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## **Light responses and leaf nitrogen of invasive and non-invasive *Rosa* sp.**

**Esther D'Mello**

### **Abstract**

Invasive species pose a major threat to ecosystems worldwide. Therefore, understanding the traits that promote invasiveness is a key research focus for invasion biologists. The objective of this project was to assess light responses of invasive and non-invasive roses by using gas exchange measurements and to relate these responses to leaf nitrogen concentration. I compared the light response curves and leaf nitrogen concentrations of non-invasive and invasive roses, hypothesizing that increased photosynthetic rates and green leaf nitrogen concentrations are associated with invasiveness in these species. Using a greenhouse experiment, the plants were placed in a randomized block design and grown under controlled conditions. Light response curves were made with a LICOR 6400 infrared gas analyzer. Following gas exchange measurements, leaf nitrogen concentration was measured via micro-Dumas combustion on a CN analyzer. Contrary to expectations, there were no significant differences in photosynthetic light responses among invasive and non-invasive roses. However, the data suggest that invasive roses may use nitrogen more efficiently than non-invasive species. The goal of this study was to distinguish traits that allow invasive roses to outcompete non-invasive roses. Understanding the traits that facilitate the spread of invasive species can lead to interventions that may mitigate their negative effects on native environments.

### **Introduction**

Invasive plants are plant species that are able to grow and spread at high rates in introduced, native areas (Drenovsky et al. 2012). They are of concern because they have the

ability to negatively alter native plant populations, communities, and ecosystems (Drenovsky et al. 2012). Invasive species have the potential to outcompete non-invasive species, which may be due to their fast growth rates (Leishman et al. 2007). Understanding what drives invasiveness, as well as understanding invasive species' impacts on native environments can lead to invasive species prevention (Drenovsky and James 2010).

Invasive species are characterized by specific traits that distinguish them from non-invasive species. Invasive plants tend to have a higher leaf area per leaf mass (i.e., specific leaf area, SLA) and thus thinner leaf tissue (Grotkopp et al. 2002). Because invasive species have a high SLA, the tissues they produce are less dense, resulting in higher relative growth rates (RGR) (Grotkopp et al. 2002, James and Drenovsky 2007, Drenovsky et al. 2012). Overall, having a high SLA with thinner leaves translates into “cheaper” leaf production because the plant does not need to spend as much energy producing leaves (Drenovsky and James 2010). Another factor promoting higher growth rates in invasive species is increased leaf nitrogen (N) concentrations, which enable invasive species to allocate more nitrogen to photosynthesis (Grotkopp et al. 2010). Thus, higher leaf nitrogen concentrations and photosynthetic rates of invasive species could be directly and positively correlated with their invasiveness.

Light is one of the most important factors influencing photosynthetic rates; therefore it is necessary to understand how these two variables are related in invasive and non-invasive plants (Lachapelle and Shipley 2012). Given the mechanistic links between leaf traits, photosynthetic rates, growth rates, and their variation among invasive and non-invasive species, it is important to understand how environmental factors can influence these relationships. Light-response curves are used to model photosynthetic properties of leaves, which can provide us with information on plant adaptations to light in their environments and the efficiency at which plants

use light for photosynthesis (Lambers et al. 2008; Figure 1). The segment of the curve before the x-intercept is when there is a negative exchange of  $\text{CO}_2$  (i.e., the plant's respiration rate exceeds its photosynthetic rate). At the x-intercept, the plant's uptake of carbon dioxide ( $\text{CO}_2$ ) through photosynthetic assimilation is equal to the amount of  $\text{CO}_2$  released by respiration; this portion of the curve is known as the light compensation point (LCP). Initially, the net photosynthetic rate of the plant increases linearly, and this positive increase indicates the range of light-intensities at which photosynthesis is light-limited. This means photosynthesis is limited by the rate of electron transport due to the amount of available light. Eventually, the leaf reaches the point of saturation, or the point at which the photosynthetic rate reaches a stable point; it no longer increases with an increase in light availability. At this point, the curve starts to level off; this portion is known as the  $\text{CO}_2$ - limited part of the curve. Photosynthesis for the leaves is no longer limited by light but instead it is limited by biochemistry.

