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Superior Adaptation to Drought in Rubus Armeniacus (Himalayan Blackberry) in Northwest Oregon

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CIPM Research Grant Final Report

Project Title: Superior adaptation to drought in *Rubus armeniacus* (Himalayan blackberry) in northwest Oregon
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Proposal: Despite the status *Rubus armeniacus* (Himalayan blackberry) has as one of the most prolific and damaging plant invaders in the Pacific Northwest, we know little about the role of water relations in its success. The information available on invasive blackberry water relations (Fotelli et al. 2001; McDowell and Turner 2002) suggests that an ability to avoid water stress has been critically important to their proliferation in regions with Mediterranean climates (Amor et al. 1998). We had two objectives regarding the role of water relations in the invasive success of *R. armeniacus*:

Objective 1. Determine if *R. armeniacus* is better adapted to the Pacific Northwest's water regime than congeneric natives. To address this objective we tested three hypotheses:

a) *R. armeniacus* remains less water stressed than native congeners throughout the growing season;
b) *R. armeniacus* maintains a higher stomatal conductance at all levels of evaporative demand; and
c) *R. armeniacus* has lower hydraulic resistance than congeneric natives throughout the growing season, as a consequence of lower root and shoot resistances.

Objective 2. Determine if and how the water relations of *R. armeniacus* help it to outgrow native Pacific Northwest competitors.

<u>*Water Relations*</u>. To address the first objective we performed a field study at four sites in Portland natural areas. Sites were established where two stands of *Rubus armeniacus* (Himalayan blackberry), *R. spectabilis* (salmonberry), and *R. parviflorus* (thimbleberry) co-occurred. From April through September 2007 we visited each site four times. During each site visit we measured leaf water potential (with a pressure chamber) and stomatal conductance (with a leaf porometer) approximately every two hours through the course of the day (Pearcy et al. 1991; Boyer 1995). We also measured pre-dawn water potential (a metric of soil moisture accessible to the plant) and stem water potential at mid-day (used for differentiating root vs. shoot hydraulic resistance) (Nardini et al. 2003). We also characterized factors that commonly

influence water stress: photosynthetic photon flux density (PPFD), vapor pressure deficit (VPD, a measure of evaporative demand), leaf, and air temperature (Farquhar and Sharkey 1982; Kramer and Boyer 1995).

We computed a water stress index (WSI) score for each stand on each sampling day (using leaf water potentials), and compared the species means by month with ANOVA and Tukey HSD tests (Nardini et al. 2003;Zar 1984). We used linear regression to determine if the relationship (i.e., intercept) between stomatal conductance and VPD differed among species (Myers 1990). We used ANOVA and Tukey HSD tests to determine if hydraulic resistance varied among species by month, and used paired t-tests to determine whether root and shoot resistances differed in their contribution to overall plant resistance in each species during each month (Zar 1984). In the near future we will perform further statistical analyses (e.g., repeated measures ANOVA).

Growth Rate and Morphology. To address the second objective we grew *R. armeniacus* and four native species (*R. spectabilis*, *R. parviflorus*, *Rubus ursinus* (trailing blackberry), and *Rosa nutkana* (nootka rose)) in a greenhouse experiment with two treatment groups ("wet" and "dry", watered approximately weekly and biweekly, respectively). We controlled the genetic variability in plant material by propagating softwood cuttings before the experiment. During the growth phase (approximately three months) we monitored stomatal conductance (with a leaf porometer) and soil moisture levels (with a time domain reflectometer) in a subset of plants (Pearcy et al. 1991; Evett 2003). We measured these variables, as well as cane diameters, in all plants before the final harvest. We also measured correlates of biomass (cane length and leaf number) in all plants at the beginning, middle, and end of the experiment. After the harvest we measured the leaf areas of all leaves as well as the dry biomass of all roots, shoots, and leaves. We also measured pre-dawn water potential and an estimate of cumulative water-use efficiency (leaf $\delta^{13}C$) (Farquhar et al. 1989) for plants in the dry treatment at the end of the growth phase.

