1. **USING *MOGULONES BORRAGINIS*, A POTENTIAL BIOCONTROL AGENT FOR HOUNDSTONGUE, AND *CEUTORHYNCHUS CARDARIAE*, A POTENTIAL BIOCONTROL AGENT FOR HOARY CRESS, TO DEVELOP HOST-SPECIFICITY TESTING METHODS BASED ON OLFACTORY AND VISUAL HOST SELECTION BEHAVIOR**

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4. **REQUESTED FUNDS:** $115,000 (Year 1: $57,500 and year 2: $57,500), Project Leveraging: University of Idaho $38,334; USDA APHIS: $77,000 (not reflected in budget); Idaho and Wyoming Counties: $38,000 (not reflected in budget).

5. **PROJECT GOALS AND SUPPORTING OBJECTIVES:** The eventual goal of this project is to receive USDA APHIS **approval to release the seed feeding weevil *Mogulones borraginis*** for the biological control of houndstongue and for the stem galling weevil *Ceutorhynchus cardariae* for the biological control of hoary cress. We intend to accomplish this through the **development of host-specificity testing methods based on the olfactory and visual host selection behavior** of *M. borraginis* and *C. cardariae*. This project will develop or refine host range testing for potentially all biological control agents (BCIP Project Priority No. 1) by providing a new level of experimental host-specificity data for *M. borraginis*, and developing and refining a process which can universally be applied to improve host range predictions for biocontrol candidate species (pre-release) and non-target risk assessments of released biocontrol agents (post-release). This project has four objectives:

   Objective 1: We have developed and will optimize a **new method to nondestructively collect and store** the scent, that is floral and leaf **volatile organic compounds (hereafter VOCs)** of herbaceous plant species in the field. In the context of weed biocontrol this is of particular importance for sensitive rare and federally threatened or endangered (hereafter T&E) listed confamilial plant species of a target weed, especially those T&E species, which cannot be propagated in the greenhouse because these species could not be tested in the past.

   Objective 2: We will conduct **host-choice behavioral trials** with *M. borraginis* **simultaneously combining olfactory and visual cues** in a newly developed **Double Stacked Y-tube Device** (hereafter D-SYD) using native confamilial T&E and sensitive plant species. For chemical cues we will used the stored filed collected VOCs (Objective 1) and potted plants (for those

T&E species that we can propagate under greenhouse conditions). For visual cues, we will use fresh flowers from propagated greenhouse plants or collected in the field and ice-stored.

Objective 3: We will conduct analyses to better interpret the findings of the host selection behavior trails (Objective 2). To do so, we will conduct simultaneous **electroantennography (EAG) flame ionization detector (FID) gas chromatography-mass spectrometer (GC-MS)** trials, which will allow us to identify those VOCs, to which the weevil antennae react. Analogous, we intend to conduct **electroretionography (ERG)** using a monochromator (an optical device that transmits a mechanically selectable narrow band of wavelengths of light) to identify specific wavelengths to which the insect compound eye retinas react. Those wavelengths will be compared to measured wavelength spectra reflected by rare and T&E plant species flowers.

Objective 4: We will conduct all research outlined in Objectives 1 – 3 with a second weed biocontrol candidate system using the stem galling weevil *C. cardariae* considered for the biological control of hoary cress, *Lepidium draba*. Similar to *M. borraginis,* we have much conventional host-specificity data available for the weevil and it demonstrates a disjunct host range, which makes it an ideal candidate for the research outlined in objectives 1- 3. This objective will not only provide additional data to strengthen the proof-of-concept but will also potentially result in a permit for release of *C. cardariae* against hoary cress in North America.

Combined, the objectives will provide a comprehensive and unique set of data on the host selection behavior of *M. borraginis* and *C. cardariae.* With this research, we may also be able to explain the commonly experienced differences in weed biocontrol exploration programs between the fundamental and realized host range of candidate biocontrol agent species. The data set will be submitted to the Technical Advisory Group as supplemental and supporting material for the respective petitions to release *M. borraginis* and *C. cardariae* in the United States.