From the light-response curve (Figure 1), we can identify key traits describing the photosynthetic properties of a plant. The initial slope of the light-response curve is based on absorbed light, which is also the quantum yield and describes the efficiency of the rate at which light is used to fix carbon. Differences in the light compensation point and saturation point between species can be determined as well. For instance, a lower LCP indicates a lower respiratory demand, which in some comparisons has been linked to the high growth rates of invasive compared to native species (Pattison et al. 1998). Higher saturation points are indicative of plants successful in high light environments; the plant has a greater capacity to process light and thus can achieve higher overall photosynthetic rates.

Thus, leaf traits associated with rapid growth rates such as the quantum yield, light compensation point, saturation point, and leaf N concentration may help us better understand the

factors that determine the invasiveness of plant species. Using light-response curves we can better understand the efficiency of photosynthesis in invasive compared with non-invasive species, as well as the potential range of light environments in which both species may be successful. These traits may help distinguish factors enabling invasive plants to spread and outcompete with non-invasive plants.

### **Objective and Hypothesis**

The primary objective of this project is to determine the light responses of a suite of invasive and non-invasive rose species. In order to accomplish this, I tested five hypotheses. First, I hypothesized that invasive rose species have a higher light compensation point ( $A = 0$ ) than non-invasive rose species, due to their higher respiratory demands. Second, I hypothesized that invasive species have a higher quantum yield (steeper slope), representing their greater efficiency at processing light. Third, I hypothesized that invasive roses have a higher saturation point than non-invasive rose species based on previous research on the high relative growth rate and maximum photosynthetic rates of invasive species. Fourth, I hypothesized that invasive rose species have a higher maximum assimilation rate ( $A_{\max}$ ), because invasive species tend to photosynthesize at higher rates. Lastly, I hypothesized that invasive rose species have higher leaf nitrogen concentrations and that leaf nitrogen concentration is positively and linearly correlated with maximum photosynthetic rates in species.

### **Study Species**

Roses were selected as the study species for this experiment because they are a large genus whose evolutionary relationships are well understood. Also, roses vary in their global invasiveness; some are highly invasive while others are non-invasive. All roses from this

experiment were ranked for their global invasiveness or weediness, based on the classifications detailed in the Global Compendium of Weeds (GCW <http://www.hear.org/gcw/>). For my measurements, I compared non-invasive and highly invasive rose species. Plants which are classified as non-invasive are found on only one continent and plants which are classified as highly invasive are found on three or more continents. This classification scheme follows that of Grotkopp et al. (2012). For this experiment, I included the six rose species. Three are non-weedy roses; these include: *Rosa palustris*, *Rosa spinosissima*, and *Rosa virginiana*. Three are weedy rose species: *Rosa multiflora*, *Rosa rugosa*, *Rosa wichuraiana*.

### **Plant Growth Conditions**

Plants were grown under controlled conditions in the John Carroll greenhouse. Plants were germinated from commercially available seed following species-specific stratification protocols, as based on information from the relevant seed companies. Following germination and one month of growth, seedlings were transplanted into D40 deepots (6.4 cm in diameter x 25 cm in depth, 656 mL in volume; Stuewe and Sons Inc., Tangent, OR, USA) in a 60% mixture of organic potting soil (The Espoma Company, Millville, NJ, USA), 30% organic seed starter mix (The Espoma Company, Millville, NJ, USA), and 10% Turface Athletics MVP mix (Turface Athletics Com., Buffalo Grove, IL, USA). Greenhouse conditions were kept constant during the experiment. The plants were watered 2-3 times per week or as needed to maintain field capacity. All plants were grown in ambient light.

### **Experimental Design and Measurements**

The plants were placed in a randomized block design with 8 blocks and were grown under these conditions in the greenhouse for at least three months prior to measurements. Light

