# Optimizing rose crop fertilization and irrigation over hourly, daily and seasonal time scales:

## Integration of diurnal ion and water uptake

**Raúl I. Cabrera and Alma R. Solís-Pérez**
Texas A&M University
Research and Extension Center
17360 Coit Road, Dallas, Texas 75252

Dr. Cabrera is now at Rutgers University
Cabrera@aesop.rutgers.edu

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ICFG-HILL, P.O. Box 99, Haslett, MI 48840
ICFG.HILL@yahoo.com

The overall objectives of the current research project have been to characterize and confirm the seasonal, and more particularly the diurnal (hourly, over 24-h intervals), water and nutrient uptake patterns in hydroponically-grown roses. While the seasonal uptake patterns in roses had been previously reported in the past (Cabrera, 2003; Cabrera *et al.*, 1995; Mattson and Lieth, 2005), we have been keenly interested in evaluating the short-term diurnal uptake behavior.

The most compelling reason to evaluate this short-term water and nutrient uptake characteristics in roses is to take potential advantage of modern computerized irrigation systems that allow programming multiple and precise fertigation applications within a day. The management of these systems is often controlled by or linked to environmental variables, and in the particular case of water, a common underlying premise is to maintain and/or replenish water into the system as it is lost due to evapotranspirative processes. The use of soil moisture sensors to determine water use by a plant/crop and trigger water applications to a substrate moisture set-point are perhaps more attuned to the actual or real water usage by the plants. However, given that modern rose production is based on fertigation, the application of a volume of water implicitly adds nutrients to the rootzone of the crop, and to assume that the crop is using nutrients in rates proportional to water uptake has not been substantiated by research (Cabrera *et al*., 2003, 2005). Coming back to the management of fertigation application over the course of a single 24-h period, the logical questions to ask are: To what extent are water and nutrient uptake linked over a diurnal (24-h) cycle? Do roses (or other cut flower crops) absorb nutrients during the night, and is so, how much? Could water and fertilizer applications be uncoupled (thanks to programmable fertilizer injectors) as to optimize both water/fertilizer uses efficiency and minimize undue osmotic stress to developing rose shoots?

We already reported that the uptake of water and nutrient over the course of flowering cycles and daily (24-h) cycles were not influenced by the rootstock (in 'Happy Hour' scion grafted on 'Manetti' and 'Natal Briar'). In addition, we also reported that the average hourly rates of total ion (fertilizer salt) uptake were significantly lower during the days when maximum shoot elongation rate were observed, and were higher on the days approaching flower harvest. Recently we also tried monitoring nitrogen (nitrate-N) uptake rates over the course of two discrete 24-h periods (Figure 1). As reported in our previous trials, we observed the characteristic diurnal pattern of water uptake that peaks at midday and is minimal during the dark hours (Fig. 1 A). Diurnal $NO_3$-N uptake rates during the time when shoot elongation rates were at their maximum (Day 24) showed a cycling that included net efflux (i.e. negative values) during the night and early morning hours, and a peak that was displaced by about 2 hours (later) with respect to that of transpiration (Fig. 1 B). The diurnal $NO_3$-N uptake rates observed during the day close to harvest (Day 44) denoted only net influx (only positive values), and this time the absorption peak was much broader (noon to 4PM), overlapping the peak of transpiration. Over a decade ago we reported that 'Royalty' roses (on *R.* 'Manetti') showed a diurnal pattern of $NO_3$-N uptake in both well-fertilized and N-starved plants, with maximum uptake rates occurred several hours after maximum water uptake occurred (Cabrera *et al.*, 1996), an observation that also has been made on other plants species. Although the literature does not report much more on these diurnal patterns of N uptake in plants, it has been proposed that fluctuations in the rate of photosynthate supply from shoots to roots may account for these diurnal uptake patterns (Cabrera *et al.*, 1996).

