Applicant Overview

1. Project Title: **Experimental investigation of the effects of deficit irrigation on plant vigor, floral display and insect interactions in California landscape plants**

2. Project total Budget: **$24,989**

3. Applicant Organization: **University of California, Davis**

4. Applicant address: **43 Briggs Hall, Davis, CA**

5. Project location: **Davis, CA**

6. Principal Investigator(s): **Rachel Vannette, Haven Kiers, Louie Yang, David Fujino**

7. Project Manager name and contact information (person responsible for all submissions and reporting): **Rachel Vannette**

8. Cooperating Entities (other organizations involved in this project): **University of California, Davis, College of Agricultural and Environmental Sciences, Departments of Biological and Agricultural Engineering and Human Ecology, UC Davis Arboretum and Public Gardens and California Center for Urban Horticulture; Horticulture Industry Stakeholders (California Flora Nursery, Hedgerow Farms, Netafim, Hunter Industries, Scotts Miracle-Gro, Ewing Irrigation, Baseline System, Agromin, Garden Enlightenment)**

Executive Summary

1. Project Summary: Please provide a summary of your proposal that briefly identifies the problem and your proposed solution addresses the problem. **200 words or less**

Encouraging the planting of water-conserving species for ornamental and landscape use is a key goal in California and other drought-prone areas. One challenge with landscape plants is determining to what extent low-water irrigation influences plant survival and attractiveness, including for beneficial insects like pollinators. Here, we propose to install a replicated irrigation experiment in a public space to examine effects of irrigation treatments on native landscape plant species and their performance in a landscape horticulture context. This project spans research and outreach in a number of ways. Our general research questions include 1) how do different watering regimes influence the growth and phenology of landscape plants and their floral display? 2) how do different watering regimes influence visitation of plants by beneficial insects, including pollinators? Our outreach goals include 1) engaging future horticultural leaders in an internship program to plan, install and maintain the exhibition experiment and 2) engaging classes at UCD and public audiences in landscape plants and water use. To achieve these goals, we will install plants into 15 plots, where three irrigation levels will be replicated five times. Plant species will be monitored for survival, floral display and phenology, and interactions with beneficial insects.

2. Does this project address one of the four identified research and education priorities of the SHRE? Please visit our website at http://ucanr.edu/sites/SaratogaHort/Call_for_Proposals/ to review the priorities. If yes, identify which priority(s) and briefly describe how your proposal addresses the priority(s**). 100 words or less**

This project addresses multiple priorities including: *(2)* Researchers and students will examine effects of three irrigation levels on the performance and display of multiple plant species for use in the landscape horticulture context. Signage designed by student interns will engage audiences on water-conserving landscape plants. We address (3) by assessing suitability of landscape plants to perform under reduced irrigation and *(4)*: Our experimental setup will allow us to link specific deficit irrigation treatments based on MWELO guidelines to soil moisture and plant performance metrics in an experimental and active landscape context.

Needs and Outcomes
In this section, you will identify how your project will address specific needs of the horticulture industry and what results you expect from working on the project. Please state each need and outcome separately to a maximum of four pairs.

Need 1: Use scientifically robust methods to assess effects of reduced irrigation on plant performance in a landscape horticulture context.

Outcome 1: Our project will install a long-term irrigation experiment that can be used to quantify effects of reduced irrigation (and validated using soil moisture sensors) on plant survival and performance in a landscape context. We will assess effects of three irrigation treatments (very low, low, and medium per WUCOLS IV) on plant survival, flowering phenology, display and duration, and beneficial insect visitation to multiple California native plant species of interest for landscape horticulture.

Need 2: Encourage the transition to more water-conserving plant species for ornamental use

Outcome 2: Our project will install this replicated experiment in a high-visibility area of campus. Further, we will highlight the experiment to multiple audiences by: 1) by engaging student groups with plot design and installation, 2) employing student interns for data gathering, and 3) highlighting our plantings in public outreach events, including producing signage for display at the experimental site.

Need 3: Develop appropriate irrigation guidelines for California landscape plants

Outcome 3: As per the MWELO budget equation and using WUCOLS IV plant factors, we will be able to compare applied water versus estimated water use for each hydrozone. By quantifying applied water, soil moisture, and plant responses, we will be able to calculate a total water budget for each hydrozone replicate, and compare to the estimated water use and maximum applied water allowance (as per MWELO guidelines). We will also use plant qualitative evaluation methodology to assess plant response to each irrigation treatment. We will also attempt to correlate plant health for each irrigation treatment using of a multi-spectral imaging camera mounted to an unmanned aerial vehicle (drone).

Main project narrative (6 pages maximum)

1. Introduction

Given predictions of variable and reduced water supply in California, homeowners, municipalities and businesses may be increasingly incentivized to conserve water. One area where these diverse groups can realize large water savings is in managed landscapes. Landscape plantings can be designed and maintained in a number of ways to reduce water use (Kjelgren, Rupp et al. 2000). First, installing low-water use plants, including native plant species that are adapted to low water conditions, can reduce water use and at the same time promote wildlife conservation. Irrigation systems are frequently used in cities and large landscape projects. These systems can also be used to reduce water use by targeted application to plants, timing watering for ideal times during the day, and through the use of sensors, to eliminate excess water application (Dukes 2012). However, the implementation of these water-saving landscape elements is limited by familiarity with systems, few guidelines on water application frequency or amount, or plant species water requirements. In the scientific literature, few studies examine how water supply influences desirable traits of ornamental landscape plants, particularly with regard to flowering phenology, duration, and other traits (Fereres, Goldhamer et al. 2003, Costa, Ortuño et al. 2007).

