University of Vermont Horticulture Research and Education Center
2021 Outline of Activities

THE UNIVERSITY OF VERMONT AGRICULTURE & LIFE SCIENCES

HREC Director: Dr. Terence Bradshaw
https://www.uvm.edu/cals/hrec

Farm Maintenance & Operations: Andrew Bessette

The UVM Horticulture Research and Education Center (HREC), purchased in 1952, is the primary field laboratory site for applied teaching, research, and outreach activities on horticultural and some agronomic crops conducted by CALS and Extension faculty. In addition, the HREC hosts collections of ornamental plants of significance to the green industry, including legacy plantings of crabapples, rhododendrons and azaleas, flowering shrubs, shade trees, lilacs, and ferns. The facility is located four miles south of the main UVM campus and is accessible to numerous programs across CALS and other colleges.

HREC by the Numbers

- In 2021, the HREC hosted **24 research and outreach projects** by Investigators from across CALS and the University totaling over **$5 million** in funded activity
- Catamount Farm produces ten acres of fruit and vegetables annually to over **100 CSA shareholders**, farm stand customers, and UVM food service accounts.
  - **Produce sales** in 2021 totaled over **$85,000**
  - Over **300 student and farmer stakeholder visits** per year to Catamount Educational Farm
- **Friends of the Hort Farm**, the HREC non-profit community affiliate partner, maintains ornamental plant collections and holds community work days and garden talks at the farm
- Courses based at Catamount Farm accounted for over **400 student credit hours**
- **Eleven PSS and other CALS courses** use the farm for labs and field visits

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Catamount Educational Farm



'Cat Farm' Manager: Ava Murphey

Catamount Educational Farm (Cat Farm) is a division of HREC whose mission is to model sustainable farming practices through a working vegetable and fruit farm that provides educational and research opportunities for the UVM community. Farm plots include six acres of vegetable and cover crop fields, five acres of orchards, and just under one acre of grapes. Students are integral in carrying out all activities of the farm, and this experiential learning environment provides them with real and diverse sustainable farm management skills. The farm also

contributes to the local food system of the university by marketing the student-grown produce back to the UVM community through a campus farm stand, CSA shares, and wholesale accounts with University Dining Services.

The Catamount Farm initiative was launched in 2014 to facilitate improved teaching, research, and outreach activities in specialty crops through establishment of a model educational farm. All edible produce on the farm is produced under Catamount Educational Farm direction to provide for long-term soil fertility, crop planning, and integration with teaching and research activities. Produce grown on the farm is sold to the UVM community to fund the program, through over 100 summer and fall community-supported agriculture (CSA) shares; weekly farm stands at the Burlington Old North End Farmers' Market (Tuesdays) and at the farm (Fridays); and institutional sales to UVM's Sodexo food service. Students in associated programs provide the majority of farm labor in an experiential learning setting.

Educational Programs

UVM Farmer Training Program

Director: Rachel Stievater

The UVM Farmer Training Program (FTP) is a 6-month, full-time intensive program for aspiring farmers and food systems advocates that provides a hands-on, skill-based education in sustainable agriculture. Established in 2011, this full-time program offers participants the unique opportunity to manage their own growing site, take classes from professors and expert farmers, and rotate as workers and learners on successful, diverse farms in the Burlington area.

Undergraduate Internships

Instructor: Dr. Terence Bradshaw

Students enrolled in PSS 190: Catamount Farm Internship during the spring and fall semesters completed numerous farm operations and management activities, and contributed to research and outreach projects. In 2021, **26 interns** completed a total of **52 student credit hours** while pruning orchards and vineyards; harvesting crops; operating the farm stand; collecting and analyzing project data; and developing outreach materials for Extension projects.

Catamount Farm Summer Experience

Summer 2021 University of Vermont Plant & Soil Science and Catamount Educational Farm Courses												
Day	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2	8/9
MW	PSS 209: Diversified Farm Operations(6 credits; Bradshaw, Stievater)											
TR	PSS 156: Permaculture (3 credits; White)				PSS 120: Cold Climate Viticulture				PSS 161: Fundamentals of Soil Science			
R,Sa									PSS 195: Hands-on Beekeeping			
M-F	Agroecology (3 credits; Mendez, Izzo, Caswell) (Online 5/20-6/14; on-site								PSS 195: Introduction to Beekeeping (online, 3 credits; Alger)			

https://www.uvm.edu/~summer/programs/catamount-farm-summer-experience/

2021 Instructors: Samantha Alger, Terence Bradshaw, Martha Caswell, Josef Gorres, Vic Izzo, Ernesto Mendez, Rachel Stievater, and Annie White. This suite of integrated undergraduate PSS courses in 2021 included study on: sustainable, diversified vegetable production; beekeeping, herb production, advanced agroecology; and soil management. Total **enrollment** for all summer courses was **69 students** and a total **383 student credit hours**.

UVM Staff and UVM Undergraduate Class Tours

A variety of UVM staff and undergraduate classes visit the farm each season for tours or guest lectures, led by HREC and FTP staff and students. While tours were reduced in 2021 compared to pre-COVID years, over 300 stakeholders visited the facility. Many UVM classes utilize the HREC and Catamount Farm in labs and other coursework, including: PSS 010: *Home and Garden Horticulture*; PSS 106 *Entomology & Pest Management*; PSS 112: Weed *Ecology and Management*; PSS 117 *Plant Pathology; PSS 120: Cold Climate Viticulture;* PSS 125 *Woody Landscape Plants;* PSS 138 *Commercial Plant Propagation;* PSS 156 *Permaculture*; PSS 208: *Diversified Farm Planning; and* PSS 221 *Sustainable Orchard Management.*

Community Service

Catamount Farm Community Partnerships

Several community partners work closely with Cat Farm and FTP staff and students to integrate service learning, social justice, and community embeddedness components to program curricula. Partnership projects include:

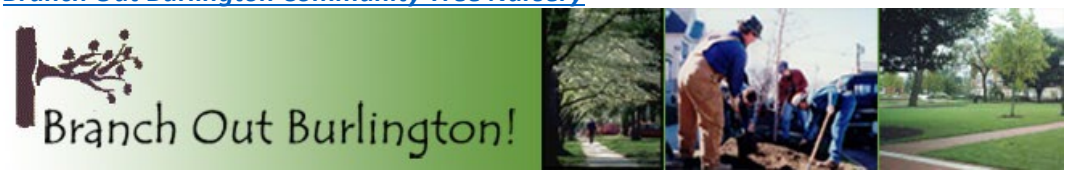
- UVM Extension Huertas project: Catamount Farm and affiliated students grew starter plants for distribution to migrant farmworker communities to improve food security among that marginalized population. https://www.uvm.edu/extension/agriculture/huertas;
- Alnôbaiwi Seeds of Renewal Project: Farm staff and students worked with Abenaki leaders Chief Don Stevens and Dr. Fred Wiseman to grow out culturally significant varieties or squash, corn, and beans for seed saving and distribution to the Abenaki community. https://www.alnobaiwi.org/seeds-of-renewal;
- New Farms for New Americans African Eggplant project: Catamount Farm paired with Janine Ndagijimana to explore scaling-up of African eggplant suited for production in Vermont.

Friends of the Hort Farm

Co-Presidents: Hayley Hornus & Kitty Werner

Formed in 1994, FHF is a grassroots organization dedicated to protecting, enhancing and promoting the significant plant collections and natural areas of the UVM HREC for education, research, and public enrichment. The group, composed of interested citizens, local garden club members, professional horticulturists, and landscape architects, is working in partnership with the University of Vermont to develop both short-term and long-term plans to provide for the stewardship of this wonderful and important resource. The Friends also sponsor public programs, and engages in fundraising and collections preservation. http://www.friendsofthehortfarm.org/

Branch Out Burlington Community Tree Nursery



Sponsor: *Branch Out Burlington!*; CALS; HREC
PI: Dr. Margaret Skinner

To combat the negative effect of climate change, the city of Burlington has a goal of increasing the tree canopy cover from 43 to 50%. Trees help to cool the city in summer, reduce air pollution and decrease harmful stormwater runoff into the lake. To meet their goal, the Burlington Department of Parks, Recreation and Waterfront plant hundreds of trees every year. With the threat of the emerald ash borer looming, the Parks Dept. are planning ahead, removing declining ash trees in the urban forest, and inter-planting along ash lined streets so when trees become infested, there will be established trees to replace them. For 25 years *Branch Out Burlington!*, a local volunteer tree organization, has maintained the nursery in cooperation with the city Parks Dept. Over this time they have provided over 100 trees annually for planting along the city's streets and parks. The nursery is the envy of towns and cities across the state and beyond. It saves the city thousands of dollars and provides a wide variety of high quality trees that are well acclimated to the local climatic conditions. It also engages the general public in caring for the urban forest of Burlington and neighboring towns.

Goals and Objectives

Over 100 bare-root trees are planted in the nursery annually and cared for by volunteers. The trees are grown up for 2-3 years and then transplanted onto Burlington's streets. Novel methods of growing trees in the nursery have been evaluated, including growing them in special fabric "grow bags" and as bare-root stock without a container. The nursery is a site for educational events for students (UVM, St. Michael's College and local high schools, etc.), Master Gardeners and the general public. Training sessions on tree planting and care, and pruning are regularly held there.

Research

2021 UVM Horticulture Research & Education Center Research Use Summary

PI	Project	Start	End	Funder		
Bradshaw	Vermont IPM Extension Implementation Program: 2017-2020. Orchard and Vineyard Scouting and Commercial Grower Outreach	2017	2021	USDA CPPM	$	208,630
Bradshaw	VitiNord 2022: A pivotal opportunity for education, collaboration, and innovation among Vermont grape and wine producers	2021	2023	VT SCBGP	$	20,548
Bradshaw	Evaluating systems components for orchard and vineyard crops in Vermont	2020	2025	Hatch	$	63,942
Bradshaw	Exploring Low-Phosphorous Wool Pellets as Fertilizer and Soil Conditioner for Vegetables	2020	2022	NESARE	$	28,329
Bradshaw	New England Cider Apple Program: Optimizing Production for High-Value Markets	2019	2022	NESARE	$	229,867
Bradshaw	Improvements for HREC Irrigation System	2020	2021	UVM OVPR	$	23,013
Brody	Effects of ericoid mycorrhizal fungi on aboveground interactions in highbush blueberry.	2018	2021	NSF	$	199,528
Collins	American chestnut germplasm conservation orchard	2009	2024	American Chestnut Society	$	10,000
Hurley	Efficacy of the 2017 Vermont Stormwater Management Manual	2020	2023	Stone Env., Inc. & Lake Champlain Basin Program	$	65,000
Izzo, Lewins	Vegetable pest scouting program	2021	2022	VVBGA	$	5,000
Izzo, Lewins	AX (Agroecology and Extension) Undergraduate Research Fellowship Program	2021	2026	AFRI Education and Workforce	$	500,000
Izzo, Lewins	Strategies for Leek Moth Control on Diversified Vegetable Farms	2019	2021	NESARE	$	102,799
Izzo, Lewins	Biological and Cultural Tactics for the Control of Wireworms in Root Crops	2020	2022	NESARE	$	116,189
Keller	Ecological genomics of climate adaptation in	2019	2023	NSF	$	2,500,000
Parker	ER1836GR for management of Thrips tabaci in onion	2019	2021	Chonbuk National University, South Korea	$	90,000
Faulkner	Turn the tap: Integrated research to support sustainable irrigation practices on Northeastern vegetable farms	2019	2021	NESARE	$	124,783
Parker	Developing Vermont's Saffron Industry as a High-Value Crop for Small Family Farms Developing Vermont's Saffron Industry as a High-Value Crop for Small Family Farms	2020	2023	VT SCBGP	$	40,000
Skinner	Biological Control for Saffron Pests in High Tunnel and Field Production	2017	2022	Hatch	$	107,500
Skinner, Schneebli	Nanocages for Assessing Saffron Quality	2019	2022	USDA NIFA	$	185,728
Stievater	Catamount Farm Community Partnerships	Ongoing				
von Wettberg	New Roots for Restoration: Kernza in Vermont	2021	2026	NSF	$	392,000
von Wettberg	Evaluating Performance of Winter Tolerant Peas	2020	2022	Hatch	$	63,692
von Wettberg	Evaluating the potential of tuber forming legumes	2020	2022	Hatch		
von Wettberg	Wild hops development and disease resistance	2020	2022	Hatch		

Evaluating systems components for orchard and vineyard crops in Vermont
PI: T. Bradshaw. Graduate students: B Pelletier and J. Leahy.
Sponsor: VAES Hatch Funds. $63,392
Effective Dates: October 2020 – September 2025.