6. **PROJECT JUSTIFICATION/URGENCY:** The importance of host choice behavioral chemical ecological data to more reliably and convincingly ensure the environmental safety of a proposed weed biological control agent will only increase with the level of scrutiny being placed on weed biocontrol agent petitions by USDA APHIS (An invited review article on the importance of chemical ecology in classical biological control of weeds is currently in preparation by Wheeler and Schaffner and will be submitted to the Journal of Invasive Plant Science and Management on 30 November 2011). This project will employ exciting new technology and methodologies to strengthen the petition for release of the seed-feeding weevil *Mogulones borraginis* Fabricius (Coleoptera, Curculionidae), a prospective biocontrol agent for houndstongue, *Cynoglossum officinale* L. in the United States. Once the potential of these insect behavioral and chemical ecological techniques to assist researchers characterizing the host specificity of potential biocontrol agents has been demonstrated, the methodologies will likely be used in future biocontrol programs.

Houndstongue is a facultative biennial or short-lived perennial native to Europe and western Asia (de Jong et al. 1990). It was first introduced to North America in the 1800s (Brand 1921, Upadhyaya et al. 1988) and has spread to eight Canadian provinces and 44 states in the U.S. (USDA NRCS 2010). It infests forests, rangeland, pastures, roadsides and waste places

(Dickerson and Fay 1982). Established populations displace valuable range species, decreasing forage availability for grazing (Upadhyay*a* et al. 1988*)*. Rangeland value is further decreased by the high toxicity of *C. officinale* to grazing animals (Upadhyaya and Cranston 1991, and references therein). Each plant produces large quantities of burred nutlets that are readily transported by animals and humans alike (Svensson and Wigren 1990, De Clerck-Floate 1997). Nutlets not only spread this weed great distances, but they also interfere with the health and marketability of vectoring livestock (Upadhyaya and Cranston 1991.

In the state of Wyoming houndstongue has been documented encroaching and competitively excluding *Gaura neomexicana* ssp. *coloradensis* (Rydb.) P.H. Raven & Gregory, a species federally listed as "threatened" the United States (Fertig and Arnett 2001). In *G. n.* ssp. *coloradensis*'s original listing determination noxious weeds were identified as posing one of the greatest threats to this species (Federal Register 62302, October 18, 2000). Petitioners recognized the need to control noxious weeds in order to protect *G. n.* ssp. *coloradensis*, but highlighted the susceptibility of *G. n.* ssp. *coloradensis* to commonly used herbicides, and urged the exploration of alternative control methods, including biological (Federal Register 62302, October 18, 2000). Given the acreage *C. officinale* currently inhabits in North America, additional negative effects on other co-occurring, threatened and endangered species is likely.

Not only does *C. officinale* impact native sensitive species directly through competition and possible allelopathy, but this weed excludes the plant hosts of species dependent on the natives for food, reproduction or shelter. In addition, when *C. officinale* is pollinated (primarily by bees, de Jong et al. 1990 and references therein), pollination services occur at the expense of the native true hosts of pollinators.

Proposed action: The seed-feeding weevil *Mogulones borraginis* Fabricius (Coleoptera, Curculionidae) was first discovered during foreign exploration efforts in 1993 at houndstongue field sites in southern Hungary. The weevil is federally protected in many European countries and is considered extremely rare. However, its rarity is largely assumed to be due to a specialist Braconid parasitoid. Consequently, in the absence of that parasitoid in the United States, *M. borraginis* has the potential to reach outbreak densities. Adult weevils emerge in spring and commence feeding on the developing stem and later on the buds and flowers of houndstongue. Females lay eggs into the developing fruit of houndstongue and one larva will typically consume all four developing nutlets within a fruit tetrad. Adult weevil feeding on flowers and larval feeding within the fruit impacts the seed production of houndstongue equally. The weevil reduced seed production under controlled conditions by approximately 50%. Because the population biology of houndstongue is seed limited, it is assumed that the weevil can greatly impair the population dynamics of houndstongue.

Mogulones borraginis has consistently been demonstrated to be far more specific than other biocontrol candidate species for *C. officinale*. All host-specificity data has been summarized in a petition for release of the insect in the United States to the Technical Advisory Group (hereafter TAG). Because of the increased scrutiny with which USDA APHIS currently reviews weed biocontrol petitions, we see the need to provide supplemental data on the host selection behavior of *M. borraginis* to TAG and USDA APHIS to convince the regulatory agency that this insect is indeed absolutely environmentally safe for release in the U.S. In anticipation of permission to release the weevil in the field we have selected approximately 20 permanent release sites in

Idaho and Oregon at which we collect pre-release plant community data using the Standardized Impact Monitoring Protocol (SIMP).