Despite the availability of general irrigation guidelines, how variation in water supply influences landscape plants is poorly understood, particularly with regard to flowering traits. Studies on low water use or reduced irrigation are generally not conducted in a standardized manner where conclusions can be applied outside that particular study system. For example, watering conditions in one location may not be comparable to another simply because of variation in evapotranspiration (ET) or other conditions. Here, we propose to install replicated hydrozones with water sensors so that we can apply a water budget as per Model Water Efficient Landscape Ordinance (MWELO; https://water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance). This offers benefits for replicability and applicability across systems for a few reasons. First, in-ground Time Domain Reflectometry (TDR) water sensors will allow us to adjust flow and water application to ensure equivalent soil moisture across replicates of the same treatment (hydrozone). Second, managing soil moisture within and across treatments will allow our setup to be comparable to other sites, making our findings relevant to a large audience. Finally, the use of flow meters, soil moisture sensors and plant measurements will allow us to calculate the water budget for each hydrozone individually, so we can compare within and among treatments, as irrigation treatments can also influence water use efficiency (WUE) and other plant physiological traits (Stabler and Martin 2000).

Although effects of watering on plant survival and growth have been documented for some plant species, few other traits of landscape plants have been examined (and published) with regard to deficit irrigation. One key trait of importance for both gardeners, landscape designers and wildlife is floral display and floral traits. Floral number and flowering season determine both the color display of plantings as well as the amount of floral resources, including nectar and pollen, available for pollinators and other beneficial organisms. Except for a few common plants (e.g. Petunia, Rosemary, Rose), effects of deficit irrigation on floral display or floral traits have not been rigorously documented. Moreover, most studies documenting the effects of deficit irrigation on landscaping plants have been performed in pots or containers, further limiting their applicability to field conditions.

Moreover, insects often rely on plant tissues for food, shelter or other resources. Specifically, many pollinators and beneficial insects (predators and parasitoids of pests) consume floral resources like nectar and pollen. Insects of conservation concern, including butterflies, rely on foliar material for larval stages. Of particular interest, monarch butterflies (*Danaus plexippus*) are also sensitive to plant foliar quality, which is influenced by drought conditions. Previous work has shown that water availability can influence nectar quality, flowering phenology and floral resources. Given the effects of water availability on plant quality and flower number and quality, irrigation regimes within a hydrozone are likely to cascade through plant quality to influence multiple insect groups, particularly in urban or suburban settings where alternate food sources are not readily available. However, these effects are poorly understood and have only been documented for a few species. Given the importance of landscape plantings for the maintenance of biodiversity, including urban populations of insects and other beneficial organisms, studies documenting how irrigation influences plant health and resource for these organisms will be essential.

As landscape managers transition from turf and other high-water landscape plantings to low-water installations, demonstration plantings and the results of rigorous experiments such as those proposed here will be key to guide both the planting and irrigation guidelines to ensure good survival, attractiveness and flowering of landscape plantings. Here, we propose to investigate the effects of variation in irrigation on the survival, flowering phenology, and floral resources produced by multiple California native plant species, as well as its effects on insect visitation to plants. We outline our specific objectives below.

Statement of goals and their relevance to the purpose of the endowment.

Goals:

1. **Install high visibility irrigation experiment containing multiple native plant species.**

Relevance to the endowment:
This project is of direct relevance to the endowment's goal of supporting research to "enhance western ornamental horticulture through the introduction of shade trees, California natives, or other drought-tolerant plants suitable for landscape use in California." This installation will enhance research for years to come and serve as a focal outreach tool for diverse classes, internships, and public events demonstrating deficit irrigation for landscaping plants, including native plant species (as we detail below).

2. **Assess effects of irrigation treatments on plant performance, floral display and phenology, and visitation to plants by beneficial insects.**

Relevance to the endowment:
Our research into how deficit irrigation influences plant survival, floral display and flowering phenology will directly inform the use of native California plants and other drought-tolerant plant species and their suitability for landscape tools in California, particularly with regard to flowering, a key trait for both visual appeal and provisioning wildlife.

Outline of the proposed research and education project

Overview

The proposed experiment is part of a larger installation on the campus of UC Davis within the "Smart Farm" site (Figure 1). Although funding for the site prep has been provided by the UC Davis campus, funding for installation of the experimental plots is not provided. See budget details below including in-kind donations etc. Within this site, we propose to install replicated irrigation plots (hydrozones) (Fig 1) with three water regimes, very low, low, and medium, as classified by MWELO. Specifically, we will calculate expected ET for the plant species and number of plants included in each plot per WUCOLS IV (https://ucanr.edu/sites/WUCOLS/Download_WUCOLS_IV_User_Manual/) and estimate water application needs for late spring/summer irrigation. Each hydrozone plot will contain a TDR soil moisture sensor and will be individually controlled to maintain evapotranspiration levels as per MWELO guidelines using a Baseline irrigation unit and adjusted as necessary to account for variation in plant survival and other hydrozone-specific factors. Replicated plantings of multiple native species will be outplanted in each plot and monitored for survival, plant quality and flowering parameters and interactions with beneficial insects as detailed below.

Site specifications

The site will be graded, compost incorporated (as per MWELO) and water main line and lateral irrigation lines installed in May-June 2019. Further site prep will be completed by summer 2019 and ready for irrigation system installation (smart controller, inline drip, irrigation valves and flow meter) and outplanting in fall 2019. Each hydrozone will be 15' x 25' edged by landscape-grade material and separated by buffer strips. Plants will be installed in fall 2019 and mulched to retain moisture and reduce weed pressure.

