Development of a model for rose productivity

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This project is a multi-faceted project with the ultimate goal of developing a rose crop model that can serve various purposes. While the overall model is being developed, various aspects of the overall system are being researched and quantified. Where possible, this information is exploited to develop specific tools and information that growers can use in crop production.

Progress was made in three areas during the past year
1. Tool for rose crop timing (Heiner Lieth)
2. Salinity work related to rose production (Loren Oki and Heiner Lieth)
3. Photosynthesis modeling work (Soo Hyung Kim and Heiner Lieth)
Each of these areas is briefly described here.

A Tool for rose crop timing

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The major thrust of this work was reported in the previous progress report. So only a summary and update are provided here.

A model for rose shoot development was developed earlier. This model served as a basis for a software tool designed to allow growers calculate lengths of time between harvesting or pinching and subsequent harvests. It also allows determination of intermediate stages to verify that a crop is on time.

Last year the tool was introduced to growers and disseminated via a web site. The previous progress report showed the status and use of the tool for version 0.20.

Some growers discovered a few problems. This was largely due to incompatibility with some computer installations. This required substantial reprogramming to by-pass the problem and this version (0.35) was introduced at the ICFGA meeting in Denver in March 2001. During this time we also used several rose varieties to calibrate the tool for more varieties.

The current version and all available documentation can be found at:
http://Lieth.UCDavis.edu/Research/HU/RoseTime/0.35/index.htm

At this point we are accepting grower feedback before proceeding further with this tool.
Effect of salinity on stem elongation of Rosa hybrida 'Kardinal'

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Introduction

It is well known that increasing salinity levels can have negative effects on rose productivity. Salinity in soils and substrates can increase with the addition of solutes to the solution or by the removal of water without reducing the amount of solute. Plants selectively extract water at greater rates than nutrients during the day to offset losses due to transpiration. In roses, studies have demonstrated that at night, the solution that is absorbed is higher in nutrient concentration than during the day. This means that during the day, as water is being removed from the soil and the solutes are left behind, salinity in the soil solution increases.

An easy method of determining salinity is by measuring the electrical conductivity (EC) of the soil solution. The most common method is to make a saturated paste of a soil sample and measuring the EC of the paste or of an extract. The disadvantage of this method is that it is a “point-in-time” measurement and does not indicate how this condition changes over short time periods. Previous work in our lab developed a method to measure EC continuously. With this EC measurement method, we can quantify the effect of levels of salinity on stem elongation rates.

The objective of this work was to determine how salinity affects stem elongation of roses. Ultimately, our goal is to develop a model that can be used to predict how increases in salinity reduce stem length.

Experiments

Six containerized Rosa hybrida L. ‘Kardinal’ plants in coir were moved from the greenhouse into a growth chamber and allowed to acclimate for at least twenty-four hours. They were first irrigated with nutrient solution consisting of a half-strength modified Hoagland’s solution and the length of one of the shoots on a plant was measured electronically for two hours to determine a reference growth rate. Then the plants were treated with either deionized water or nutrient solution salinized with NaCl to increase the EC of the solution by 1, 2, 4, or 8dS/m. The stems were measured for two more hours to determine the effect of the treatment on the growth rate. Finally, all of the plants were irrigated again with the nutrient solution and measurements continued for two more hours. This enabled us to determine how the plants recovered from the treatments. At least 12L of solution was applied to the 8L containers at each application. Data were logged automatically every six minutes (ten times per hour).

In a second experiment, plants were treated similarly as in the previous experiment, except that the final irrigation with nutrient solution was not applied and stem measurements were done for 12 hours after the treatments were applied. EC was measured continuously during both experiments.
Figure 1 Stem elongation rates are affected by the salinity of the treatment solutions. Treatment with deionized water (DI) causes an increase in growth rate compared to the pretreatment rate. Elongation rates decrease as salinity increases. When the solutions are leached from the substrate, the rates were greater with the more saline treatment.

Results

In the first experiment with the two hour exposure to the treatment solutions, stem elongation rates decreased as salinity increased (Fig. 1). It is significant that there was an increase in the elongation rate of 0.3mm/hr over the initial rate of 1.0mm/hr when treated with deionized water (DI). The +8dS/m treatment caused the rate to decrease by about 0.9mm/hr.