response curves were used to assess how photosynthetic rates are influenced by light intensity in my suite of species. Plants were measured using a LICOR 6400 infrared gas analyzer between 10:00AM-2:00PM on cloudless days. Light response curves were assessed under the following conditions: CO<sub>2</sub> concentration inside the chamber was set to 400  $\mu\text{mol mol}^{-1}$  at a flow rate of 400  $\mu\text{mol s}^{-1}$ , and the temperature inside the leaf chamber was set between 30-33° C and kept constant between plant species for that given day. Relative humidity inside the chamber was maintained at  $\geq 40\%$ . Light was supplied via a red/blue LED light source at the following photosynthetic photon flux densities (PPFD): 1500, 900, 500, 250, 100, 50, 25, and 0  $\mu\text{mol m}^{-2} \text{s}^{-1}$ . Each leaf was allowed to equilibrate at light intensities for 2-3 minutes prior to measurement. Because most leaves were smaller than the chamber and all measurements were made on a leaf area basis, measured leaves were collected and scanned using an image analysis program (WIN Rhizo; Regent Instruments Inc., Saint-Foy, Quebec, Canada). The leaf area measurements were used to recalculate gas exchange measurements.

Following gas exchange measurements, leaf tissue was collected, triple-rinsed with deionized water, dried at 60°C, and finely ground with a ball mill. Leaf nitrogen concentration was measured by micro-Dumas combustion on a CN analyzer.

### **Statistical Analysis**

Nonlinear regression was used to determine parameters associated with light response curves, including quantum yield, light compensation point, and  $A_{\text{max}}$ . Curves were fit to two nonlinear equations (Mitscherlich equation and Michaelis-Menten equation) to determine these parameters. ANOVA was used to compare LRC parameters between invasive and non invasive roses. Linear

regression was used to determine the relationship between maximum photosynthetic rate ( $A_{\max}$ ) and leaf nitrogen concentration. All data was analyzed with SAS v9.2.

## Results

Photosynthetic assimilation ( $A$ ) as a function of photosynthetic photon flux density (PPFD) was similar among all species, regardless of weediness (Figure 2). The respiration rate ( $R_d$ ),  $A_{\max}$ ,  $q_{lcp}$ , and LCP did not differ between species or weediness groups ( $P>0.05$ ; Table 1). However,  $R_d$  was significantly different among blocks ( $P=0.03$ ). Green leaf nitrogen concentration was significantly different among species ( $P<0.0001$ ;  $P=0.2375$ ), with non-invasive roses having significantly higher leaf N than the invasive roses ( $P<0.0001$ ; Figure 3 A). Maximum photosynthetic rates did not vary significantly with green leaf nitrogen concentration ( $r^2=0.26$ ,  $P>0.05$ ; Figure 3 B).

## Discussion

In this experiment I used a greenhouse study to determine if photosynthetic rates and leaf nitrogen concentration were linked to invasiveness in a suite of roses. I expected higher LCP in invasive roses due to presumed faster growth rates and thus greater respiratory demands; neither was observed. This could be due to soil nutrient limitations. I predicted higher quantum yield which was not observed in the experiment. These findings suggest that roses were similar in their ability to use light energy to fix carbon.

There are many factors that influence photosynthesis, e.g., temperature, soil moisture, relative humidity, and soil nutrient availability (Thompson et al. 1995). In this experiment temperature and relative humidity within the LICOR 6400 infrared gas analyzer and soil moisture were taken into account when measuring photosynthetic rates. One environmental

factor that was not examined in this experiment was soil nutrient availability. The soil in which each plant was grown had a limited supply of nutrients. Towards the end of the experiment the plants became root-bound, requiring more soil volume and, potentially, more soil nutrients to grow. Soil nutrient levels can play an essential role in promoting species' invasibility in an area (Davis et al. 2000), as fast-growing species, invasive species often are adapted to high resource availability (Blumenthal 2006). Nutrient limitations could have affected the plants' ability to photosynthesize at higher rates (Lambers et al. 2008), and as a result, may have influenced why the invasive roses did not have significantly different light responses (including different LCP,  $q_{LCP}$  and  $R_d$ ) compared to non-invasive roses.