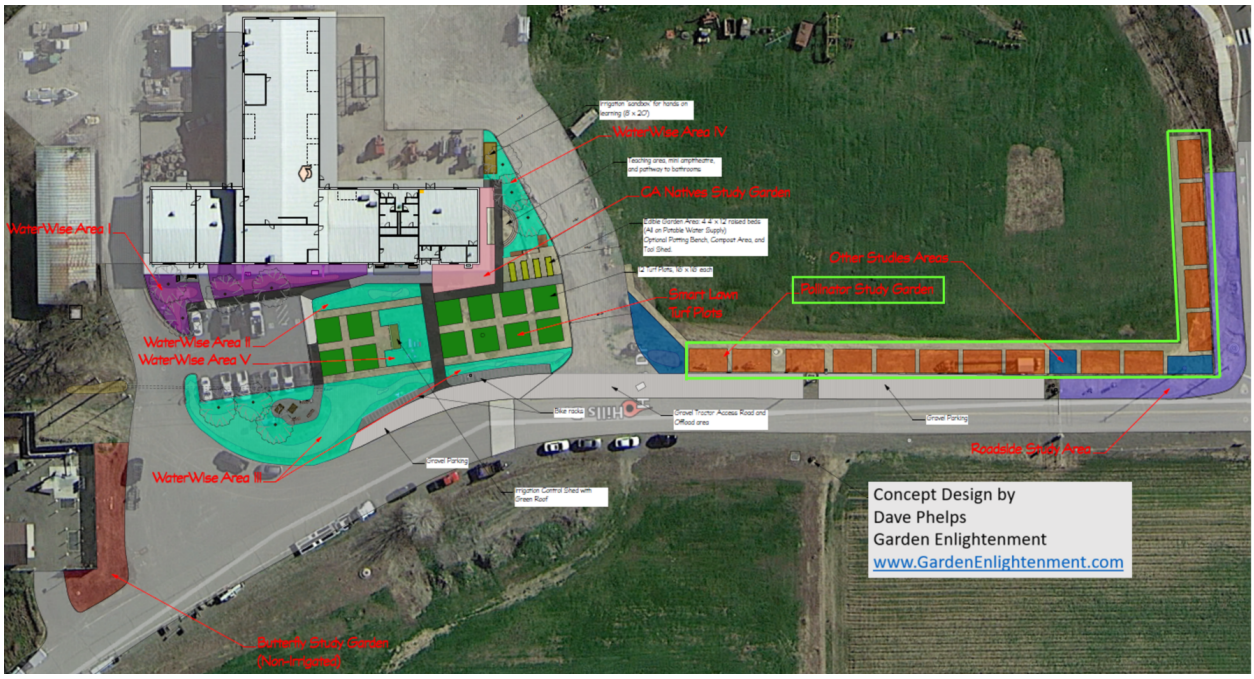

Figure 1. Smart farm A) site plan, including 15 replicated hydrozones for the pollinator study garden, outlined in green with each replicate hydrozone indicated by an orange rectangle.

Plant species

In fall 2019, we will plant each plot with plant species native to California chosen for their ability to withstand low water irrigation conditions, their bloom timing and duration, attractiveness to beneficial insects and other organisms including pollinators, and aesthetic value. Moreover some of these species are also important for conservation (e.g. monarch butterfly food source). In each plot, we will include at least three replicates of focal plant species *Asclepias fascicularis* (narrow-leaved milkweed), *Asclepias speciosa* (showy milkweed), *Epilobium canum* "Everett's Choice", *Epilobium septrionale* "Wayne's Silver", *Epilobium canum* "Mark West", *Epilobium canum* "canum", and *Epilobium canum* "Cloverdale". *Epilobium* (aka *Zauschneria*/) cultivars have been chosen to maximize variation in floral traits, including flowering phenology and flowering morphology (Vannette et al, in prep). Additional plant species will include low water use or water conserving California native ornamental grasses and flowering perennials, selected by student interns. Plants will be sourced from California flora nursery (https://www.calfloranursery.com/), Hedgerow Farms (https://www.hedgerowfarms.com/), and/or Cornflower Farms (https://www.cornflowerfarms.com/).

Experimental plans

We propose to sample plants within the experimental plantings (Figure 1) after establishment. Specific monitoring protocols and data gathered will be determined by project type but a general methods set will be used for assessment of irrigation treatment on all species vigor and flowering parameters. For each of species or variety, three representative plants within each plot will be chosen and tagged. Chosen plants will be monitored monthly for the presence and the number of flowers produced per plants.

Student groups will also perform plant qualitative assessments across plots using methodology proposed by Reid et al. Briefly, plants will be scored based on foliage, flowering, pest tolerance and disease, vigor and overall appearance (Table 1). Students will not be informed of the hydrozone treatment in the sampled plots until after assessments are completed.

Table 1. Description of quality ratings **RATING**	**5**	**4**	**3**	**2**	**1**
Foliage	perfect to excellent; plant is in full leaf with no signs of leaf burn, disease or insect damage, and has an appealing shape and uniformity	same as 5 except for minor tip burn, edge damage, or minor damage to only a few leaves that does not much affect the overall appearance	acceptable but not its best; non-uniform; minor damage to all leaves that is less evident from a distance, or severe damage to no more than 25% of plant	unacceptable; moderate damage to most of the plant or major damage to more than 25%; plant is declining and may not recover; may be extremely non-uniform	unacceptable; close to dead
Flowering	full bloom; the height of bloom for the species	61-80% of plant in bloom	41-60% of plant in bloom	21-40% of plant in bloom	1 bloom open to 20% in bloom
Pest Tolerance/ Disease Resistance	no visible damage	minor to moderate damage to one or two	minor damage to many of the leaves or flowers;	major damage; appearance unacceptable	severely damaged and probably dying

		leaves or stems, or only very minor damage to a few leaves (<25%)	appearance still acceptable from a distance (25-50%)	(51-75%)	(>75% affected)
Vigor	pushing out a lot of new growth from every growing point	pushing out new growth from many growing points (50-75%)	Plant is surviving and healthy, but not pushing out much new growth, if any (<50%)	Plant is very small for the species or unhealthy, and declining	Plant is barely alive; close to death
Overall Appearance	An impressive plant; everything works together: flowers (if present), leaves, the shape and condition of the plant are all very appealing. It has the WOW factor that makes it an attractive garden plant, even if each individual factor isn't perfect.	a very attractive plant; may be a 5 when in bloom, or just a very nice plant that lacks the WOW factor, or is not quite at its prime	Acceptable; may be past or not quite to its prime; might be better if more uniform; may be described as an 'okay' plant.	unacceptable for any of the above reasons	completely unacceptable and not likely to improve