Apples are Vermont's second-most valuable specialty crop with total annual value over $10 million. Most Vermont apples are grown for fresh markets and comprise traditional dessert cultivars. However, as dessert apple production has been level for over ten years, increased demand for organic apples and specialty cider apples presents opportunity for growers to exploit those alternative markets and increase sales. Production systems differ for organic and specialty cider apples, and changes from traditional systems presents a knowledge gap among both researchers and growers which limits growing for those markets. This project includes assessment of rootstock effects on organic and cider apple production systems, as well as multiple leader training systems on cider apples for effects on tree growth, crop yield, and juice quality. Objectives and protocols are part of and informed by the multi-state NC-140 Regional Rootstock Evaluation Trial (Cowgill Jr, Autio et al. 2017). Apple production systems are a complex collection of interrelated factors, and this project supports a larger, nationally and internationally recognized ongoing research program supporting organic and cider apple production in Vermont. Vineyard research is part of a coordinated trial (NE- 1720 Multistate Evaluation of Winegrape Cultivars and Clones) including representation from 23 other US states.

Publications:

- Bradshaw T., Autio, W. Blatt, S. Clements, J. Einhorn, T. Elkins, R. Fallahi, E., Francescatto, P., Lordan, J., Minas, I., Peck, G., Robinson, T., and Yao, S. Performance of 'Modi' apple trees after 5 years under Organic management as affected by several dwarf rootstocks in the 2015 NC-140 Apple Rootstock Trial. (J Amer Pomol Soc). *Submitted January 2022.*
- Hazelrigg, A. L., T. L. Bradshaw and G. S. Maia. 2021. "Disease Susceptibility of Interspecific Cold-Hardy Grape Cultivars in Northeastern U.S.A." Horticulturae 7(8): 216. Special issue on Grape Responses to Abiotic and Biotic Stresses. DOI:10.3390/horticulturae7080216

New England Cider Apple Program: Optimizing Production for High-Value Markets
PD: T. Bradshaw. PIs: D. Cooley, J. Clements, J. Pinero (UMASS); R. Moran (U Maine)
Sponsor: Northeast SARE Research & Extension Program.
Effective Dates: September 2019 – August 2022.

In a recent survey of apple growers, one prominent Vermont respondent stated, "The cider apple market represents the first real increase in demand for New England Apples in a generation. While sales of our dessert fruit have been flat or declining, we see this market as essential to maintaining the competitiveness of our industry."
New England apple growers have increased production of hard cider apples, but currently, demand for such fruit exceeds supply despite potentially high returns. Production of cider apples is limited by: unknown performance metrics for specialty cider cultivars when grown in New England; unique pest management considerations; and alternate bearing cycles that reduce yield. At regional educational meetings in 2014-2017, and in national surveys since 2014, apple growers stated that biennial bearing, cultivar adaptability, appropriate orchard training systems, and increased susceptibility to specific diseases, particularly fire blight, present significant limitations to increased expansion of cider apple production. Specialty cider apple cultivars are highly-valued by the growing cider industry, with prices similar to high-quality dessert cultivars that have shown stagnant growth in the past decade. Cider apples also have lower infrastructure and management needs because lack of demand for blemish free fruit creates an opportunity to grow them with fewer chemical inputs. In addition, postharvest cold storage, sorting, and packing are greatly reduced compared to dessert apples.

New and existing production practices, specifically bloom thinning, mechanical pruning and reevaluation of pest management models for cider apple cultivars can alleviate these problems, but information on how to implement these techniques without reducing yield or increasing production costs is insufficient. The knowledge needed to best grow cider varieties would enable growers to diversify markets, increase profitability and reduce pesticide use, and enhance the economic and environmental sustainability of their farms. We will conduct an educational program combined with research to compare methods that alleviate biennial bearing, to document the need for crop protection chemicals and establish tolerance levels for primary pests, and to identify cultivars less susceptible to by fire blight.

This bold, multi-state and multidisciplinary project is expected to yield substantial return on NESARE investment, by supporting a growing but challenged component of the New England apple industry that will support new, high-value markets for fruit that will not compete with present dessert fruit markets. Thus, we will help growers to generate new revenue from increased production of a novel crop.

Publications:

- Foster, J. Kingsley-Richards, S.L., and Bradshaw, T. Effect of Summer Hedging on Return Bloom, Yield, Tree Growth, and Juice Quality of Apples Grown for Cider. (Acta Horticulturae). Proceeding from XII International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems. *In Press.*
- Foster, J. Kingsley-Richards, S.L., and Bradshaw, T. Summer Applications of NAA and Ethephon Show Little Effect on Return Bloom, Yield, Tree Growth, and Juice Quality of Cider Apple Cultivars. (Acta Horticulturae). Proceeding from XII International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems. *In Press.*

Vermont IPM Extension Implementation Program: 2017-2020: Orchard and Vineyard Scouting and Commercial Grower Outreach
PD: A. Hazelrigg, PI: T. Bradshaw
Sponsor: USDA NIFA CPPM EIP Program $208,630 (Fruit crops)
Effective dates: Sep 2017 – Aug 2021

Under this project, timely, evidence-based horticulture and IPM programming is delivered to commercial crop producers in Vermont. Outreach provided to apple and grape producers is informed substantially from observations including formal scouting programs in orchards and vineyards within Catamount Educational Farm. The UVM Fruit Team also coordinates with partners at Cornell University to support the Network for Environment and Weather Applications (NEWA) supported by ten on-farm and six airport-based weather stations that provide real-time pest modeling output.

Exploring Low-Phosphorous Wool Pellets as Fertilizer and Soil Conditioner for Vegetables
PD: T. Bradshaw; Staff: Kimberley Hagen, Laura Johnson; Undergraduate students: Carlin Molander, Alina Decibus, Gigi Walsh.
Sponsor: NESARE Partnerships Grant Program ($28,329)
Effective dates: Nov 2020 – May 2022

This project seeks to: 1) determine if by using wool pellets as fertilizer providing N and K, spinach and tomato plants will utilize existing P in the soil; 2) determine whether the N in the pellets releases quickly enough for plants to utilize within the growing season; and 3) understand whether wool pellets' hygroscopic property can ameliorate the fluctuating extremes of precipitation on soil moisture levels during the growing season.

These are important questions for vegetable farmers. If we find that by using wool pellets for N and K, plants utilize existing soil P, that means less leaching into nearby waterways – a win for producers and the community. And if we find the pellets release N slowly enough so there is minimal, if any, runoff of excess, that too, is a win for both producers and the community. And if we find the hygroscopic properties of the pellets shows they can help absorb the moisture in excessive precipitation events, and then release in drier periods, this could help eliminate much of the need for irrigation and running electrical pumps, both promoting resilience and saving money for producers.

Crop Genetics and Domestication Laboratory https://ericvonwettberg.wixsite.com/laboratory
Dr. Eric Bishop-von Wettberg

Evaluating Performance of Winter Tolerant Peas
PI: Eric von Wettberg. Grad students: Emmanuel Brefo, Bailey Kretzler, Edward Marques

Sponsor: VAES Hatch Funds. $63,392

Winter peas have potential both as a cover crop and also as a winter vegetable. By examining new cultivars with dual-use, which both provide the ecological benefits of a winter legume cover crop, but also the market opportunities of a new vegetable, we hope to allow more farmers to keep their soil covered in the winter. We are looking to see if winter tolerant peas will allow double cropping in Vermont

- Marques, E., Kur, A., Bueno, E. and von Wettberg, E., 2020. Defining and improving the rotational and intercropping value of a crop using a plant–soil feedbacks approach. Crop Science, 60(5), pp.2195-2203.

New Roots for Restoration: Kernza in Vermont
PI: Eric von Wettberg. Graduate students: Emmanuel Brefo, Bailey Kretzler, Edward Marques, Nilo Nikravesh, Jasmine Hart

Sponsor: NSF BII $392,000

As part of a new NSF Biology Integration Institute on root biology, we have established a five year trial of kernza, a large grained form of perennial intermediate wheatgrass, which provides deep roots for carbon sequestration, soil protection, and a yearly yield. Our plots are intersown experimentally with alfalfa, yellow alfalfa, or clover to look at their compatibility with perennial forages

No publications yet as the project started in September.

Evaluating the potential of tuber forming legumes
PI: Eric von Wettberg. Undergraduate student: Mackenzie Laverick

Sponsor: VAES Hatch Funds. $63,392

An undergrad distinguished undergraduate research project examining the potential of jicama, American groundnut, winged bean, and other tuber forming legumes to provide culturally distinct and high protein root vegetables in Vermont.

Publication: in preparation, but the basis of an extensive information page, and a student research conference publication

Vermont hops diversity
PI: Eric von Wettberg, postdoc: Gianna Sassi

Sponsor: Vt. Agency of Ag, VAE Hatch Funds $60,000

We maintain an experimental hopyard in which to examine variation in resistance to insect pests and diseases. We have found a few varieties with enhanced mildew resistance

Publication in preparation

Winter tolerance of chickpeas
PI: Eric von Wettberg. Dr. Melike Bakir, visiting scholar Ericyes University

Sponsor: Tubitak (Turkish NSF), VAES Hatch $60,000

We are using a new electrolyte leakage assay to determine the mechanistic basis of differing cold tolerance in chickpea. We will use the same technique next winter on black yed peas and snow peas.

First publication in preparation.

UVM Entomology Research Laboratory http://www.uvm.edu/~entlab/
Dr. Bruce Parker, Dr. Margaret Skinner

Evaluation of the Efficacy of ERL 836 GR (*Beauveria bassiana*) against Onion Thrips
Sponsor: Jeonbuk National University, South Korea. $90,000
Effective Dates: Jan 2019 – Oct 2022
PI: Bruce Parker; Staff: Cheryl Frank Sullivan, Erin White, Arash Ghalehgolabbehbahani, Margaret Skinner

Onion plots at UVM Horticultural Research Center.

The UVM Entomology Research Laboratory maintains a worldwide collection of over 2,000 entomopathogenic fungal isolates. One *Beauveria bassiana* isolate coded ERL 836, collected from avocado orchards, is highly pathogenic to western flower thrips, *Frankliniella occidentalis*, a major pest of greenhouse ornamentals and vegetables. It is hypothesized that this fungus could also be highly pathogenic to onion thrips, *Thrips tabaci*, a serious pest in *Allium* crops. We are collaborating with scientists at Chonbuk National University to determine the field efficacy of a granular formulation of this strain produced by Farm Hannong, South Korea. Two application rates of the granular formulation will be compared with a chemical pesticide and untreated controls. Currently, no granular formulations of *B. bassiana* are commercially available in the US. If our results show promise, biopesticide companies might be more inclined to offer this product for organic growers in the US. This study will demonstrate how biopestides stack up against conventional chemical treatments. Data on damage and population of *T. tabaci* will be taken once/week following planting. Randomized leaf sampling will be taken to assess the number of *T. tabaci* per plant.

The purpose of this project is to compare the efficacy of granular formulations of an insect-killing fungus and a standard chemical insecticide (Radiant, active ingredient Spinetoram a broad-spectrum insecticide) against onion thrips (Thrips tabaci) in onion plots at UVM Horticulture Research Center. Through this project, we determined that thrips populations on onions were significantly less in the plots treated with the chemical pesticide, though differences were not enough to represent an economically advantage to using the chemical treatment.

Saffron program

Arash Ghalehgolabbehbahani, UVM post doc, demonstrating mechanical corm planting to growers.

Developing Vermont's Saffron Industry as a High-Value Crop for Small Family Farms Developing Vermont's Saffron Industry as a High-Value Crop for Small Family Farms
Sponsor: Vermont Specialty Crops Block Grant, $40,000.
Effective Dates: Oct. 2020 – Mar. 2023
PI: Bruce L. Parker; Staff: Erin White, Arash Ghalehgolabbehbahani, Margaret Skinner; Undergraduate students: Shannon Harty, Emma Hendra

The purpose of this project is to establish a statewide network of saffron-growing demonstration sites in several counties and plant hardiness zones. The UVM Horticulture Research Center is one of the sites. Commercial growers and home gardeners have attended educational events at the saffron fields at the Horticulture Center. In addition, data is collected on saffron production which is used to validate our saffron enterprise budget.

Biological Control for Saffron Pests in High Tunnel and Field Production
Sponsor: VAES USDA Hatch Program, $107,500.
Effective Dates: Oct 2017 – Sep 2022
PI: Margaret Skinner; Staff: Erin White, Arash Ghalehgolabbehbahani, Bruce L. Parker; Undergraduate students: Shannon Harty, Emma Hendra

Saffron (*Crocus sativus* L.) is the most expensive spice in the world, with a retail price >$5,000/lb. Saffron is commonly used as a culinary flavoring and coloring agent in Asian and European cuisine, but also is reported to have medicinal properties, which increases its economic value. In 2015-16 the first Vermont growing saffron was conducted in a high tunnel and in the following years the trial was repeated in the fields. The initial results showed the VT saffron yield surpassed that reported for key saffron-growing areas and saffron could generate $100,000/ acre. Based our early trials, the most significant source of damage and crop loss to saffron is voles and other small mammals. This trial is designed to assess the efficacy different soil treatments to deter damage from voles and rabbits. The treatments include crushed oyster shells applied on the surface and in the soil around the corms, and several repellants. The saffron corms were planted in 3 x 5 ft raised beds in September 2018 at depth of six inches and density of 10 corms/sq. ft. In this experiment, untreated plots serve as controls. Data on saffron yield, leaf area index (LAI) and number of secondary corms are collected annually to compare the direct effect and interactions of the treatments.

The purpose of this project is to evaluate various biological controls and organic treatments to minimize small mammal damage in saffron plantings and assess the efficacy of a soil-dwelling predatory mite against bulb mites. Field plots were established at the UVM Horticulture Research Center to test oyster shells and a rodent repellent in terms of their ability to protect saffron corms from rodents and rabbits. To date, rodent pressure on the saffron corms has been minimal. However, there were more and larger secondary corms produced in plots where both oyster shells and the repellent spray were applied.

Nanocages for Assessing Saffron Quality
Sponsor: USDA NIFA Seed Grant. $185,728
Effective Dates: May 2019 – May 2022
PI: Severin Schneebli (Chemistry Dept.) & Margaret Skinner; Staff: Erin White, Arash Ghalehgolabbehbahani, Bruce L. Parker; Undergraduate students: Shannon Harty, Emma Hendra

The purpose of this project is to develop tools for assessing saffron quality using nanotechnology. To do that we had to produce sufficient quantities of saffron at UVM Horticulture Research Center. Through this project, NMR methods were used to determine the best temperature at which to dry saffron stigmas to obtain the highest quantities of the key chemical components, crocin, picrocrocin and safranal.

Refereed Publications:

- Ghalehgolabbehbahani, A., C.F. Sullivan, A. Davari, B.L. Parker, A. Razavi & M. Skinner. 2022. Biological control of *Rhizoglyphus robini* using the entomopathogenic fungus, *Metarhizium brunneum* and predatory mite, *Strateiolaelaps scimitus* under laboratory conditions. Experimental and Applied Acarology. *In press.*
- Ghalehgolabbehbahani, A., O. Vestrheim, M. Skinner, J. Li & S.T. Schneebeli. 2022. Nuclear magnetic resonance-based quality assessment of Vermont-grown saffron (*Crocus sativus* L.)—Optimal drying conditions and mechanistic implications. ACS Food Sci. Technology. https://doi.org/10.1021/acsfoodscitech.1c00404

Extension Related:
https://www.uvm.edu/~saffron/

- Skinner, M., B.L. Parker, J. Chapple-Sokol & A. Ghalehgolabbehbahani. 2021. Saffron Corm Harvesting. UVM North American Center for Saffron Research & Development, Burlington, VT.
- Ghalehgolabbehbahani, A., M. Skinner, B.L. Parker & S. Schneebeli. 2021. Saffron Drying Methods. UVM North American Center for Saffron Research & Development, Burlington, VT.
- Skinner, M., B.L. Parker & A. Ghalehgolabbehbahani. 2021. Where Can You Order Saffron Corms? UVM North American Center for Saffron Research & Development, Burlington, VT.
- Skinner, M., B.L. Parker & A. Ghalehgolabbehbahani. 2021. Harvesting Saffron Flowers. UVM North American Center for Saffron Research & Development, Burlington, VT.
- Skinner, M., B.L. Parker & A. Ghalehgolabbehbahani. 2021. Saffron: A Golden Opportunity. A New Crop to Support Small Family Farms. UVM North American Center for Saffron Research & Development, Burlington, VT.
- Skinner, M., B.L. Parker & A. Ghalehgolabbehbahani. 2021. Saffron Production for Home Gardeners: Planting Depth and Density for Saffron Corms. UVM North Amer. Center for Saffron Research & Development, Burlington, VT.
- Skinner, M., B.L. Parker & A. Ghalehgolabbehbahani. 2021. Saffron Cultivation: Descriptions of Planting Methods. UVM North American Center for Saffron Research & Development, Burlington, VT.
- Parker, B.L., M. Skinner, A. Razavi & A. Ghalehgolabbehbahani. 2021. How to Balance Your Saffron: UVM North American Center for Saffron Research & Development, Burlington, VT.

UVM Farming & Climate Change Program
Dr. Joshua Faulkner

Turn the tap: Integrated research to support sustainable irrigation practices on northeast vegetable farms
PI: Joshua Faulkner
Sponsor: SARE Research for Novel Approaches in Sustainable Agriculture ($124,783)
Effective Dates: 3/1/19 – 11/30/21

The northeastern (NE) U.S. is home to a growing vegetable industry. While irrigation is widely used on NE vegetable farms, few growers rely upon soil moisture sensors to schedule irrigation. Many farmers over-irrigate (leading to nutrient leaching) or under-irrigate (leading to decreased yields/quality). Better information about soil moisture conditions, tailored to the scale and diversity of NE farms, can greatly improve irrigation efficiency while protecting water quality/supply in an era of climate change. Soil moisture sensors are commonly used in other regions and sectors, but systems are often not optimized for NE growers, nor are they widely used by this group. This project's goal was to work towards enhanced use and usability of precision irrigation in NE vegetable systems through an integrated field and social science investigation. We installed replicated plots of common vegetables (pepper, tomato, and cucumber) irrigated based on three different scheduling methods (i.e., timer, feel of soil, and soil sensor guided). Yields and quality of vegetables were measured, as well as volume and mass of nitrogen leached below the root zone. Results are currently being compiled and extension fact sheets and at least one peer reviewed publication will be produced within the year.

Ecological Landscape Design Laboratory

Dr. Stephanie Hurley https://www.uvm.edu/cals/pss/hurley-lab

Efficacy of the 2017 Vermont Stormwater Management Manual

PI: Dr. Stephanie Hurley; Postdoctoral Associate: Paliza Shrestha; Graduate Student: Samantha Brewer; Undergraduate Researcher: Bryce Carleton

Sponsor: Stone Environmental, Inc. and Lake Champlain Basin Program, $65,000

Effective Dates: December 2020-September 2023

Stormwater pollution from impervious surfaces is a significant contributor to water quality degradation and algal blooms in Lake Champlain and other waterways. Bioretention systems are a popular form of green stormwater infrastructure that use soil media (engineered soil mixes) and vegetation to store and filter stormwater runoff. In 2017, the Vermont Agency of Natural Resources (ANR) updated the Vermont Stormwater Management Manual (VSMM) to reflect advances in stormwater management practices and design. Nationwide, some standardized bioretention soil specifications have been found to export phosphorus rather than reducing them. In response, the VSMM update included a new bioretention soil specification to be a low nutrient mix. However, some members of the BMP design community are concerned about the ability of this soil specification to promote vegetation growth due to its low organic content and water-holding capacity. The goal of this study is to evaluate the performance of the VSMM bioretention soil specification with regard to reduction of pollutants and promotion of vegetation growth.

In Spring 2021 Dr. Hurley's research lab, in collaboration with Stone Environmental, Inc. constructed a system of bioretention mesocosms on a gentle slope at the HREC site. The team will conduct a second year of sampling in 2022. The experiment consists of twelve ~3x6' wide stormwater bioretention planters, with perforated underdrains and pipe systems for effluent stormwater. Four different soil treatments in three replicates each include a range of components from low-phosphorus topsoil, to woodchips, to drinking water treatment residuals (rich in Aluminum, to bind phosphorus). Each bioretention planter contains three plant species, native to the northeastern US: Milkweed, Echinacea, and Joe-Pye Weed. The team mixes recipes in the lab for concentrated synthetic stormwater runoff including nutrients and heavy metals, then dilutes the concentrated solution on site at HREC in large tanks, with water released through small perforations in an outflow pipe to simulate a rainstorm. See Figures Attached. Water percolates through the bioretention mesocosms to an underdrain which then connects to a downstream outflow sampling tank for each of the twelve cells. In the

2021 summer and fall, we captured stormwater during eight simulated and ambient storm events and anticipate another dozen events starting with spring 2022 sampling. Vegetation has been evaluated during the plant establishment phase as part of a UVM undergraduate research award ("SURF" program funding) by Bryce Carleton (ENSC major), who will present at the UVM Student Research Conference in 2022. His study explores the bioretention plants with regard to growth, coverage of the bioretention cell surfaces and general observations about vegetation health by species. The second year of data will combine with 2021 storm data as part of a MS thesis by Sam Brewer in Plant and Soil Science. The work was featured in a November 2021 Vermont Magazine Cover Story by Josh Brown: https://www.uvm.edu/news/story/fixing-phosphorus.

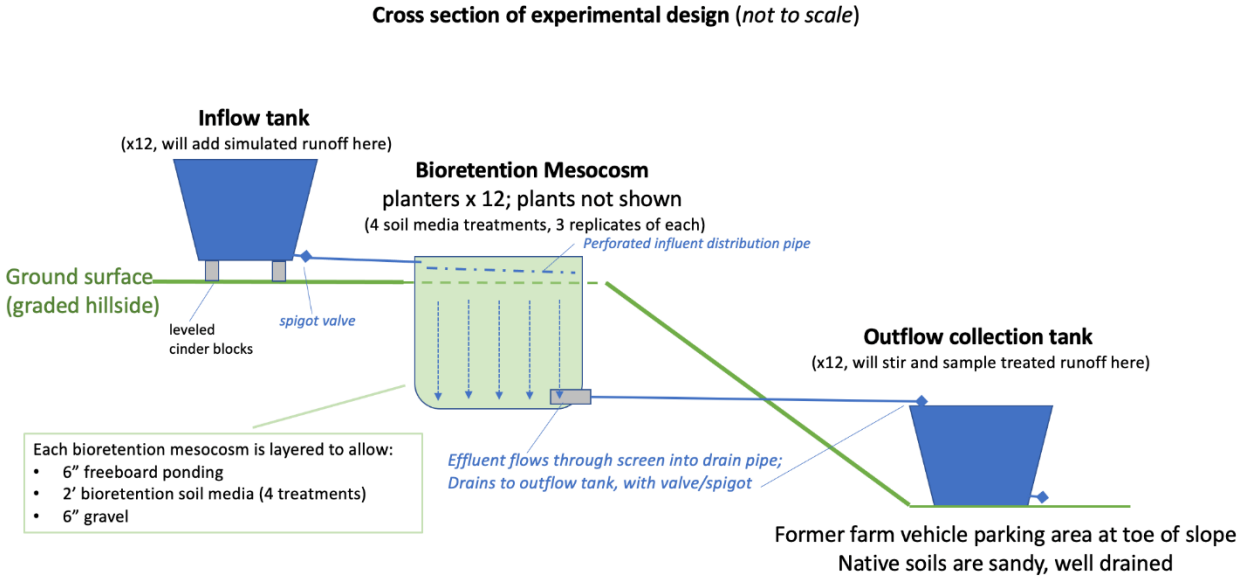


Figure 1. Schematic Diagram of Project Layout by S. Hurley

Figure 2. Research Team & Bioretention Mesocosms at HREC

Vermont Entomology and Participatory Action Research Team (VEPART)

https://www.uvm.edu/agroecology/research/vepart/

Scott Lewins (UVM Extension & PSS); Dr. Vic Izzo (PSS & Environmental Studies Program)