Next, I predicted that invasive roses would have a higher leaf nitrogen concentration than non-invasive roses and that higher leaf nitrogen concentrations would be positively and linearly correlated with maximum photosynthetic rates. However, my results show that the non-invasive roses had higher leaf nitrogen concentrations than the invasive roses. Although leaf nitrogen concentration is often linked to leaf photosynthetic rates (Givnish 1986), in this experiment there was no significant relationship between leaf nitrogen concentration and photosynthetic assimilation rates. One reason this could be is because leaf nitrogen is correlated with photosynthesis only when carbon fixation is at its maximum rate (Meziane and Shipley 2001). As stated above, soil nutrient limitations may have obscured relationships between photosynthetic rates and leaf nitrogen concentrations. However, it is interesting to note that invasive roses were able to photosynthesize at similar maximal rates as non-invasive roses while allocating less nitrogen to their leaves. Overall, leaf biomass was greater for invasive species than non-invasive species (J. Murphy, unpublished data). If the invasive roses were producing more leaf biomass with a limited supply of nitrogen, and still maintaining similar photosynthetic

rates (A) as the non-invasive species, then these data suggest that the invasive species may have a higher photosynthetic nitrogen use efficiency and plant nitrogen productivity than the non-invasive species (Lambers et al., 2008). A study comparing the leaf traits of invasive and non-invasive rainforest plants found that invasive species had a greater nitrogen, energy, and water use efficiency than non-invasive species in resource limited environments, suggesting that greater resource use efficiency provided a competitive advantage to the invasive species over the non-invasive species (Funk and Vitousek 2007). My data indicates that invasive roses may be highly efficient in their use of nitrogen, suggesting that future work should focus on the role of resource use efficiency in promoting the invasiveness of roses.

## **Conclusions**

The goal of this experiment was to understand specific traits of invasive and non-invasive roses that might help explain why some species are invasive and others are not. Even though I detected no significant differences in photosynthetic light responses among invasive and non-invasive roses, my data suggested that invasive roses may use nitrogen more efficiently to build biomass. Although not tested in this experiment, the efficient use of nitrogen in invasive species could be linked to their ability to out-compete non-invasive roses (Funk and Vitousek 2007, Drenovsky et al. 2008). Some suggestions for future studies include testing the resource use efficiency (RUE) in invasive and non-invasive rose species to examine which species are more efficient at using resources in a set time scale. To further test if high leaf nitrogen concentrations in leaves are correlated with invasiveness it could be beneficial to test specific leaf area (SLA) of the leaves. Another suggestion for future studies is to assess how light quantity and light quality influence growth of invasive and non-invasive roses, as some invasive roses can invade forest interiors, but it is unknown how successful they will be in these low light environments over

time. Overall, understanding the traits influencing invasiveness is an important first step in predicting which plants may become invasive when entering novel environments.

### **Acknowledgements**

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### **Literature Cited**

Blumenthal, Dana. 2006. Interactions between Resource Availability and Enemy Release in Plant Invasion. *Ecology Letters* 9: 887-895.

Davis, Mark, Philip Grime, and Ken Thompson. 2000. Fluctuating Resources in Plant Communities: A General Theory of Invasibility. *British Ecological Society* 88(2): 528-734.