The total (integrated) $NO_3$-N uptake for the first diurnal 24-h period (Day 24) was 15±5 mg/plant, compared to the 67±8 mg/plant absorbed for the diurnal period close to harvest (Day 44). This four-fold difference corresponds very closely to the $NO_3$-N uptake values we reported over a decade ago with the cultivar 'Royalty' (Cabrera *et al*., 1995). These patterns of $NO_3$-N uptake mirror closely those observed for total ion uptake (see our last report). We have to admit that unfortunately we observed a relatively high degree of statistical variance (i.e. standard errors) in the $NO_3$-N uptake data, and we attribute these to the inherent analytical difficulties in detecting small changes or differences in concentration when using relatively high volumes of solution. Each hydroponic unit contained up to 25 liters of solution, and even with a with a background $NO_3$-N concentration of around 50 ppm (0.25X Hoagland solution), analytical resolution of small changes in concentration (± 2ppm) over a 24-h period was a challenge.

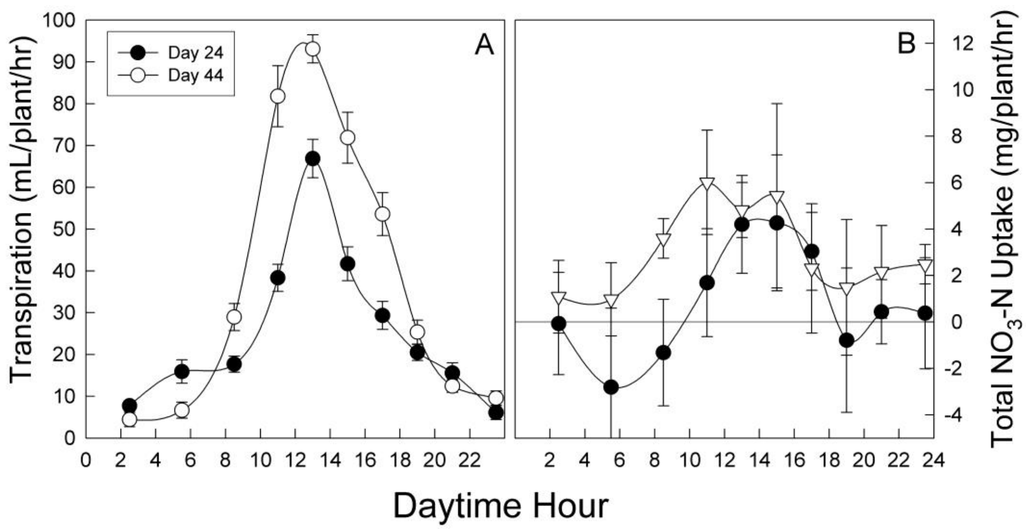


**Figure 1.** Transpiration (A) and nitrate-N uptake rate (B) at two 24-hr periods within a growth & flowering cycle of hydroponically-grown 'Erin' roses grafted on the rootstock *R. manetti*. Data points are means± S.E. of eight plants.

We decided to integrate the diurnal (i.e. hourly) water and total ion uptake rates over broader intervals during the day, and chose to do it in four intervals of 6 hours each, and we did it for two days within two flowering cycles (Fig. 2). With respect to water uptake, it was readily apparent, and expected, that the bulk of transpiration (~ 80%) occurred during daylight hours (Fig. 2A, B), and 20% or less of it was absorbed during the hours of darkness (8PM to 8AM). Physiologically, this is largely explained by the stomata on the leaves being open only during daylight hours, and pretty much closed in darkness. It was interesting to note that nighttime water use was relatively smaller during the stages closer to harvest (Days 44 and 46) than when the new flower shoots were rapidly elongating and developing (Days 24 and 28). The literature in other woody plants reports that indeed stomatal conductance (i.e. transpiration) is higher than old leaves irrespective of the time of the day (Syvertsen, 1982). Because during the period of rapid shoot elongation a significantly high proportion of leaf area is from new developing leaves (plus the basal much older leaves) it is expected to have higher nighttime water use than when the leaves are more mature (close to harvest).