RESEARCH ACTIVITIES

Evaluation of swede midge tolerance and resistance among four popular kale varieties
Sponsor: New England Vegetable and Berry Growers Association (NEVBGA) - $2000

The swede midge, *Contarinia nasturtii* Kieffer, is a gall-forming insect pest species of cruciferous plants. Historically distributed throughout Europe and southwestern Asia, the first documented reports of swede midge infestations within North America occurred during the early 2000s in Ontario, Canada (Chen et al., 2011; Hallett, 2007). Following its arrival, the midge is expanding its distribution eastward and southward, and currently inhabits farming regions within Quebec (CA), New York, and much of Northern New England (Chen et al., 2011). As an oligophagous pest of the family Brassicaceae (Chen et al., 2011; Hallett, 2007) the midge is particularly problematic in cooler temperate regions where brassica crop production constitutes a valuable portion of the local fresh vegetable market.

This project looks to directly add to the current IPM toolbox for the management of swede midge on Northeastern vegetable farms by evaluating the efficacy of a commonly used cultural control – variety selection. Using kale as the selected brassica cultivar, we assessed the variability in swede midge susceptibility and tolerance among several popular varieties in a replicated field trail at the University of Vermont.

Biological and Cultural Tactics for the Control of Wireworms in Root Crops
Sponsor: Northeast Sustainable Agriculture and Education (SARE) - $116,189
Effective Dates: 2020-2022

Wireworms are the larval stage of the click beetle. Click beetles lay eggs at the base of grass hosts where larvae then feed upon available roots/tubers. Though wireworm risk can be avoided by the absence of grass cover crops, this strategy is incongruous with sustainable farming systems. For diversified vegetable farmers, wireworms are particularly problematic as they incur damage on various root crops. Root crops represent a bulk of the market storage crops, especially sweet potatoes. Nationally, sweet potato production has increased 6.1%/year since 2000. In the northeast, sweet potato production covers close to 1500 acres (~$7 million value).

This project explores three strategies to reduce wireworm pressure in sweet potato. These include: the use of entomopathogenic fungi for biological control, high glucosinolate mustard (HGM) biofumigation, and the development of a cover crop ranking system to identify the most problematic cover crops for wireworm recruitment.

Strategies for Leek Moth Control on Diversified Vegetable Farms
Sponsor: Northeast Sustainable Agriculture and Education (SARE) - $102,799
Effective Dates: 2019-2021

Leek moth (LM) is an invasive pest severely affecting allium production in the Northeast. First positively identified in northern New York in 2010, the invasive distribution now includes New Hampshire, Maine and Vermont. According to our recent monitoring efforts in Vermont, 75% of surveyed vegetable growers in the region with significant plots of alliums are experiencing leek moth damage. We estimate that the LM assemblage is expanding southward at approximately 33 mile/year. As such, the pest is projected to reach Connecticut by 2020. Leek moth larvae feed internally on host plants and are therefore difficult to manage via chemical sprays. Consequently, few management tactics are proving effective for organic growers. LM is especially of concern for Northeastern diversified vegetable growers, as alliums represent a high-value and generally low investment crop.

This project investigates both pre and post-harvest tactics for reducing the impact of the pest. These include: the release of a readily available parasitoid wasp and adaptive curing practices to reduce bulb damage from late season LM larvae.

EXTENSION ACTIVITIES

Vermont Pest and Disease Monitoring and Scouting Program
Vermont Vegetable and Berry Growers Association (VVBGA) - $3000

Effective Dates: 2021-2022

The recent arrival and establishment of several important diseases and insect pests to the Vermont region has exposed the increasing vulnerability of Vermont vegetable and berry growers to invasive insect and disease outbreaks. Because non-native insects and diseases often arrive rapidly (and unexpectedly), regionally specific information on their respective life cycles and behaviors is generally limited. Currently, within Vermont, consistent and coordinated information on the seasonal population dynamics of many high priority native and non-native insects and diseases is lacking. Despite a clear need for easily accessible, regionally specific pest information, minimal investment in the necessary financial and human resources has precluded the development of a robust Vermont-based monitoring and scouting program. This project proposal attempts to directly address this deficiency through the development of a farmer-centered, participatory, regional-specific scouting and monitoring station located at the University of Vermont.

This project provided Vermont growers with weekly Vermont-specific information on the population dynamics of important vegetable and berry diseases and insect pests as selected by growers in the VVBGA. This first season (2021) effectively served as a pilot project with the potential to replicate the scouting/monitoring program to other locations, potentially on commercial farms, in the state to better serve the geographic diversity of Vermont vegetable and berry farms.

EDUCATION ACTIVITIES

AX (Agroecology and Extension) Undergraduate Research Fellowship Program
Sponsor: AFRI Education and Workforce Development Program - $500,000
Effective dates: 2021-2026

The AX Fellowship program is designed to engage students in innovative “high impact” teaching and learning practices that are shown to be beneficial for college students from multiple backgrounds. Through our student-centered design, the AX Fellowship program will advance the AFRI EWD Developing Pathways goal and the REEU program area goals by preparing students with the diverse skills necessary for entering the agricultural workforce or pursuing graduate school after graduation.