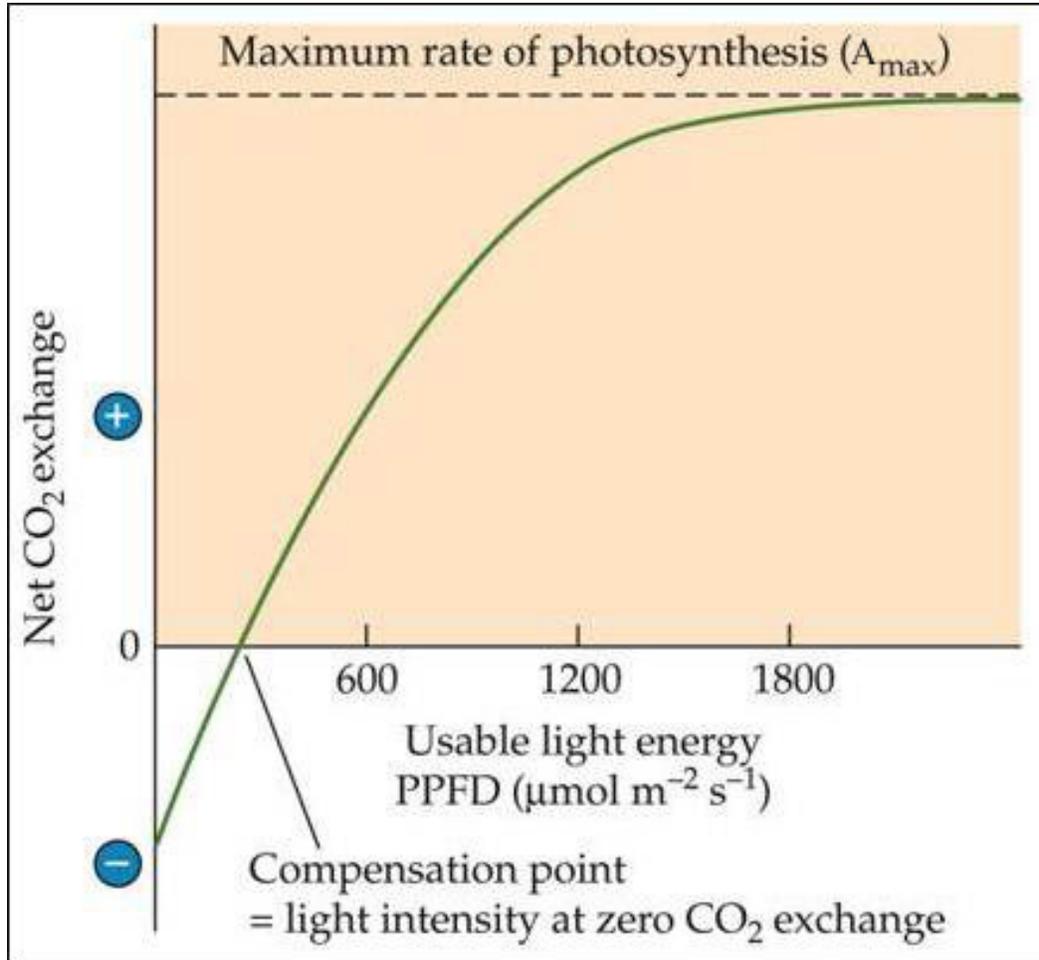
Drenovsky, Rebecca, and Jeremy James. 2010. Designing Invasion-Resistant Plant Communities: The Role of Plant Functional Traits. *Rangelands* 32(1): 32-37.

Drenovsky, Rebecca, Albina Khasanova, and Jeremy James. 2012. Trait convergence and plasticity among native and invasive species in resource-poor environments. *American Journal of Botany* 99: 1-11.

- Drenovsky, Rebecca, Brenda Grewell, Carla D'Antonio, Jennifer Funk, Jeremy James, Nicole Molinari, Ingrid Parker, and Christina Richards. 2012. A functional trait perspective on plant invasion. *Annals of Botany* 110(1): 141-153.
- Funk, Jennifer, and Vitousek Peter. 2007. Resource-use efficiency and plant invasion in low-resource systems. *Nature* 445: 1079-1081.
- Givnish, T. J. 1988. Adaptation to Sun and Shade: a Whole-Plant Perspective. *Australian Journal of Plant Physiology* 15(2): 63 – 92.
- Gleason, Henry, and Arthur Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. Bronx: New York Botanical Garden.
- Grotkopp, Eva, Jennifer Erskine-Ogden, and Marcel Rejmánek. 2010. Assessing potential invasiveness of woody horticultural plant species using seedling growth rate traits. *Journal of Applied Ecology* 47: 1320-1328.
- Grotkopp, Eva, Marcel Rejmánek, and Thomas Rost. 2002. Toward a Causal Explanation of Plant Invasiveness: Seedling Growth and Life-History Strategies of 29 Pine (*Pinus*) Species. *The American Naturalist* 159(4): 396-419.
- Gurevitch, Jessica, Samuel Scheiner, and Gordon Fox. 2006. *The Ecology of Plants*. 2nd ed. Sunderland: Sinauer Associates, 574.
- James, Jeremy, and Rebecca Drenovsky. 2007. A Basis for Relative Growth Rate Differences Between Native and Invasive Forb Seedlings. *Rangeland Ecology & Management* 60.4: 395-400.