When the plants were irrigated with nutrient solution to leach out the treatment solutions, the growth rate of shoots on plants exposed to the lower salinity solutions (DI, NS, +1dS/m, and +2dS/m) recovered to the initial, pretreatment rate. However, the stems of plants treated with the +4 and +8 solutions actually grew at a rate greater than the pretreatment rate.
Effect of salinity on growth rate

![Graph showing stem elongation rate over time for different treatments](image)

**Figure 2** Growth rates were calculated every six minutes. The pretreatment irrigation was applied at 1:00a.m. Treatments were applied at 5:00a.m. and the post-treatment irrigation followed two hours later.

Since data were recorded ten times per hour, it was possible to observe how the shoots responded over time as the different solutions were applied. The +8dS/m treatment shows the most dramatic effects (Fig. 2, bottom right). Elongation nearly ceased briefly following the application of the saline solution. Elongation began to increase slowly after about one hour. When the saline solution was leached from the substrate, growth rate dramatically increased to about 3.5mm/hr but then recovered to the pretreatment rate after about 45 minutes.

The effect of the +4dS/m treatment (Fig 2, bottom center) was similar to but less dramatic than the +8 treatment. The NS, +1, and +2dS/m treatments showed no effect on the growth rates. The DI treatment caused an effect opposite that of the saline treatments: an increase in growth as the DI was applied and a decrease in growth when the DI was leached from the substrate with nutrient solution.

The electrical conductivity of the substrate was measured to be about 1.0 dS/m after the initial irrigation at 1:00a.m (Fig. 3). After the treatment solutions were applied, it took about 15 minutes for the measurement equipment to detect changes in the EC. Measurements stabilized more rapidly when EC increased than when it decreased. Except for the NS treatment, the EC did not achieve the intended level in the soil solution. For example, it was expected that the...
Figure 3 Changes in electrical conductivity (EC) of the substrate as nutrient and treatment solutions are applied. Responses to increasing EC occur more rapidly than when it is decreasing due to the characteristics of the measurement equipment.

+4dS/m treatment should result in an EC treatment of 5dS/m. The actual level attained was only about 4.6dS/m. This may be due to a dilution of the treatment solution by the solution that was present in the substrate at the time of the treatment application.

When plants were exposed to the treatment solutions for 12 hours (fig. 4), the shoots of plants that were treated with the +2, +4, and +8 dS/m solutions showed an immediate decrease in growth as in the previous experiment. An increase in growth then followed. Growth rates recovered to the initial rate before treatments were applied on shoots of plants treated with +2 and +4 dS/m, but not when treated at +8dS/m.

Discussion

Since the stem length of roses as cut flowers has a large impact on the crop value, then it is important to understand the factors that affect shoot elongation. Now that we can measure the salinity of the soil solution in the same condition as plants are exposed to, it is possible to quantify the effects of salinity on shoot growth. From the experiments presented, it is shown that
relatively small changes in substrate EC can have significant effects on stem elongation. From this information, it will be possible to increase the detail of shoot growth models and include the effect of salinity on the length of rose stems. These models may provide information that aids in the development of practices that optimize the production of roses as cut flowers.

**Figure 4** Stem elongation rate during 12-hour salinity treatments
Rose photosynthesis work

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Development of a coupled model of photosynthesis-stomatal conductance-transpiration

We refined our photosynthesis model to encompass the estimation of transpiration rate and leaf temperature using the energy balance equation. The results of this research was reported at ASHS meeting in July (Kim and Lieth, 2001a). The model was formulated and calibrated using ‘Kardinal’ (Fig 5). The model operates using the environmental variables available from the greenhouse control computer: light, CO₂, relative humidity and air temperature. It predicts the rates of photosynthesis, dark respiration and transpiration as well as stomatal and boundary layer conductances.

![Figure 5](image_url)  
**Figure 5** Model calibration. (a) CO₂ responses at two temperatures, (b) temperature response at three CO₂ levels (ppm), (c) light response at CO₂ of 350 ppm at 25°C, (d) the relationship between stomatal conductance ($g_s$) and the value of net photosynthetic rate times relative humidity divided by CO₂ concentration of the ambient air (represented by $A_{ha/Ca}$).
The model prediction was validated under various conditions for ‘Kardinal’. This model could be used as a standalone tool as well as a module to be integrated into the shoot model and/or crop simulation model. We also investigated the photosynthetic parameters for 5 other rose cultivars: Fire’n’Ice, Cara Mia, Sonia, Orlando and Tineke.