Results: In the field, *Rubus armeniacus* had a numerically lower WSI scores than both native species in all months but June (Figure 1). WSI scores increased the least for *R.* armeniacus as the dry season progressed, with the difference between *R. armeniacus* and *R. parviflorus* showing statistical significance during the driest period (September). Stomatal conductance decreased with increasing VPD for all three species, with *R. armeniacus* having significantly higher levels across the full range of VPD (Figure 2). Whole plant hydraulic resistance of *R. armeniacus* was significantly lower than that of *R. spectabilis* in all months but September, and was numerically lower than both native species during all months (Figure 3). Root hydraulic resistance was lower than shoot hydraulic resistance for *R. spectabilis* during the first two months, for *R.* parviflorus in April, and R. *armeniacus* in June. All species had similar root and shoot resistances during July and September.

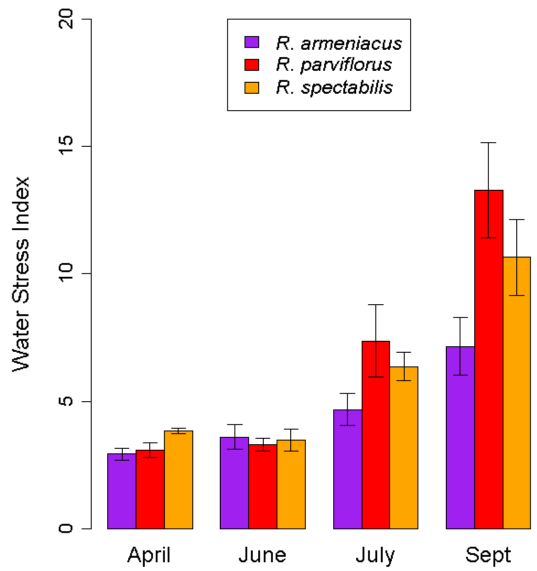

Figure 1. Mean water stress index scores by month (±SE). N=8 stands per species.

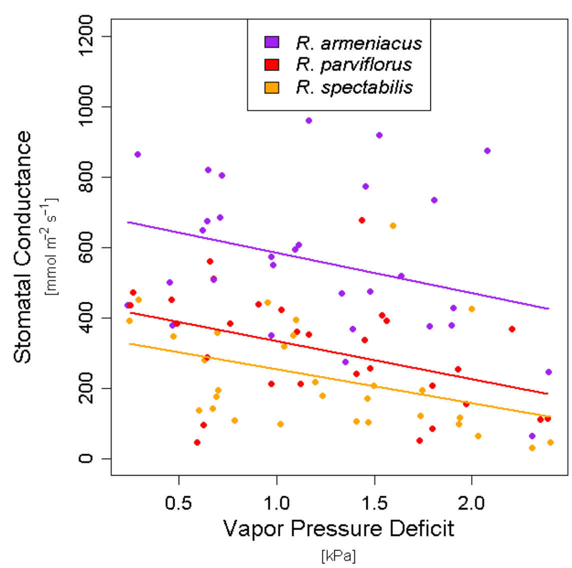

Figure 2. Stomatal conductance (daily mean) as a function of vapor pressure deficit. N=30 stand-days per species.

The greenhouse experiment concluded around March 1, 2008, which coincided with J. Caplan becoming a first-time parent. In addition, we are still awaiting data on carbon isotope levels from the Oregon State University stable isotope lab. Results from this experiment are forthcoming. Our expectation is that *R. armeniacus* had the fastest growth rate and stomatal conductance under both water regimes, and that the difference in these factors between the two treatments was the smallest among the set of species studied. Further, we expect that *R. armeniacus* had a higher water-use efficiency in dry conditions. We also expect to show that morphological characteristics contributed to *R. armeniacus* superior performance in growth and water relations. Key morphological characteristics will likely include a greater investment in roots, a greater capacity for storing water in shoots (seen in cane diameters and pre-dawn water potentials), and/or a greater investment in specific leaf area (leaf area divided per unit leaf mass).

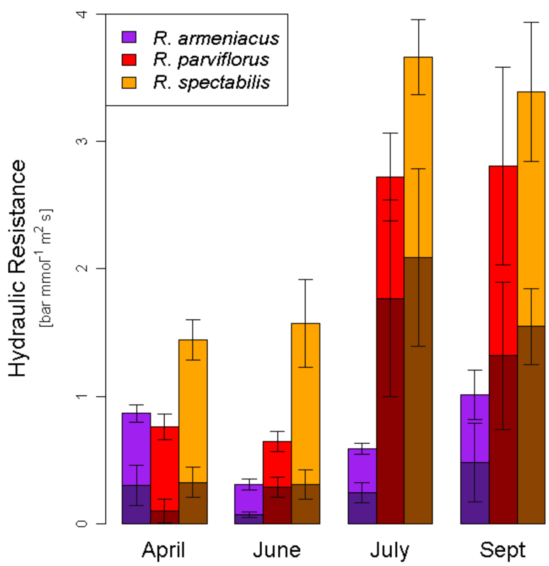

Figure 3. Mean hydraulic resistance by month (±SE). Whole plant resistance is the combination of root (shaded) and shoot (not shaded) resistances. N=8 stands per species.

Discussion: Results from the field study demonstrate that the invasive *Rubus armeniacus* releases water more liberally throughout an increasingly dry growing season even relative to presumably well-adapted native species. At the same time, it appears to remain less water stressed, a factor attributable to advantages in both its root and shoot systems. In combination, these results suggest that *R. armeniacus* can access water that other native congener shrubs cannot. Water relations may therefore enable *R. armeniacus* to maintain the rapid carbon fixation rates its leaves are capable of achieving (McDowell 2002) into the late summer, contributing to its rapid growth.

In sum, our results demonstrate that *R. armeniacus* is capable of both rapid water use when water is widely available, and effective water acquisition when it is in short supply. While rapid resource use is typical of plants invading high-resource communities (Alpert et al. 2000; Davis et al. 2000; Daehler 2003), the additional ability to acquire a resource in low-resource communities is not common among invasive plants (Funk and Vitousek 2007). Our research contributes to the understanding of how extremely successful plants differ from more commonplace weeds (Daehler 2003) and helps to explain why invasive blackberries are abundant in regions with Mediterranean climates (Amor et al. 1998), in urban riparian areas (O'Neill 1999), and in locations with well-drained (often disturbed) soils (Caplan and Yeakley 2006). By extension, natural resource managers may be able to reduce *R. armeniacus* invasion in urbanizing areas by minimizing alterations to native soils and hydrologic regimes. While our data do not directly pertain to conditions east of the Cascade Range, they are consistent with the possibility that *R. armeniacus* could become an increasingly widespread invader in east-side riparian habitats. Future research on other ecophysiological attributes of *R. armeniacus* (cold tolerance foremost among them) would be useful in assessing this risk.

Publications: The two studies funded by this research comprised the greater part of J. Caplan's doctoral dissertation research. J. Caplan gave a talk on the results of Objective 1 (above) at the ESA annual meeting in San Jose in August, 2007. The two dissertation chapters (currently being written) will be submitted soon to peer-reviewed journals for review:

Caplan JS, Yeakley JA. Water relations as a factor in Rubus armeniacus (Himalayan blackberry) invasive success in the Pacific Northwest. Oral presentation. Ecological Society of America, Annual Meeting, San Jose, CA, August 7, 2007.

Caplan JS, Yeakley JA (*in prep*) Water relations as a factor in *Rubus armeniacus* (Himalayan blackberry) invasive success in the Pacific Northwest. *Journal of Ecology.*

Caplan JS, Yeakley JA (*in prep*) Morphological contributions to water relations of invasive *Rubus armeniacus* (Himalayan blackberry) and four native competitors at high and low water availability. *Biological Invasions.*

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Products: No products in addition to publications were produced by this project.

Long Term Goals and Continued Progress: Our original proposal listed two possible long-term objectives of this research, about which we have taken the following actions:

(1) *Assess the risk of R. armeniacus invasion in PNW ecosystems east of the Cascade Range.* This objective continues to be an important issue and a viable research goal, although we are yet a couple of important steps away from being able to address that potentiality. Our more proximal goal is to address the issue of *R. armeniacus* distribution and spread in disturbed riparian areas. We submitted a proposal to NSF (Division of Environmental Biology) entitled "Expansion of an invasive shrub in urban riparian areas in the Pacific Northwest" in January, 2008. Results from that research would have important implications for R. armeniacus invasions in anthropogenically disturbed areas, including those east of the Cascades. We also submitted a pre proposal to USDA-NRI to investigate additional physiological attributes of *R. armeniacus* specifically relevant to its success invasion east-side conditions (e.g., tolerance of cold and ability to recover from cavitation) as well as assessing the habitat conditions under which it can invade. We were invited to submit a full proposal but were unable to get that finished in time for this round. We plan to submit that proposal to USDA-NRI next year.

(2) *Determine how Phragmidium violaceum affects R. armeniacus' water relations and growth.*
After meeting with a USDA-ARS plant pathologist who is investigating the effects *P. violaceum* on *Rubus* spp. and its status in the Pacific Northwest (Dr. Walter Mahaffee, Corvallis, Oregon), we have determined that this is a less viable direction for future research.

Benefits of Seed Money: CIPM seed money was critical to the success of this project. After a theft that occurred one month into the field study, CIPM funds allowed us to replace the main instrument being used to assess plant performance (the leaf porometer). We are very grateful to the grant committee for allowing us to change our budget for purchasing a replacement. CIPM funds enabled us to measure the water-use efficiency of a subset of plants in the greenhouse study (via carbon isotope data). CIPM funds also made important components of the greenhouse study possible, for example, by allowing us to carry out plant propagation at a specialized Oregon State University greenhouse, hire a work study student, and purchase a variety of supplies.

Advancing this Research: As described above under "Long-Term Goals," we are proposing further research both in urban riparian areas and in areas east of the Cascades. Urban riparian areas in western Oregon already have abundant R. armeniacus invasions, while drier areas of eastern Oregon and Washington have yet to see significant invasive blackberry presence. Future research on other ecophysiological attributes of *R. armeniacus* such as cold tolerance would be useful in assessing this risk.

Budget:

As per the budget amendments approved by memo from Director Liz Galli-Noble, here follows an itemized list of costs:

<u>Personnel and Fringe</u>		
Mary Wright salary		183.22
Mary Wright fringe		8.23
	Personnel/fringe total	**191.45**
<u>Operating Expenses</u>		
Supplies		
Porometer		$2,408.33
Irrigation supplies		$86.43
Clippers and tags		$78.72
Optivisor		$57.00
Hydrometer		$49.35
Wooden stakes		$26.55
Wooden stakes, ties		$17.97
Calipers		$17.00
Rite in rain notebook, clipboard		$16.45
Sample bags		$16.00
Wrench for N tank		$14.99
Wooden stakes		$13.23
Pesticides, tote box		$11.98
Plant labels		$11.96
Caddy, pen light		$10.98
Fertilizer sprayer		$9.99
Wooden stakes		$7.35

Cutter, velcro	$5.78
Bolt screws	$4.20
Snap knife, batteries	$3.98
Battery CR-2032	$3.98
Battery 9V	$3.29
Supplies subtotal	**$2,875.51**
Services	
Carbon isotope samples	$792.00
Sensor calibration	$90.37
Services subtotal	**$882.37**
Communications	
Postage - porometer shipping	$9.97
Operating Expenses total	**$3,767.85**
Travel	
Mileage 02/07-07/07	$329.80
Motor Pool 08/07	$155.31
Mileage 02/08	$71.35
Travel total	**$556.46**
Total direct costs	**$4,515.76**
Indirect costs (10%)	**$451.57**
Total costs	**$4,967.33**
Total budget	$4,969.00
Unexpended balance	$1.67

Addendum:

I want to emphasize that we are very grateful to the Center for Invasive Plant Management for this award, and also for working with us during the course of the grant. We hope the products of our work live up to the expectations of CIPM in granting us these funds. We look forward to publishing our results in the peer-reviewed literature, and will be sure to acknowledge the generous support from CIPM in any publication or presentation coming from this work. We will stay in touch and send you copies of reprints as they are produced. Thank you!