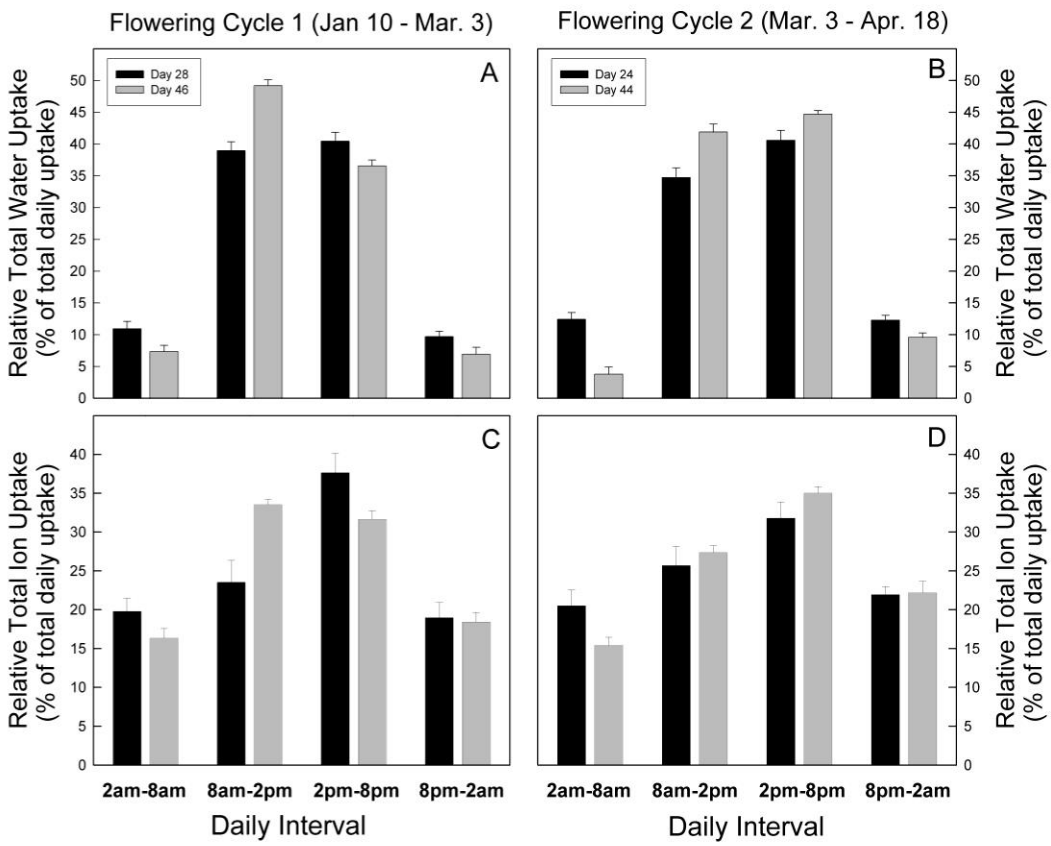


**Figure 2.** Relative water (A, B) and total ion (salt) uptake (C, D) within two 24-hr periods belonging to two distinct (6-7 week) cycles of growth & flowering in hydroponically-grown 'Erin' roses grafted on the rootstock *R. manetti*. Data points are means± S.E. of eight plants.

Now, when looking at the integrated total ion (i.e. fertilizer salt) uptake over the course of a single day, the largest portion of ions (35 to 40% of the total daily uptake) are absorbed during the afternoon hours (2PM to 8PM), regardless of the stage of crop development. Interestingly, nocturnal (dark hours) uptake of fertilizer elements is still significant (accounting for ~ 20% from 8PM to 2AM and another ~20% from 2AM to 8AM to), despite the fact that water use is relatively low. This information once again, supports our previous reports that although intrinsically linked, water and nutrient uptake are still regulated differentially by a rose crop (Cabrera *et al*., 1993, 1995).

The implications of these observations are very important and could help optimize both fertilizer & water use efficiency, as well as shoot elongation potential. According to the elegant work of Oki and Lieth (2004), maximum shoot elongation rates in roses are observed during the early night hours (i.e. 6PM to 10PM), and they are adversely affected even by relatively small changes in the salinity of the rootzone. Putting together all this information, from a practical horticultural perspective, it would seem logical to sustain maximum fertilizer concentration application during daytime hours, up until the late afternoon, and then cut the fertilizer concentrations (but not eliminate them) as to minimize any undesirable osmotic (i.e. salinity) effects on shoot elongation rates, which tend to be maximum during the early night hours. This scenario would be, of course, only practically suitable and applicable to a hydroponic production system or an intensively managed (i.e. frequent fertigation) soilless system. It would be advisable to test this procedure in a commercial production system, using only a small section and under careful observation, until finding the fertilizer concentrations (i.e. nutrient solution EC's) more suitable to sustain flower productivity and quality (i.e. longer stems), while potentially maximizing fertilizer use efficiency (discharging less concentrated leachates or drainage volumes).

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