**Effect of bending on photosynthesis**

The effect of bending on photosynthesis and stomatal conductance was investigated. The preliminary results of this experiment has been introduced to the growers during the last year’s ICFGA meeting at Aptos. This experiment was completed and the results were presented at ASHS meeting in Sacramento in July as well (Kim and Lieth, 2001b). The following is the summary of the results.

a. Bending resulted in a 10 to 20% reduction in net photosynthesis (A), stomatal conductance (g) and transpiration rate (E) of the leaves on the bent shoot (Fig 6)

b. The reduction in photosynthesis disappeared about three weeks after bending while the reduction in stomatal conductance and transpiration persisted.

c. Flower removal accompanied by bending appeared to exacerbate the reduction in net photosynthesis due to bending. Some growers in pinch off the flower buds first then bend the shoot a few days later. This approach seems to make sense so as to reduce the damage due to pinching in addition to bending.

d. The effect of bending was consistent over different leaf positions

e. Our results support the hypothesis that hydraulic conductivity is reduced in bent stems, that this is due to destroyed xylem tissues, and that reduced photosynthesis rates of the leaves on the bent stems are a function of water status.

![Figure 6](image.png) Changes in gas exchange characteristics over time in response to shoot-bending. Error bars represent one standard error (SE).

**Experimental Conditions:**
- PPFD: 1500 μmol m\(^{-2}\) s\(^{-1}\)
- CO\(_2\): 350 ppm mol\(^{-1}\)
- Fully expanded young leaves at day 0 (approx. 20 days old)
Effect of root zone water status on whole-plant photosynthesis

The effect of water stress on whole-plant photosynthesis was investigated. The data were also used to validate the performance of our comprehensive photosynthesis model. When a rose plant was experiencing water stress it exhibited the midday depression in photosynthesis. Based on this, we attempted to model this photosynthetic behavior of midday depression by reducing the stomatal conductance to 50% of what it would have been without the water stress. This preliminary attempt was able to mimic the pattern of midday depression reasonably well (Fig 7). Modeling root-zone and plant water status and its effect on production should be carried out in more detailed and mechanistic fashion down the road.

Figure 7 Diurnal responses of whole-plant photosynthesis ($P_n$) and transpiration (E) of a rose plant on which water stress was imposed. Diurnal courses of PAR, CO$_2$ concentration inside the greenhouse, air temperature (T) and relative humidity (RH) are also shown. Circles and solid lines represent for observations and simulation, respectively, in the photosynthesis and transpiration graphs.
Modeling photosynthesis of bent canopy

The efficacy of bent canopy has been evaluated using simulation. The bent canopy was simplified to consist of an upright hedge and a mat of bent shoots between the hedges (Fig 8). A radiative transfer model was developed for a bent canopy. Diffuse and direct light distribution and absorption were simulated by calculating the path length of attenuated light through the canopy. Assimilation rates of sunlit and shaded leaf area were then calculated in relation to position within the canopy and time of day. Numerical integration of the sunlit and shaded assimilation rates over the respective leaf area index (LAI) and leaf age, and over the day yielded diurnal course of canopy photosynthesis. The geometry of the canopy was described by hedge height and width, depth and width of bent portion, row direction, leaf angle and leaf area density (LAD).

The simulation (Fig 9) indicated that bent canopy is less sensitive to row direction than hedgerow canopy. This is probably due to the bent shoots capturing light falling into the aisle space when the elevation of sun is high. Daily integral of net canopy photosynthesis was simulated to identify the optimal LAI (or LAD for given geometry). This analysis showed that the optimal LAD of the bent portion of the canopy was negatively related to LAD of upright hedge. This means that when the upright hedge is dense, high leaf area in the bent portion would not contribute much to net carbon gain because many of the leaves in the bent portion would be shaded to light levels below the
compensation point much of the day. The benefit to the overall carbon budget of having bent shoots was less pronounced during winter where day length is short and light intensity is low. In particular, in the winter bent portion should be kept below an LAD of 1 for a full upright or between 1 and 2 for a thin upright canopy.

References:
