

Nutrient uptake dynamics have been a major focus of our modeling work. We developed a relatively-simple model to describe nitrogen and potassium dynamics in cut-flower rose production. This model was used as the basis for expanding the focus to include other nutrients. We already noticed in the initial model that it’s behavior, while reasonably accurate, could not adequately mimic the nutrient concentrations that are typically seen in the plant. We also found that the only way we would get this model to describe patterns of nutrient uptake seen by other scientists would require that the plant be represented to have storage pools. Such storage has traditionally been reported by scientists working with large woody plants or plants with specific storage organs. In rose plants, old tissues (such stems, leaves, and roots) have been previously reported to act as storage organs for nitrogen. We are currently determining whether these organs can store N, P, K and carbohydrates to provide these to new growing flower stems. Preliminary analysis shows that storage of these elements likely plays an important role in nutrient dynamics. For example, following pinch back of plants, the base stems, leaves, and roots accumulated N until new shoots are initiated. Following appearance of new flower shoots there is a decline in N concentration as nutrients are mobilized from perennial tissues to support new flower shoots. Near the end of a crop cycle, remobilization from perennial tissues is

predicted to cease during this stage N absorbed by the plants goes to new flower shoots as well as to begin to replenish the base tissues. old tissues. We are currently developing the storage pool concept into our nutrient absorption model.

In collaboration with Korean colleagues we have also looked at nutrient uptake in relation to a light utilization model. This work is also showing promising results and may be key to development of a decision support tool for fertilization that is accurate across a range of canopy densities (described below).

### Grower Software Tools

Two areas have seen significant development with the first being available for use in the hands of growers, while the second one is still in the early formation stage.

The cut-flower rose production timing tool is a tool that lets growers make decisions about greenhouse temperature management so as to maximize the number of available flowers for holiday sales (when the return on investment is greatest). Our recent work involved polling growers as to how they were using the tool and to determine what issues needed to be addressed. Internationally, two types of growers were found to have somewhat different needs. Growers with high levels of greenhouse environment control, typically with lots of sophisticated equipment, needed more information on how the tool would work in the presence of supplemental lighting and modern crop management techniques such as “bending”; while growers with simpler greenhouse structures needed more information on how to use the tool for forecasting harvestable flower counts in relation to weather forecasts. Both groups needed the original tool to be more flexible in relation to calibration for the multitude of different varieties that are used in the various areas of the world.

Our recent research showed that we could use the tool in settings with and without supplemental lighting. We found that the best approach is to use temperature management that focuses at the shoot level rather than greenhouse air temperature. We also found that bending worked in the same way as pinching as a trigger for a new flush. A component was added to the software to allow growers to easily adapt the model for the specific varieties of roses they are growing. As part of refining the tool for broad international use we made the tool easy to use regardless of whether the grower was used to metric or non-metric units. A user guide was developed to show how to use the tool for strategic production management as well as for forecasting. The tool is available to growers through the internet at no charge.

A second tool is current in conceptualization stage. This tool has the objective of assisting with decision making on fertilization in hydroponic greenhouse flower production. While much of our information is focused on roses, we anticipate building this tool to easily adapt to a wide variety of continuously-cropped greenhouse crops. The objective of this tool is to help growers manage all macronutrients that are typically managed as part of a fertigation program (i.e. liquid feed). The goal is to accurately predict water and nutrient absorption by the plant so that these can be optimized for both open and closed irrigation systems. The model would determine amount of water and nutrients that has been removed by a plant since a previous irrigation event so that the appropriate concentration of nutrients can be provided in the irrigation water to replace this.

Unfortunately the current state of the mathematical modeling information regarding the various processes is still at a stage where it is not possible to make reliable decisions about all macronutrients. But we anticipate that starting this development of the tool will be primarily a starting point. Initially this tool will focus on growth patterns in relation to N, P, and K. It will incorporate uptake variables such as temperature, moisture availability and dissolved oxygen concentration, in addition to the concentrations of the nutrients themselves.

The current model divides a rose plant into four parts: base parts (old leaves, stems, and roots) and new growing flower shoots, which will be removed from the plant at harvest. Nutrient uptake at the root level is a function of nutrient concentration in the media, root surface area, and the plant's demand for a nutrient. Plant demand for a nutrient is driven by two factors. The first is that an increase in plant biomass (i.e. growth) requires a certain proportion of nutrient as building blocks for cells. The second is that replenishment of the storage pools in base tissues also adds to plant nutrient demand.

The principle components of the model are in place, while several components could be looked at in greater detail to improve model accuracy. Some of these components include the influence of rootzone parameters such as dissolved oxygen content, pH and EC on nutrient absorption; as well as the influence of suboptimal nutrient availability on plant growth.

### **Future work**

With considerable financial support from various sources, we have been fortunate to make excellent progress on the modeling work and its applications. The support base for this work is currently shifting as domestic flower growers are switching from growing roses to growing other plants, while the increasing consumption of roses in the US is being supplied from off-shore. However, internationally the total commercial production of roses is still increasing even while other greenhouse crops are becoming more important. We are committed to continuing both the scientific model development as well as the creation of tools that can benefit growers. An overriding goal of this work is to develop tools to optimize plant yield and quality while reducing inputs. This is important globally as the costs of greenhouse temperature control continue to rise both domestically and abroad and every country is seeking reductions in environmental impacts (especially nutrient runoff).

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The project has been and continues to be an international project with collaborators throughout the world, especially Israel and Korea.