Students will also engage in independent research projects using *Epilobium canum* cultivars and other plant species within the plots. These may include examining the relationships among traits, correlating specific trait values with pollinator visitation, or conducting additional experiments using the *Epilobium* plants on campus. Students from an undergraduate class (ABI 50A), taught by PI Vannette, will assist with the plant survey and projects focusing on *Epilobium* cultivars. The goal of this large (~100 students) undergraduate class is to examine plant-pollinator interactions, learn about plant biology, and conduct research using this plant system. A prominent activity of this lab-based class will be teaching students techniques to quantify plant quality and floral traits (Table 1) and monitor floral visitation by pollinators and other insect visitors to plants. During lab periods, student groups will monitor plant size and floral density, quantify floral traits, and assess evidence of floral visitation on flowers by conduct observations of floral visitation for 5 minutes per plant and laboratory. Students will quantify visitation by organisms including: 1) hummingbirds 2) bees (carpenter bees, honey bees) 3) predators (Vespid wasps, ladybugs, etc) and other abundant and evident insect groups. Students take a subset of flowers back to the lab for measurements of corolla dimensions and floral resources, including nectar volume and pollen. Student groups enter data into a shared document and the instructor (Vannette) and course TA will curate data collection and data entry both in the field and in the lab. Students will gain an appreciation for the value of horticultural plants and effects of irrigation on plants, pollinators and other beneficial organisms.

Additional monitoring and sampling will be conducted to assess the phenology of leaf and floral traits of two native milkweed (*Asclepias)* species, and to quantify seasonal changes in their

suitability for monarch (*Danaus plexippus*) development under different watering regimes. Plant growth and defensive traits will be measured at multiple intervals throughout the growing season to evaluate how varying levels of water availability affect milkweed phenology and the likelihood of monarch developmental success. These studies will use established protocols to quantify how prolonged drought affects the seasonal timing, availability and quality of native milkweed floral and foliar resources, providing essential data to inform the management of perennial milkweeds and the conservation of monarch butterflies in a changing climate.

We will examine if plant quality assessments, floral traits including peak flowering or duration of flowering differ between watering treatments using ANOVA. We will compare flowering distributions and examine if watering treatments alter flowering phenology. Student interns will also calculate actual water use budgets and compare to estimated water use. We will prepare these results for publication in peer-reviewed journals, see google scholar pages of Vannette and Yang for publication records: https://scholar.google.com/citations?user=Sh3ZdAYAAAAJ&hl=en; https://scholar.google.com/citations?user=2TKnDG8AAAAJ&hl=en&oi=ao) and presented to local audiences (e.g. Master gardener presentations).

Water budgets as per MWELO will be performed for all hydrozones. The Maximum Applied Water Allowance (MAWA) and Estimated Total Water Use (ETWU) for each hydrozone using plant factors (WUCOLS IV). Hydrozone landscape designs for each treatment will comply with WUCOLS' very low, low and medium water use categories. Applied water will be measured by an inline flow meter for each hydrozone and will be compared to the ETWU. Hydrozone Evapotranspiration Factor (ETAF) will be calculated to determine if it meets the MWELO standard of 0.55.

Education and outreach

A key aspect of our proposed project is the close integration of project design, installation and management with an internship program called Learning by Leading, developed by the UC Davis Arboretum and Public Garden and based on the philosophy that students learn best when leading others. These leadership internships provide a training ground for students to learn real-world skills and lead efforts to create a healthier environment and a more sustainable world. The unique curriculum focuses on team-based, peer-led, experiential leadership lessons that prepare students to learn applied horticultural and ecological skills, lead with confidence through mentorships and hands-on teaching, and contribute to more sustainable spaces. For this project, interns will be part of a new SmartLandscape internship focusing on the design and development of water conserving and water efficient landscapes, plant selection to improve irrigation efficiency and promote wildlife habitat, irrigation landscape measuring and monitoring (water conservation and water efficiency) utilizing soil moisture sensor technology, the creation of interpretive signage for the experimental plots, and installation and maintenance of water conserving landscapes.

Project Timeline
Provide a timeline for your project beginning in July 2019 and ending in June of 2020. Format the timeline by months, describing what will be accomplished each month of the project.

Year	Month	Tasks
2019	July	Site preparation and design planning
	August	Plant acquisition, design planning
	September	Site prep and design planning
	October	Work on site and plant installation
	November	Complete plant installation, initial plant assessments
	December	Experiment planning
2020	January	Begin spring phenology measurements
	February	Phenology and plant trait assessments
	March	Phenology and plant trait assessments
	April	Phenology and plant trait assessments
	May	Continue phenology and plant assessments, data analysis
	June	Submit final report to SHRE

Budget Detail

Item	Cost	Number	Subtotal	In-kind	SHRE
Experimental array					0
Flow meter (Baseline)	684.00	1	$684.00		$684.00
Soil moisture sensor (Baseline)	255.00	15	$3,825.00		$3,825.00
Smart irrigation controller (Baseline)	4,850.00	1	$4,850.00	x	$0.00
Drip irrigation tubing and fittings (Netafim & Ewing)	2,000.00	1	$2,000.00	x	$0.00
Compost (Agromin)	30.00	23	$690.00	x	$0.00
Edging (price/ft)	3.80	1200	$4,560.00		$4,560.00
Construction (CA&ES)	5,000.00	1	$5,000.00	x	$0.00
Mulch (Scotts Miracle Gro)	1.00	100	$100.00		$100.00
Landscape and construction documents (Garden Enlightenment)	750.00	1	$750.00	x	$0.00
Project management (CCUH)	400.00	$60	$24,000.00	x	$0.00
Plants					
#1 or 4"	3.00	500	$3,000.00		$3,000.00