7. **APPROACH:**

Test plant species and insects: We have obtained research permits from respective state and federal agencies and received seed material to grow all five T&E listed plant species in the Boraginaceae family. These are *Amsinckia grandiflora, Cryptantha crassipes, Hackelia venusta, Plgiobothrys strictus,* and *P. hirtus.* We also have permission to visit field populations for VOC collections for each species from agencies. We are propagating other native confamilial species of *C. officinale,* either because they are rare, e.g. the single population *Dasynotus daubenmirei* or because they have large fruit and/or were not included in previous host range tests, e.g. *Cynoglossum virginianum, Hackelia californica.* All plant species (that can be propagated) are maintained along with potted *C. officinale* plants at a greenhouse at the University of Idaho. We maintain a colony of ***M. borraginis*** at the Northwestern Biological Control Insectary and Quarantine (hereafter NWBIQ) at Washington State University, and all tests that require living weevils (behavioral trials) are conducted at that facility. All electrophysiological experiments and chemical analyses are being conducted at the University of Idaho chemical ecology laboratory (Eigenbrode lab) using insect weevil heads only.

Objective 1: PVCS: The Portable Volatile Collection System (PVCS) was designed especially for collecting floral and leaf volatile organic compounds (VOCs) in the field (see Appendix I for a description of PVCS). The main advantages of using PVCS is the: 1) light weight (3.5 lbs), 2) ability to simultaneous collect VOCs from multiple neighboring plant individuals under identical air pressure, 3) non-destructive nature of the method, and 4) possibility to test an insects' behavioral response to a VOCs from individual T&E listed plants that otherwise could not be tested.

Objective 2: Semiochemicals are considered the principal communication systems in insect-plant interactions and are especially affecting the host selection behavior of herbivorous insects in response to different olfactory cues. However, visual cues also play a significant role in insect foraging behavior for suitable host plants (Reeves, 2011). For this reason, we designed the **Double Stacked Y-tube Device (D-SYD)**, a portable apparatus for assessing behavioral responses of a weed biological control candidate agent to given olfactory or visual cues or both cues simultaneously (see Appendix I for a description of D-SYD). D-SYD will be used for behavioral bioassays of *M. borraginus* to olfactory cues from eluted VOCs from PVCS (Objective 1). If a *M. borraginus* weevil does not reach the decision line after 5 minutes, it will be recorded as non-responding individual (NI). There will be three replications for each bioassay. For statistical analysis, we will perform Chi-square goodness-of-fit test (PROC FREQ, SAS statistical software v.10, SAS Institute, Cary, NC). For each test plant species, we will perform four bioassays with *C. officinale* (control): 1) olfactory cues from the test plant and control, 2) visual cues from the test plant and control, 3) olfactory and visual cues from test plant and control, and 4) potential permutations. The host-choice behavioral data collected under objective 2 will be summarized as supplemental data and submitted to TAG and USDA APHIS.

Objective 3: To further analyze *M. borraginus* host selection behavior we will conduct simultaneous **gas chromatography with electro antennographic detection (GC-EAD) trials** (see Appendix I for a description of the GC-EAD experimental setup). Analogous, we will conduct **electroretinogram (ERG) trails using a monochromator** to measure to which wavelengths the retinas of *M. borraginis* compound eyes react with an electric signal. We will compare response between female and male weevils to identify sensitive wavelengths that may affect the host selection of *M. borraginis* (see Appendix I for a brief description of the ERG experiments). And we intend to conduct **floral reflectance spectra measurement for all test plant species** (see Appendix I for a description of the floral reflectance spectra measurements). We will then compare floral reflectance spectra with the results of the ERG experiments and the behavioral bioassays from D-SYD (Objective 2) to identify which wavelengths are associated with the host selection behavior of *M. borraginis* and whether native non-target plant species reflect respective wavelengths.

8. **EXPECTED PRODUCTS AND OUTCOMES:**

The methods and technologies developed in this project will be published in **3 refereed journal articles** (on PVCS, D-SYD and ERG). This project will provide novel and comprehensive data on the host selection behavior of the biocontrol candidate species *M. borraginis.* The data set will **be submitted to TAG and USDA APHIS as supplemental material for the petition to release the biocontrol agent** for *C. officinale* in the United States. This project will **provide the necessary data to obtain the permission for field release of *M. borraginis*** and we intend to be able to release the agent within or immediately after the conclusion of this 24-months project. As an added synergism, we anticipate that some or all methodologies developed in this project will be used commonly in host-specificity testing programs in the future. To illustrate this point, the USDA ARS has already asked us whether we could conduct D-SYD and GC-EAD tests with another candidate weed biocontrol agent, the root weevil *Ceratapion basicorne* for the biological control of *Centaurea solstitialis* which was initially rejected by USDA APHIS for release in the United States.