- Lachapelle, Pierre-Philippe, and Bill Shipley. 2012. Interspecific Prediction of Photosynthetic Light Response Curves Using Specific Leaf Mass and Leaf Nitrogen Content: Effects of Differences in Soil Fertility and Growth Irradiance. *Annals of Botany* 109: 1149-157.
- Lambers, Hans, Stuart Chaptin, and Thijs Pons. 2008. *Plant Physiological Ecology*. Springer, New York, New York, USA.
- Leishman, Michelle, Tammy Haslehurst, Adrian Ares, and Zdravko Baruch. 2007. Leaf Trait Relationships of Native and Invasive Plants: Community- and Global-scale Comparisons. *New Phytologist* 635-43.
- Meziane, Driss and Bill Shipley. 2001. Direct and Indirect Relationships between Specific Leaf Area, Leaf Nitrogen and Leaf Gas Exchange. Effects of Irradiance and Nutrient Supply. *Annals of Botany* 99. 915-927.
- Pattison, Robert, Guillermo Goldstein, and Alicia Ares. 1998. Growth, biomass allocation and photosynthesis of invasive and native Hawaiian rainforest species. *Oecologia* 117: 449–459.
- Thompson, W.A., GC Stocker, and PE Kriedemann. 1988. Growth and Photosynthetic Response to Light and Nutrients of *Flindersia brayleyana* F. Muell., A Rainforest Tree with Broad Tolerance to Sun and Shade. *Australian Journal of Plant Physiology* 15(2): 299 – 315.

Figure 1.



Light-Response Curve from Gurevitch et al. (2006).

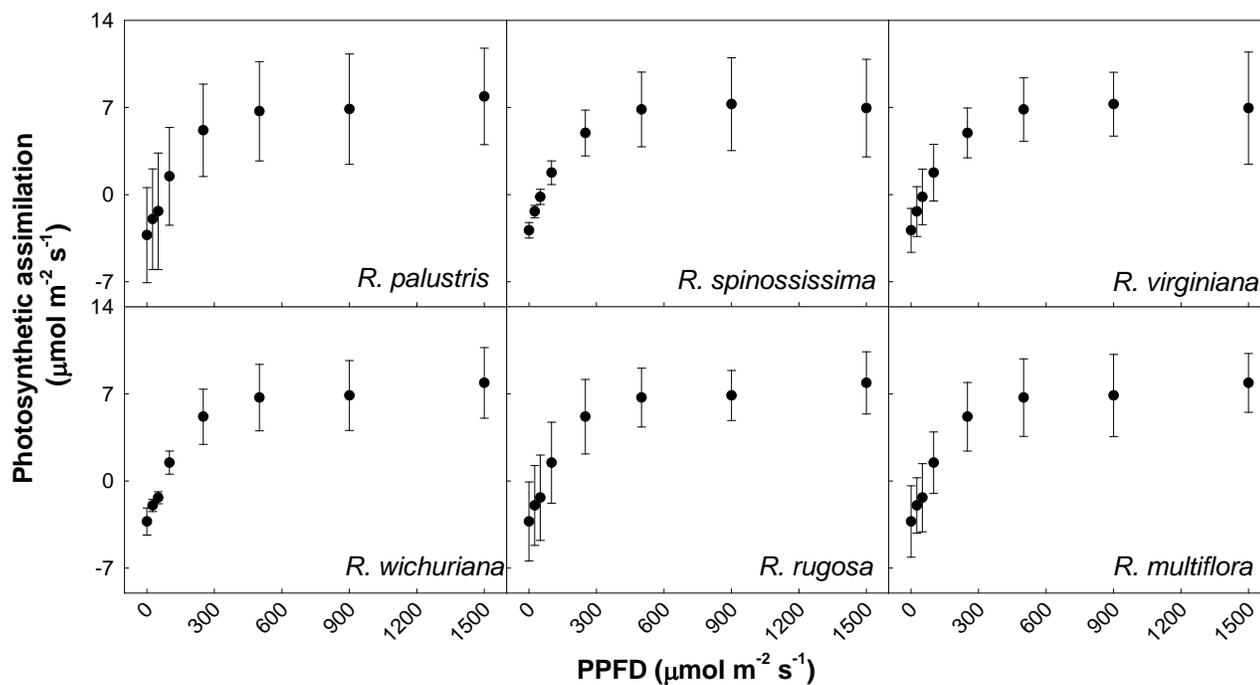
**Table 1.**

Comparison of light response measurements with invasive and non-invasive roses.