Student support					
Learning by Leading	1.00	2500	$2,500.00		$2,500.00
1 quarter GSR (stipend)	1.00	8000	$8,000.00		$8,000.00
Undergraduate research assistant @$11.50/hr	11.50	90	$1,035.00		$1,035.00
Undergraduate research assistant @$11.50/hr	11.50	90	$1,035.00		$1,035.00
					$0.00
Interpretation and outreach					$0.00
Educational signage	250.00	1	$250.00		$250.00
Bench	500.00	1	$500.00	x	$0.00
			Total project cost	**In-kind contribution**	**SHRE request**
			$62,779.00	$37,790.00	$24,989.00

Justification

Materials and equipment for experimental arrays are requested as above. Many components have been donated or are likely to be gifted as indicated above, saving this project substantial costs in equipment, design, and construction. We request funding for edging, flow meter and sensors, as well as plants and mulch. We further request funding for student support to help with experimental design and installation. The learning by leading team and undergraduates will help with plot design, installation, and maintenance as well as data collection. The graduate student will assist in study design, data collection and data analysis. Interpretive materials (signage) will be installed near the experimental array for outreach purposes.

References cited

Costa, J. M., M. F. Ortuño and M. M. Chaves (2007). "Deficit irrigation as a strategy to save water: physiology and potential application to horticulture." Journal of integrative plant biology **49**(10): 1421-1434.

Dukes, M. (2012). "Water conservation potential of landscape irrigation smart controllers." Transactions of the ASABE **55**(2): 563-569.

Fereres, E., D. A. Goldhamer and L. R. Parsons (2003). "Irrigation water management of horticultural crops." HortScience **38**(5): 1036-1042.

Kjelgren, R., L. Rupp and D. Kilgren (2000). "Water conservation in urban landscapes." HortScience **35**(6): 1037-1040.

Stabler, L. B. and C. A. Martin (2000). "Irrigation regimens differentially affect growth and water use efficiency of two southwest landscape plants." Journal of Environmental Horticulture **18**(2): 66-70.

RACHEL L VANNETTE, PH.D.
Department of Entomology and Nematology, University of California, Davis
email: rlvannette@ucdavis.edu

A) PROFESSIONAL PREPARATION

Calvin College	Biology	2006	B.S.
University of Michigan	Ecology and Evolutionary Biology	2011	Ph.D.
Stanford University	Biology	2011-2015	Postdoc

B) APPOINTMENTS

2015-present Assistant Professor, Department of Entomology and Nematology, University of California, Davis

C) PRODUCTS MOST CLOSELY RELATED TO PROPOSED WORK:

Vannette RL & Fukami T, **2018**. Contrasting effects of yeast and bacteria on floral nectar traits, *Annals of Botany*, 121 (7), 1343-1349.

Rering C.C, Beck J.J., Hall, G., McCarthy, M., **Vannette RL**, **2018**. Nectar-inhabiting microorganisms influence nectar volatile composition and attractiveness to a generalist pollinator. *New Phytologist doi:* 10.1111/nph.14809.

Vannette RL & Fukami T. **2017** Effects of dispersal on beta diversity in flowers. *Ecology Letters* 20(7) 901-910.

Vannette RL & Fukami T. **2016** Nectar microbes can decrease nectar toxicity and alter toxic effects on nectar consumption by pollinators, *Ecology.* 97 (6), 1410-1419.

Vannette RL, Gauthier M-P, and Fukami T. **2013**. Nectar bacteria, but not yeast, weaken a plant-pollinator mutualism. *Proceedings of the Royal Society B: Biological Sciences* 280: 20122601.

UP TO 5 ADDITIONAL SIGNIFICANT PRODUCTS:

Lee, C. Tell L, T Hilfer, **Vannette RL**. (in press) Microbial communities in hummingbird feeders are distinct from floral nectar and influenced by bird visitation. *Proc R Soc B.*

Mittelbach, M. & **Vannette RL**. **2017**. Mutualism in yeasts. Springer edited edition of Yeasts in natural ecosystems: ecology, 155-178

Schaeffer RN, **Vannette RL**, Brittian C, Williams N, Fukami T. **2017**. Non-target effects of fungicides on nectar-inhabiting fungi of almond flowers, *Environmental Microbiology Reports*. 9(2), 79-84.

Schaeffer, R.N., **Vannette RL**, Irwin RE. **2015**. Nectar yeasts in *Delphinium nuttallianum* (Ranunculaceae) and their effects on nectar quality. *Fungal Ecology* 18 100-106.

Vannette, RL, Mohamed A., Johnson, BR. **2015**. Forager bees (*Apis mellifera*) highly express immune and detoxification genes in tissues associated with nectar processing. *Scientific Reports* 5:16224.

D) SYNERGISTIC ACTIVITIES

SCIENTIFIC OUTREACH:

I have been active in engaging K-12 students to the process of scientific inquiry, hypothesis testing, and educating students about specific projects through leading scientific nature walks at local Biological Preserve (2012-present), participating in women in science summer camp activities, and engaging students through discussion and interactive displays at the community science day during the AAAS meeting. Since 2016, I have presented outreach talks at growers meetings, horticultural meetings and beekeeper's meetings. Vannette lab members actively participate in on-campus outreach activities including pollinator education days, arboretum tours and environmental justice symposia, and welcoming visiting groups (most recently a group of bee ecologists from Mexico in May 2018).