APPENDIX I: Description of methods to be employed and preliminary results

The Portable Volatile Collection System (PVCS) consists of three major parts: a polyvinyl acetate bag, a push-pull pump, and two pairs of push-pull flowmeters. We chose a polyvinyl acetate bag for floral VOC collections because it was the most commonly used material (Steward-Jones and Poppy, 2006). Using a vacuum sealer, it is possible to make various sizes of a polyvinyl acetate bag. Also, carrying and using glass can be complicated especially under field conditions. A Rena Air 400 pump (Mars Inc. Hackettstown, NJ) will be modified to create a push-pull pump by switching the direction of diaphragms within the pump assemblage. Then, two pairs of flowmeters were connected to the outlets of the pump via a Teflon® Y-splitter. Pure air, filtered by an activated charcoal filter, will enter a polyvinyl acetate bag while volatile will be trapped in Toyopearl Super-Q adsorbent resin (Tosoh Bioscience LLC, King of Prussia, PA). Floral headspace VOCs with control will be collected for 3 hours at 300 ml per minute in the field. The trapped VOCs will be eluted with dichlomethane to make 200 µl solutions and will be stored at 4°C until further use. Heat and humidity in a glass chamber or a polyvinyl acetate bag would increase in a static headspace volatile system (Tholl et al, 2006). Alternatively, in our dynamic headspace volatile system, the push-pull pump maintains constant air flow between air outlet and inlet in the enclosed polyvinyl acetate bag, and thus sensitive T&E plant will endure less stress during the 3-hour VOC collection time.

Double Stacked Y-tube Device (D-SYD) is a portable apparatus for assessing behavioral responses of a weed biological control candidate agent to given olfactory or visual cues or both cues simultaneously. D-SYD consists of two glass y-tubes. For assessing responses to olfactory cues, the two arms of the top glass Y-tube will be connected to plastic caps in which a filter paper (2 mm^2) is placed for injection of 2 µl of eluted VOCs from PVCS (Objective 1) for behavioral bioassays. Each plastic cap is connected to a push-push pump via Tygon tube (diameter: 3 mm, length: 450 mm, Murdock Industrial Inc. Akron, OH). For assessing visual cues, the identical size bottom glass Y-tube is placed under the top Y-tube. Fresh leaves and/or flowers of test plants will be placed in one arm and the control or a standardized shape of leaves/flowers in the other arm. For each test plant species, *M. borraginis* weevils (n=40; males=15, females=25) will be placed on the tip of the bottom part of the top glass Y-tubes and will be monitored for 5 minutes. For VOCs in the top Y-tube flow rate will be kept at 10 ml per minute. The D-SYD will be covered with a white plastic dome (40 by 30 by 20 cm) to prevent any potential distraction. A single LED light source will be used and will be the sole light source in the laboratory during trials. The top glass Y-tube will be cleaned using 70% ethanol every two trials and it will be rotated 180 degrees every five trials to prevent potential false negative/positive results. If a weevil doesn't reach to the decision line (5 cm from the bifurcation point in each arm within the top glass Y-tube) after 5 minutes, it will be recorded as non-responding individual (NI).

In preliminary tests, D-SYD itself did not affect the behavioral response of *Mogulones borraginis* (χ^2 =0.66^{ns}, n=24). However, *M. borraginis* distinguished between *C. officinale* and its native North American congener *Cynoglossum occidentale* when only visual cues were tested (χ^2 =7.00, p<0.001, n=24). Using olfactory cues only, *M. borraginis* also distinguished *C. officinale* from its sensitive native congener regardless of whether potted plants or PVCS VOCs were used (location on *C. officinale* compared to *C. occidentale* using VOCs from potted plants: χ^2 =15.36, p<0.001, n=44; and eluted VOCs from PVCS: χ^2 =11.56, p<0.001, n=25).

Gas chromatography with electro antennographic detection (GC-EAD) trials. For this *M. borraginis* adults will be decapitated and the heads will be cooled on ice and transported within 20 minutes to the University of Idaho, where the antennae will be placed between two Tungsten electrodes which measure electric voltage deflections as response to VOCs over time (Figure 1). Simultaneously, the composition and content of VOCs will be analyzed using an Agilent 6890N gas chromatograph–mass spectro-meter (Agilent Technologies, Santa Clara, CA) and responses of the weevil antennae can be traced to specific components in VOCs (Figure 1).