photosynthetic rate) of non-invasive and invasive roses. Values are means  $\pm$  SD

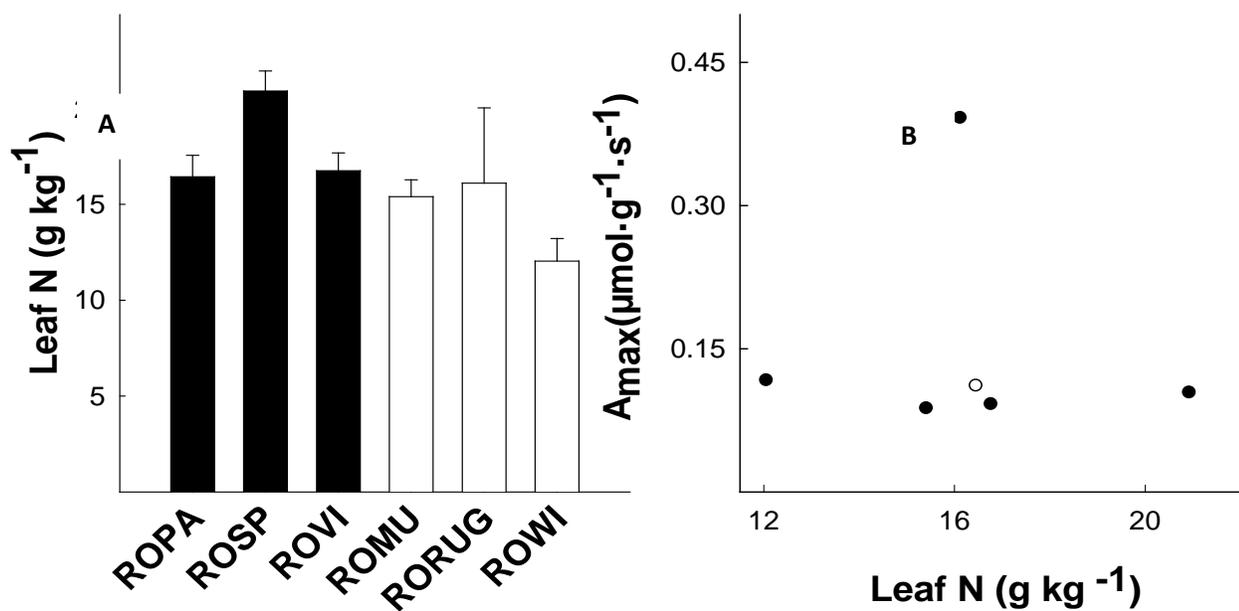
	$R_d$	$A_{max}$	$q_{Icp}$	LCP
<b>Non-invasive</b>				
<i>R. palustris</i>	3.51 $\pm$ 3.55	9.36 $\pm$ 4.34	0.04 $\pm$ 0.03	126.08 $\pm$ 167.45
<i>R. spinosissima</i>	3.16 $\pm$ 0.54	7.27 $\pm$ 3.77	0.04 $\pm$ 0.01	55.24 $\pm$ 13.83
<i>R. virginiana</i>	2.11 $\pm$ 1.93	8.21 $\pm$ 3.12	0.07 $\pm$ 0.03	36.16 $\pm$ 40.62
<b>Invasive</b>				
<i>R. multiflora</i>	-0.68 $\pm$ 2.40	6.77 $\pm$ 1.35	0.07 $\pm$ 0.03	1.12 $\pm$ 48.01
<i>R. rugosa</i>	2.04 $\pm$ 3.22	8.56 $\pm$ 1.94	0.07 $\pm$ 0.03	39.04 $\pm$ 57.50
<i>R. wichuriana</i>	2.85 $\pm$ 0.98	4.63 $\pm$ 2.84	0.04 $\pm$ 0.02	52.99 $\pm$ 12.84

Figure 2.



Light response curves of photosynthetic assimilation rate as a function of photosynthetic photon flux densities (PPFD) for *Rosa* sp. under eight light conditions. Data points represent the means  $\pm$  standard deviation (n= 6).

Figure 3.



Leaf N of non-invasive (black) & invasive (white) roses (A). Data are means  $\pm$  S.D (n=6).  
Relationship between leaf N and A<sub>max</sub> (B).