UNDERGRADUATE RESEARCH SPONSOR AND BROADENING PARTICIPATION:

Since 2006, I have mentored 24 undergraduate and graduate students in research projects, including co-supervising honors thesis projects for 3 students. These students represent a diverse group, including 15 women, 5 international students, and 3 minority students. Student-led work has resulted in 2 publications (one with the student as first author) and another in preparation. My lab participates in hosting students from underrepresented backgrounds through the EEGAP program, where students participate in our lab research. My undergraduate and graduate students regularly present results of their work at local and national meetings.

EDUCATIONAL ACTIVITIES:

I teach 3 classes at UC Davis including Ent 10 Bugs in the System, an non-majors introduction to Entomology, ENT 111 Chemical Ecology, and ABI50A, a lab-based course introducing to the scientific method to Animal Biology major students. Since 2017, I have participated in a Learning Community, hosted by the Center for Educational Effectiveness at UC Davis as a group member and continue to participate in ad-hoc events and workshops. This community facilitates idea exchange among faculty members at UC Davis, including across colleges and topic areas.

MANUSCRIPT AND GRANT REVIEWS:

Since 2008, I have reviewed 38+ manuscripts for scientific journals including *Agricultural and Forest Entomology, Botany, Ecological Entomology, Ecology, Ecology Letters, FEMS Microbiology Ecology, Frontiers in Plant Science, Functional Ecology, Industrial Crops and Products, Oecologia, Oikos, PLoS ONE,* and *Symbiosis,* as well as book chapter reviews, grant applications for the National Science Foundation and international funding agencies.

A. HAVEN KIERS

University of California, Davis, One Shields Avenue, Davis, CA 95616
ahkiers@ucdavis.edu, 530.574.6718

EDUCATION

Masters in Landscape Architecture, University of California, Berkeley, Berkeley, CA, 1999-2002
Bachelors of Art in International Relations, Brown University, Providence, RI, 1992-1996

PROFESSIONAL AFFILIATIONS

Certified Arborist, International Society of Arborists, 2014
Green Roof Professional (GRP), Green Roofs for Healthy Cities, 2009
LEED Accredited Professional (LEED AP), U.S. Green Building Council, 2006
Oregon Master Gardener, Oregon State University Extension Service, 1999

ACADEMIC EMPLOYMENT

Assistant Professor, Department of Human Ecology, University of California, Davis, CA, 2018 – Present
Lecturer, Department of Human Ecology, University of California, Davis, CA, 2012 – 2017
Landscape Program Director, [IN]LAND, Summer Institute in Environmental Design, College of Environmental Design, University of California, Berkeley, CA, 2013 -2016
Instructor, University of California, Davis Extension, Department of Land Use and Natural Resources, Davis, CA, 2012-2014
Instructor, [IN]LAND, Summer Institute in Environmental Design, College of Environmental Design, University of California, Berkeley, CA, 2012

PROFESSIONAL PRACTICE

Design Principal, Restoration Landscaping Company, Sacramento, CA, 2015 – present
Special Projects Manager, UC Davis Arboretum and Public Garden, Davis, CA, 2013 – present
Facilitator and Instructor, Green Roofs for Healthy Cities, Toronto, Ontario/Various Cities, 2004 – present
San Francisco Market Development Coordinator, Green Infrastructure Foundation, San Francisco, CA, 2008-2009
Associate Planner, Mono County Community Development Department, Mammoth Lakes, CA, 2004-2008
Landscape Designer, SWA Group, Sausalito, CA, 2002-2004

SELECTED PUBLICATIONS

1. Kiers, H. (2019). “Nature Rx – Improving Health by Spending Time Outside.” Landscape Research Record No. 08 (IN-REVIEW)
2. Krimmel, B. and Kiers, H. (2017). “Native Landscaping Snapshots – Designing Meadows in Suburbia.” *Grasslands Journal*, Winter 2018, Vol.28/No.1
3. Kiers, H. (2013). “Back to Nature - An Alternative Approach to Planting Green Roofs.” *Pacific Horticulture*, October, Vol.74/No.4
4. Velazquez, L. and Kiers, H. (2012). "Green Roof and Living Wall Trends." *Green Roofs and Rooftop Gardens.* Brooklyn: Brooklyn Botanic Garden, 2012. 14-16. Print. BBG Garden Guides for a Greener Planet.
5. Kiers, H. (2010). “History and Benefits of Urban Agriculture.” *Green Infrastructure Foundation White Paper*, Toronto, Ontario, Canada.

SELECTED PRESENTATION AND CONFERENCE PAPERS

1. Conference of Educators in Landscape Architecture Annual Conference, Sacramento, CA, “Nature Rx – Improving Health by Spending Time Outside,” (2019)

2. Conference of Educators in Landscape Architecture Annual Conference, Sacramento, CA, "Living Landscape Adaptation Plan - Campus Planning in the Face of Climate Change," (2019)
3. American Public Gardens Association Annual Conference 2018, Southern California, "Nature Rx – (Re)Connecting Humans with Nature," with Stacey Parker, Don Rakow, and Jean Larson (2018)
4. California Native Grasslands Association Workshop, Davis, CA, "Landscaping with Nature –Designing Beautiful Native Landscapes that Support Wildlife and Reduce Water Usage," (2018)
5. 2017 School of Grounds Management Professional Grounds Maintenance Society, Louisville, KY, "Green Roofs – Photographed and Forgotten," (2017)
6. Hunter Industries West Coast Sustainability Event, San Marcos, CA, "Green Roofs and Irrigation," (2016)
7. American Society of Landscape Architects Sierra Chapter, Educational Session, Sacramento, CA, "Green Roofs and Biodiversity," (2015)
8. CA Center for Urban Horticulture, Davis, CA, "Urban Habitat: The Case for Green Roofs," (2015)
9. CA Master Gardeners Conference, Yosemite, CA, "Sustainable Green Roof Design," (2014)
10. Cities Alive Conference, San Francisco, CA, "Pushing Policy Forward on Green Infrastructure for Urban Resiliency," Panelist (2013)
11. San Francisco Planning and Urban Research Association, San Francisco, CA, "Green Roofs for Healthier Cities," Panelist (2013)
12. Vegetative Roofs Seminar, Santa Rosa, CA, "Mitigating Development Pressure & Ecological Impacts with Living Roofs," (2011)