Analogous to the GC-EAD trails we will conduct e**lectroretinogram (ERG) trails using a monochromator.** Five pairs of female and male adult *M. borraginis* will be decapitated and placed on electrically conductive gel (Spectra 360, Parker Laboratories, Fairfield, NJ) in a dark room for 10 minutes prior to ERG recording (Syntech, Netherlands). The tungsten electrode tip will be connected on a compound eye of *M. borraginis* while the reference electrode tip will be placed on postocciput (a connection between the head and prothorax) of the weevil. Then, 10 nm wavelengths from 300 nm to 700 nm will be projected for 1 second from a monochromator into the compound eye of *M. borraginis* to produce electrical signals. An interval between stimulated lights will be 90 seconds. We will compare response from each wavelength between female and male weevils to identify sensitive wavelengths that may affect the host selection of *M. borraginis.* We will compare this data with results obtained from **floral reflectance measurement for all test plant species:** Once sensitive wavelengths for female and male weevils were identified from ERG trials, we will compare these to floral reflectance spectra of *C. officinale* and the native North American non-target test plant species using a GER 2600 spectroradiometer (GER Corp., Millbrook, NY). The spectroradiometer can measure spectra between 300 nm and 2500 nm and is designed for use in the field (lightweight and battery-operated). An optic fiber (1.5 m) will be used to vertically measure a white reference plate (10 cm^2). Then, petals of *C. officinale* will be masked using a non-glossy black plate (5 cm^2) with an aperture (diameter: 6mm) at the center. Through comparison with the reference the reflectance spectra will be produced for the petal. The white reference plate will be measured every 10 minutes for normalization. For each test plant species, three flower petals from each of four individual plants will be used. There will be three replications for each measurement. We will compare floral reflectance spectra between 300 nm and 700 nm with both, the results of the ERG trials and the behavioral bioassays from D-SYD (Objective 1) to identify which wavelengths are associated with the host selection behavior of *M. borraginis* and whether non-target plants reflect respective wavelengths.

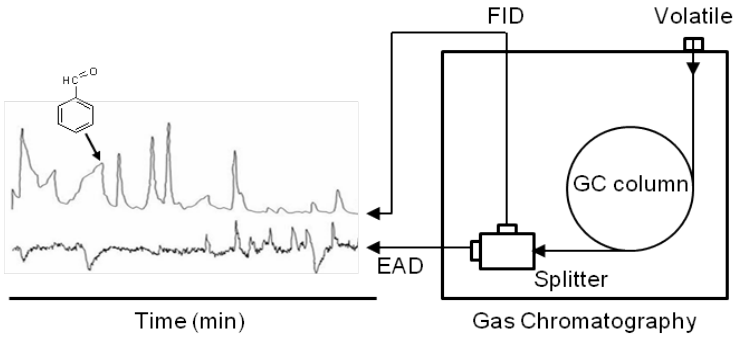

Figure 1. GC-EAD/FID with GC-MS: A total of 1 µl headspace volatile elution from *C. officinale* or any test plants will be injected into the injection port so that its components will be separated in the gas chromatography (GC) column due to different retention times. Each component will be bifurcated in the splitter. 90% will be directed towards the flame ionization detector (FID) and 10% towards the electroantenno-detector (EAD). The results are two signals: retention time peaks from the FID (upper signal line) and electrical signals from the EAD (lower signal). Thereafter, each component in the FID trace that matches an electrical signal (in this case benzaldehyde) generated from the insect antennae will be identified using gas chromatography-mass spectrometer (GC-MS).

APPENDIX II: Timeline

2012											
	Test plant & weevil propagation							Test plant propagation			
			VOC collections (Objective1)								
			Behavioral trials D-SYD (Objective 2)					BM1			
					GC-EAD & ERG (Objective 3)						
2013											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	Test plant & weevil propagation							Test plant propagation			
			VOC collections (Objective1)								
			Behavioral trials D-SYD (Objective 2)					BM2&3			
					GC-EAD & ERG (Objective 3)						
2014											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	Test plant & weevil propagation										
		BM4&5	Weevil releases								
			Field monitoring								

Anticipated project period is **04/01/2012-03/31/2012**. Benchmarks (BM) as follows: **BM1**, submission of publication on PVCS (portable volatile collection system); **BM2**, Submission of supplemental host-choice behavior data to TAG and USDA APHIS in support of the petition; **BM3,** submission of publication on D-SYD (double stacked y-tube device); **BM4,** submission of publication of GC-EAD and ERG; **BM5**; final project report to USFS FHP.

APPENDIX III: References

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APPENDIX IV: Budget estimates

Year 1	**University of Idaho Matching Funds**	**Funds provided by USFS FHP FHTET**
SALARY AND FRINGE (Ikju Park & Jessica Rendon) 20 months graduate Research Assistantship (@ $2,250/month) + 1% fringe/benefit ($20.50/month)		$45,000.00 $450.00
OPERATIONAL EXPENSES Analytical costs for VOC by GC/MS: 300 samples @ $15 ($4500); laboratory consumables and chemicals for GCMS and VOC sample collections: $1,000; partial support for bench fees for space at NWBIQ quarantine ($3,000); field supplies ($320)		$8,820.00
TRAVEL Reimbursement for private vehicle mileage for travel to field sites to collect VOCs @ $0.455/mile for 2,703 miles ($1,230)		$1,230.00
EQUIPMENT Partial support for purchase of new NIST mass spectral database ($2000)		$2,000.00
INDIRECT COST (45.2% partially waived as not allowed under this agreement $11,117); partial salary Schwarzlaender plus Indirect Cost ($5,539 and $2,511)	$11,117.00 $5,539.00 $2,511.00	
SUBTOTALS	**$19,167.00**	**$57,500.00**

Budget Justification Year 1:
Salaries: 20 months graduate Research Assistantship @ $2,250/month and 1% fringe/benefit @ $20.50/month ($45,000 and $450).
Operational Expenses: Analytical costs for VOC by GC-MS for 300 samples @ $15/sample ($4,500); laboratory consumables and chemicals for GC-MS analysis, S-SYD trials and VOC sample collections ($1,000); contribution to annual bench fee ($10,000) for NWBIQ quarantine @ 30% of annual fee ($3,000); miscellaneous field supplies ($320).
Travel: Partial reimbursement for repeated field trips travel to field sites in OR, WA, ID and CA to collect VOCs at $0.455 per mile for approximately 2,703 miles ($1,230).
Equipment: Partial contribution to support purchase of National Institute for Standards and Technology (NIST) Atomic Spectra database for GC-MS analysis of VOC ($2,000).
University of Idaho Cost Sharing: Partially waived Indirect Costs @ 45.2% ($11,117); and as RFP mandated partial matched salary of Principal Investigator Schwarzlaender (@ $5,539 plus Indirect Costs $2,511).

Year 2	**University of Idaho Matching Funds**	**Funds provided by USFS FHP FHTET**
SALARY AND FRINGE (Ikju Park & Jessica Rendon) 12 months graduate Research Assistantship (@ $2,250/month) + 1% fringe/benefit ($20.50/month)		$45,000.00 $450.00
OPERATIONAL EXPENSES Analytical costs for VOC by GC/MS: 200 samples @ $15 ($3000); laboratory consumables and chemicals for GCMS and VOC sample collections: $1,000; partial support for bench fees for space at NWBIQ quarantine ($3,000)		$7,000.00
TRAVEL Reimbursement for private vehicle mileage for travel to field sites to collect VOCs @ $0.455/mile for 2,703 miles ($1,230)		$1,230.00
EQUIPMENT Replacement cost laptop computer ($2000), photo equipment ($1820)		$3,820.00
INDIRECT COST (45.3% partially waived as not allowed under this agreement $11,117); partial salary Schwarzlaender plus Indirect Cost ($5,539 and $2,511)	$11,117.00 $5,539.00 $2,511.00	
SUBTOTALS	**$19,167.00**	**$57,500.00**

Budget Justification Year 2:
Salaries: 20 months graduate Research Assistantship @ $2,250/month and 1% fringe/benefit @ $20.50/month ($45,000 and $450).
Operational Expenses: Analytical costs for VOC by GC-MS for 200 samples @ $15/sample ($3,000); laboratory consumables and chemicals for GC-MS analysis, S-SYD trials and VOC sample collections ($1,000); contribution to annual bench fee ($10,000) for NWBIQ quarantine @ 30% of annual fee ($3,000).
Travel: Partial reimbursement for repeated field trips travel to field sites in OR, WA, ID and CA to collect VOCs at $0.455 per mile for approximately 2,703 miles ($1,230).
Equipment: Costs for laptop computer equipment/replacement ($2,000), and equipment for macro/microphotography ($1,820).
University of Idaho Cost Sharing: Partially waived Indirect Costs @ 45.3% ($11,117); and as RFP mandated partial matched salary of Principal Investigator Schwarzlaender (@ $5,539 plus Indirect Costs $2,511).

APPENDIX V: Biosketches

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Professional Preparation

Cornell University, Neurobiology and Behavior B. Sc., 1970
Cornell University, Natural Resources, M. S., 1986
Cornell University, Entomology, Ph. D., 1990
University of California, Riverside, Entomology, Post doctoral, 1990-1993
University of Arizona, Tucson, Entomology, Post doctoral, 1993-1995

Appointments

2006-date: Professor and Chair of Entomology, University of Idaho
2004-2006: Associate Professor and Chair of Entomology, University of Idaho
2001-2006: Associate Professor of Entomology, University of Idaho
1995-2001: Assistant Professor of Entomology, University of Idaho

Expertise

Insect ecology, insect chemical ecology and behavior, virus-insect-plant interactions, landscape ecology, agroecology, climate-change agroecology, tropical agroecology, interdisciplinary studies.

Recent Significant Publications (total of 105)

Bosque-Pérez, N. A., and S. D. Eigenbrode. 2011. The influence of virus-induced changes in plants on aphid vectors: Insights from luteovirus pathosystems. Virus Res. 159: 201-205.

Looney, C.N., S. D. Eigenbrode. 2011. Landscape-level effects on cynipid component communities of "orphaned" native shrubs. Journal of Insect Conservation, DOI 10.1007/s10841-010-9369-0

Varón, E., S. D. Eigenbrode, N. A. Bosque-Pérez, L. Hilje, and J. Jones. 2011. Coffee farm diversity and landscape features influence density of colonies of Atta cephalotes (Hymenoptera: Formicidae). J. Econ. Entomol. 104: 164-172.

Vemulapati, B., Druffel, K.L. , S. D. Eigenbrode, A. Karasev, and H. R. Pappu. 2010. Molecular characterization of Pea enation mosaic virus (genus Enamovirus) and Bean leaf roll virus (genus Luteovirus) from the Pacific Northwestern USA. Arch. Virol. 155: 1713-1715.

Crowley, S., Eigenbrode, S. D., O'Rourke, M., Wulfhorst, J.D. 2010 Cross-disciplinary localization: a philosophical approach. Multilingual. Web only article: http://www.multilingual.com/downloads/114LCDR.pdf

Recent Grants and Contracts (career 39 projects, total funding = $26,410,000):

Regional Approaches to Climate Change for Pacific Northwest Agriculture. Eigenbrode, S.D. and 19 other PIs from Washington State University, Oregon State University and the Agricultural Research Service of the USDA. National Institute for Food and Agriculture CAP program, $20,000,000, Award No. 2011-68002-30191

Dryland Agriculture's Impact on Soil Carbon Storage: Targeting Key Knowledge Gaps, Jodi Johnson-Maynard, Huggins, D., Mahler R., Eigenbrode, STEEP, 2010, $48,807

MARK SCHWARZLÄNDER

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Professional Preparation

University of Kiel, Germany, Biology M. Sc., 1993
University of Kiel, Germany, Biology, Ph. D., 1999

Appointments

2007-date: Associate Professor, Co-Director of CRISSP
2000-2007: Assistant Professor of Entomology, University of Idaho
1997-2000: Research Scientist, CABI Europe – Switzerland

Expertise

Biological weed control, insect herbivory, insect ecology, insect behavior, plant population biology, plant ecology, interdisciplinary studies.

Recent Publications (total 36; *graduate students)

Hinz, H.L., Schwarzländer, M., McKenney, J.L.*, Cripps, M.J.*, Harmon, B., Price, W.J. Biogeographical comparison of the invasive *Lepidium draba* in its native, expanded and introduced range. *Biological Invasions.* Accepted.

Gaskin, J.F., Schwarzländer, M., Williams, L., Gerber, E., Hinz, H.L. Genetic diversity and mode of seed production in invasive perennial pepperweed. *Biological Invasions.* Accepted.

Szucs, M.*, Schwarzländer, M., Gaskin, J.F. 2011. Reevaluating establishment and potential hybridization of different biotypes of the biological control agent *Longitarsus jacobaeae* using molecular tools. *Biological Control* 58: 44-52.

Puliafico, K.P.*, Schwarzländer, M., Price, W.J. Harmon, B.L., Hinz, H.L. 2011. Native and Exotic Grass Competition with Invasive Hoary Cress (*Cardaria draba*). Invasive Plant Science and Management, 4(1): 38-49.

Newcombe, G., A. Shipunov, S. D. Eigenbrode, A. K. H. Raghavendra, H. Ding, C. L. Anderson, R. Menjivar, R. Crawford, Schwarzländer, M. 2009. Endophytes influence protection and growth of an invasive plant. *Communicative and Integrative Biology,* 2: 249-251.