COURSES TAUGHT

1. University of California, Davis, Visiting Lecturer, Department of Human Ecology; *LDA 160 – Materials and Detailing*, (Fall 2013, 2014, 2015, 2016, 2017)
2. University of California, Davis, Visiting Lecturer, Department of Human Ecology; *LDA 191 – Workshop in Landscape Architecture: Designing Vegitecture*, (Spring 2012)
3. University of California, Davis, Lecturer, Freshman Seminar; *FRS 004 –Nature Rx*, (Fall 2017, 2018)
4. University of California, Berkeley, Academic Lead, [IN]LAND, Summer Institute in Environmental Design *Landscape Studio – Introduction to Design*, (Summers 2012, 2013, 2014, 2015, 2016)
5. University of California, Davis Extension, Department of Land Use and Natural Resources, Instructor *Practical Applications of Green Roofs and Rainwater Harvesting*, (Spring 2012, 2013, 2014)
6. Green Infrastructure Foundation, Toronto, Ontario; *Green Infrastructure: Policies and Performance*, (2008)
7. Green Roofs for Healthy Cities, Toronto, Ontario; *Green Roof Design*, (2004 – 2017)

PROFESSIONAL AND ACADEMIC SERVICE

1. Founding Member, "Campus Nature Rx Network" with Cornell University, University of Minnesota, and College of William & Mary (Current)
2. Designer, California Health Care Facility Prison Garden, Vacaville, CA, with Billy Krimmel (Current)
3. Developer, "Nature Rx Series for Staff and Faculty," Staff and Faculty Health and Well-Being Program, UC Davis, with Stacey Parker (2017)
4. Senior Project Advisor, Carmen Godinez, "Wildlife Stepping Stones: a Study of Biodiversity on Green Roofs," Davis, CA (2015)
4. Living Architecture Advisor, Bay Localize Rooftop Systems Advisory Group, Oakland, CA (2009 –2013)
2. Founding Member, Green Roof Alliance, San Francisco, CA (2009 –2013)
3. Design Editor, Greenroofs.com (2006 –2013)
4. Course Content Contributor, "Green Roof Plants & Growing Media 401," "Green Roof Infrastructure: Design & Installation 201," "Green Roof Design 101: Introductory Course," "Green Infrastructure: Policies, Performance and Projects," "Advanced Green Roof Maintenance," and "Introduction to Rooftop Urban Agriculture," (2004 – 2013)

Louie H. Yang
lhyang@ucdavis.edu
Department of Entomology and Nematology
Briggs Hall 380K
University of California, Davis
Davis, CA 95616 USA

Professional Preparation

Cornell University Biology (Ecology and Evolution) B.A. 1999
University of California, Davis Population Biology Ph.D. 2006
University of California, Santa Barbara Ecology 2006 to 2008

Appointments

2015 to present	Associate Professor, Department of Entomology, University of California, Davis
2009 to 2015	Assistant Professor Department of Entomology, University of California, Davis
2006 to 2008	University of California President's Postdoctoral Fellow, Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara

Related Publications

1. Pearse, I. S., M. McMunn, and L. H. Yang. 2019. Seasonal assembly of arthropod communities on milkweeds experiencing simulated herbivory. **Arthropod-Plant Interactions**. 13:99–108.

2. Chmura, H. E., H. M. Kharouba, J. Ashander, S. M. Ehlman, E. B. Rivest, and L. H. Yang. 2018. The mechanisms of phenology: the patterns and processes of phenological shifts. **Ecological Monographs.** doi: 10.1002/ecm.1337

3. Farzan, S. and L.H. Yang. 2018. Experimental shifts in phenology affect fitness, foraging, and parasitism in a native solitary bee. **Ecology.** 99(10):2187-2195.

4. Freedman, M., H. Dingle, C.A. Tabuloc, J.C. Chiu, L.H. Yang, M.P. Zaluki. 2018. Non-migratory monarch butterflies, *Danaus plexippus* (L.), retain developmental and transcriptional mechanisms associated with migration. **Biological Journal of the Linnean Society.** 123(2): 265–278

5. Yang, L. H., D. Ostrovsky, M. C. Rogers, and J. M. Welker. 2016. Intra-population variation in the natal origins and wing morphology of overwintering western monarch butterflies *Danaus plexippus*. **Ecography** 39:998–1007.

Other Significant Publications

1. Yang, L. 2012. The ecological consequences of insect outbreaks. in P. Barbosa, D. Letourneau, and

A. Agrawal, editors. Insect Outbreaks Revisited, 1st edition. Wiley-Blackwell.
2. Yang, L. H. 2008. Pulses of dead periodical cicadas increase herbivory of American bellflowers.
Ecology 89:1497-1502.

3. Yang, L.H. and R. Karban. 2009. Long-term habitat selection and chronic root herbivory: Explaining the relationship between periodical cicada density and tree growth. **The American Naturalist** 173(1):105-110.

4. Yang, L.H. and V. Rudolf. 2010. Phenology, ontogeny and the effects of climate change on the timing of species interactions, **Ecology Letters** 13(1):1-10.

Synergistic Activities

1. Undergraduate mentorship: created the Research Scholars Program in Insect Biology; mentored eight undergraduate students; taught a Freshman Seminar field course; mentor for ESA SEEDS
2. Graduate and postdoctoral mentorship: faculty mentor for the UC President's Postdoctoral Fellowship Program; graduate courses, seminars and workshops; UC Davis graduate groups: Entomology, Population Biology, Ecology and Animal Behavior.
3. Public outreach: provided interviews for The New York Times, Associated Press, BBC, CNN, etc., consultation for a PBS Nova web feature, public lecture for the Explorit Science Center
4. K-12 mentorship: Developed ecology-themed exhibit in collaboration with the UC Davis Bohart Museum of Entomology, mentored two high school students in the field.
5. Professional service: GRFP panelist and reviewer for NSF, subject editor for Oikos, organized and edited a Special Feature for Ecology, reviewer for numerous journals, lifetime member of the ESA

David W. Fujino, Ph.D.
44935 N. El Macero Dr.
Davis, CA 95618
530.756.6559 (Res) dwfujino@comcast.net 530.902.7676 (Cell)

SENIOR EXECUTIVE
Achieving the future through commitment based leadership.

PROFILE

- ☼ Highly adaptable leader accomplished in delivering results in a variety of senior level corporate functions including organizational development, training and development, information technology, operations, marketing and sales.
- ☼ Hands on manager proficient in eliciting optimal performance from an organization's people and processes through proven team building, performance management abilities, staff development and motivational skills.
- ☼ Ability to add value to achieving strategic objectives through extensive network of connections with academia, state/federal agencies and national industry associations.
- ☼ Talented business strategist and tactician who can produce results by aligning the right people with the right project at the right time and building organizational consensus to ensure success
- ☼ Versatile and accomplished in championing corporate interests through successful public relations / government relations, contract negotiations and client management initiatives. Skilled in the development and implementation of policies and procedures that advance the organization's mission.

EXPERIENCE

Executive Director, CCUH, UC Davis, Davis, CA, 2006-Present
Currently, the Executive Director of California Center for Urban Horticulture (CCUH). The CCUH mission is to help California develop more enjoyable and sustainable gardens, landscapes and public parks with timely horticultural information. The CCUH is located at the University of California, Davis, and draws upon the knowledge and expertise of our partners in academia, industry and the public. Urban horticulture has a significant role in water, energy and resource conservation, reducing pesticide use, native plant propagation, wildlife preservation, and controlling invasive species. The CCUH public programs, demonstration gardens, and research provide Californians with horticultural information needed for creating and maintaining environmentally sound landscapes. (http://ccuh.ucdavis.edu)

Co-Director, UCNFA, UC Davis, Davis, CA, 2009-Present
The University of California Nursery and Floriculture Alliance (UCNFA) is associated with the Floriculture and Nursery Workgroup of UC's Division of Agriculture and Natural Resources. These Cooperative Extension and university personnel engage in research and educational activities that address the needs of the nursery and floriculture production industries in California. The UCNFA provides educational programs to a $3.7 billion industry (2014), which is California's #5 agricultural commodity. (http://ucnfa.ucanr.edu)

Chair, Saratoga Horticultural Research Endowment, 2014-Present
The Saratoga Horticultural Research Endowment (SHRE) supports research and educational programs that foster the introduction of new and improved plant materials for California gardens and landscapes. The committee administers this $1.15 million endowment and allocates approximately $50,000 annually to fund horticultural research. Since its inception in 2008, the SHRE has endowed over $290,000 research projects. (http://ucanr.edu/sites/SaratogaHort/)

Horticultural Consultant, El Macero, CA 2005-2007
Serving the CA nursery industry with expertise in governmental and regulatory affairs at the state and National level by direct participation in "key" industry issues. Leadership is being provided by design and development of organizational infrastructure that aligns industry, local, state and federal stakeholders. Worked with such governmental agencies such as County Agricultural Commissioners, California Department of Food and Agriculture, USDA APHIS PPQ, USDA ARS and Canadian Food Inspection Agency. Current Chair of CDFA's Nursery Pest Advisory Task Force and Chair, California Nurseries and Garden Centers.

Hines Horticulture, Irvine, CA 1987-2005
A $300 million company producing more than 4,900 varieties of ornamental shrubs, color plants, and container-grown plants in nurseries located in 9 states. Hines distributes and sells its products to home centers, mass merchandisers, independent garden centers, and garden center chains in the United States and Canada.

Key Positions:

Vice President, Organizational Development 01.02-07.05
Charged with the reorganization of company facilities and staff as the company was challenged by continually eroding margins in the mass merchandising sector. Assisted CEO in executive with aligning the organization to the corporate strategic plan.

- Managed all corporate government and regulatory affairs. Directed training programs in sales, problem solving and employee development. Provided "one on one" executive coaching for facility General Managers and Regional Vice President. Reorganized four production facilities to offset $10 million shortfall caused by the loss of a mass merchandiser contract
- Negotiated a $15 million Option Agreement for the sale of a Northern California facility
- Directed mechanization projects which resulted in 15% reduction in labor dollars
- Directed the design and implementation of $20 million facility expansion project
- "Black Belt" trained for providing internal executive coaching and mentorship

Vice President, Information Technology 01.99-12.01
Charged with the development and implementation of a centralized and standardized IT function. Due to many recent acquisitions, Hines was challenged by a number of IT technologies and systems that failed to provide enterprise wide solutions to the delivery and dissemination of data highly critical to the company's successful operation.

- Successfully conducted company research and development and bid process for enterprise selection process
- Negotiated $10 million Oracle enterprise software/hardware system
- Successfully implemented Oracle finance and custom production planning system while moving the organization from an outdated AS 400 system to an HP UX distributed system
- In response to significant IT attrition (AS 400 staff elected to move to other companies using the AS 400) rebuilt the corporate IT department to become an internal customer satisfaction center

Vice President, Eastern Region 01.98-12.98
Charged with the successful administration and operation of Hines' four company facilities in the Eastern Region after a highly successful engagement growing the company's California operations. Developed and implemented:

- New regional leadership team comprised of general management, regional sales management and regional store management