Cripps, M.G*., McKenney, J.L.*, Hinz, H.L., Price W.J., Schwarzländer, M. 2008. No evidence for an 'evolution of increased competitive ability' for the invasive *Lepidium draba. Basic and Applied Ecology* 10(2): 103-112.

Eigenbrode, S.D., Andreas, J.E.*, Cripps, M.G.*, Ding, H., Biggam, R.C., Schwarzländer, M. 2008. Induced chemical defenses in invasive plants: a case study with *Cynoglossum officinale* L. *Biological Invasions* 10: 1373-1379.

Lau, J.A., Puliafico K.P*., Steltzer, H., Jarvis, E.P., Schwarzländer, M., Strauss, S.Y., and Hufbauer, R.A. 2008. Influence of alleopathy is complicated by effects of activated carbon on plant growth. *New Phytologist* 178(2): 412-423.

Recent Grants and Contracts (career 89 projects, total funding $2,165,000):

Mark Schwarzlaender. $31,250. Biological Control Development and Outreach – Cooperative Agreement. USDI BIA Rocky Mountain Regional Office. 06/01/10-12/31/12.

Mark Schwarzlaender. $38,500. Risk assessment and monitoring of target and nontarget plant utilization by the houndstongue root weevil *Mogulones cruciger* Hbst. (Coleoptera, Curculionidae) in northern Washington and Idaho – Cooperative Agreement. USDI APHIS PPQ CPHST. 07/01/10-06/30/11.

IKJU PARK

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Professional Preparation

Chungbuk National University, South Korea, Agricultural Biology, B.S., 2007
New Mexico State University, New Mexico, Agricultural Biology, M. Sc., 2010
University of Idaho, Entomology, Ph.D., *Expected Graduation - May 2014*

Honors & Awards (for last three years)

2011 Best Student Oral Presentation, 13th ISBCW, Waikoloa, HI
2011 Student Winner in Insect Photo Salon, PBESA meeting, Waikoloa, HI
2011 Student Runner-up in Insect Photo Salon, PBESA meeting, Waikoloa, HI
2011 Student Honorable Mention in Insect Photo Salon, PBESA meeting, Waikoloa, HI
2010 Graduate Dean's Award of Excellence, New Mexico State University, Las Cruces, NM
2010 ESA Linnaean Games Competition First Place, SWB meeting of ESA, Cancun, Mexico
2009 First President's Prize in Biological Control, Annual ESA meeting, Indianapolis, IN
2009 Master's Display Presentation Third Place, SWB meeting of ESA, Stillwater, OK

Teaching Experience

2008–2009 New Mexico State University, Las Cruces, NM, USA; EPWS 325G: Humans, Insects and the Environment

Research Presentations (last three years)

Park, I., Schwarzländer, M., and Eigenbrode, S. 2011. The use of chemical ecology to improve pre-release and post-release host range assessments for potential and released biological control agents of *Cynoglussum officinale*. 13th International Symposium of Biological Control of Weeds, Waikoloa, HI, USA.

Park, I., Schwarzländer, M., and Eigenbrode, S. 2011. Chemical ecology approaches for the host range assessment of *Mogulones borraginis*, a biocontrol agent for houndstongue. PBESA meeting, Waikoloa, HI, USA.

Park, I.J., Schwarzländer, M., and Hinz, H.L. (2010). Chemical ecology tools to improve prediction of the host range of *Mogulones borraginis*, a potential biocontrol agent for houndstongue. Northern Rockies Invasive Plant Council, Coeur d'Alene, ID, USA.

Park, I.J., Beuhler, H., Sanogo, S., & Thompson, D.C. (2010). Biology of *Asphondylia prosopidis* complex (Diptera: Cecidomyiidae) and its fungal associates: potential biological control candidates for South African mesquite. 58th SWB meeting of ESA, Cancun, Mexico.

Park, I.J., & Thompson, D.C. (2009). Phylogeny of mesquite gall midge complex in the southwestern U.S. and its relationship with ambrosia fungi. 57th annual meeting of ESA, Indianapolis, IN, USA.

Park, I.J., Thompson, D.C., Sanogo, S., and Beuhler, H. (2009). Biology of *Asphondylia prosopidis* complex (Diptera: Cecidomyiidae) and its fungal associates: potential biological control candidates for South African mesquite. 57th annual meeting of ESA, Indianapolis, IN, USA.