The AX Fellowship is a 10-week undergraduate research program dedicated to a collective and horizontal learning. The heart of AX curriculum is composed of two complementary undergraduate programs: 1) a hands-on, research-based extension mentorship program (EMP) associated with on-going extension research projects; and 2) an agroecology leadership enrichment program (ALEP) focused on sustainable leadership and applied agroecology. The objectives of the THRIVE program are: a) to provide participating fellows a transdisciplinary experiential learning experience focused on the development of adaptable research, leadership, and outreach skills; b) to help prepare students for careers and graduate education in agroecology and extension; c) to support and contribute to new and ongoing extension projects dedicated to the Land Grant mission; d) to engage farmers and other relevant stakeholders through a participatory outreach framework; and e) to expand agroecology and transdisciplinary research opportunities to underrepresented student populations.

Ecological Genomics http://www.uvm.edu/~kellrlab/index.html

Dr. Stephen Keller

Ecological genomics of climate adaptation in *Populus*
Sponsor: National Science Foundation . $2.5 million.
Effective Dates: June 2019-May 2023
PI: Stephen Keller; Staff: Sonia DeYoung, Josephine Robertson; Graduate student: Baxter Worthing; Undergraduate student: Marley Ewick

Fast-growing poplar trees (Populus spp.) are under intense development for conventional forest products and bioenergy. Poplar hybrids comprise the vast majority of trees in operational plantations due to their superior growth when compared to pure species. However, compared with hybrid crop plants, the undomesticated nature of trees makes predicting performance of their hybrids more challenging. Understanding how variation in hybrid genomes and in the environment lead to desirable (and undesirable) traits has the potential to benefit poplar breeding programs significantly. In this project, natural hybrids between two wide-ranging poplar species - black cottonwood and balsam poplar - are used to characterize, predict, and test how hybridization translates into complex adaptive traits of economic and ecological significance. Natural Populus hybrid zones provide a 'living laboratory' in which there has been a long history of natural selection testing the genomic and phenotypic outcomes of hybridization. This project has sampled across replicated Populus hybrid zones to capture the history of Genome x Genome x Environment interactions along environmental gradients, and coupled this sampling with whole genome re-sequencing and computational approaches to address the following questions: (i) How is introgression arrayed across the genome and landscape? (ii) What genomic regions control hybrid fitness and what are their environmental drivers? (iii) Can adaptive introgression be recapitulated using controlled crosses? This project also provides interdisciplinary training to the next generation of scientists, spanning field ecology, genomics, and computational biology, and results have been used in graduate courses taught by Keller at UVM.

Publications:

- Chhatre, V. E., Fetter, K. C., Gougherty, A. V., Fitzpatrick, M. C., Soolanayakanahally, R. Y., Zalensy, R. S., & S.R. Keller. Climatic niche predicts the landscape structure of local-ly adaptive standing genetic variation (in revision for Communications Biology).
- Láruson, Á.J., Fitzpatrick, M.C., Keller, S.R., Haller, B.C. and Lotterhos, K.E., 2021. Seeing the Forest for the trees: Assessing genetic offset predictions with Gradient Forest. Evolutionary Applications https://doi.org/10.1111/eva.13354.
- An, X., Gao, K., Chen, Z., Li, J., Yang, X., Yang, X., Zhou, J., Guo, T., Zhao, T., Huang, S. and Miao, D., Khan, W.U., Rao, P., Ye, M., Lei, B. Liao, W. Wang, J., Ji, L. Li, Y., Guo, B., Mustafa, N.S., Li, S., Yun, Q. Keller, S.R., Mao, J., Zhang, R., & Strauss, S. 2021. High quality haplotype-resolved genome assemblies of Populus tomentosa Carr., a stabilized interspecific hybrid species that is widespread in Asia. Molecular Ecology Re-sources 22(2):786-802.
- Fetter, K. C., Nelson, D. M., & S.R. Keller. Growth-defense trade-offs masked in unadmixed populations are revealed by hybridization. Evolution 75(6):1450-1465.
- Fitzpatrick, M.C., V. Chhatre, R. Soolanayakanahally, and S.R. Keller. Experimental support for genomic prediction of climate maladaptation using the machine learning ap-proach Gradient Forests. Molecular Ecology Resources 21(8):2749-2765.
- Gougherty, A.V., S.R. Keller, V.E. Chhatre, and M.C. Fitzpatrick. 2021. Maladaptation, migra-tion, and extirpation fuel climate change risk in a forest tree species. Nature Cli-mate Change 11(2):166-171.
- Thibault, E., R. Soolanayakanahally, S.R. Keller. 2020. Counter-gradient latitudinal clines in bud flush phenology reflect genetic variation in chilling requirements in balsam pop-lar, Populus balsamifera L. (Salicaceae). American Journal of Botany 107(11):1597-1605.
- Capblancq, T., M.C. Fitzpatrick, R.A. Bay, M. Exposito-Alonso, and S.R. Keller. 2020. Genomic prediction of (mal)adaptation across current and future climatic landscapes. Annual Review of Ecology, Evolution, and Systematics Vol. 51.

Other Labs and Affiliates

American Chestnut Germplasm Conservation Orchard
PI: Kendra Collins, TACF and UVM Affiliate
Effective Dates: Spring 2009 – Fall 2024 (or beyond – collection is of long-term value)
Sponsor: The American Chestnut Foundation – operating budget; annual intern support from The Manton Foundation $10,000

The American Chestnut Foundation (TACF) is a non-profit organization dedicated to the restoration of American chestnuts to eastern forests. The American chestnut was once a dominant eastern hardwood species with an estimated population of close to 4 billion trees. The species has been left functionally extinct by an imported fungal pathogen (chestnut blight), first identified in 1904. Those trees that do remain on the landscape are of great value to TACF's restoration programs, which include conventional breeding efforts, biocontrol methods, and biotechnological solutions.

Existing American chestnuts are scattered on the landscape and often dieback from blight before they can reproduce. Those that do flower are often isolated and unable to participate in the cross-pollination they need to produce viable offspring. A germplasm conservation orchard allows for the collection of unique, locally-adapted sources of trees to be replicated and planted in a managed environment. Trees are planted from nuts

produced by the rare open-pollination event or intentional hand-pollination, or as grafts of wild trees. Transplanting of young seedlings is also possible, though not as common.

The germplasm conservation orchard at the HRC contains unique sources of wild American chestnut from throughout New England. The oldest trees are flowering, while we are still identifying and planting new sources from across the region. Flowering trees have been used to contribute to the genetic diversification of a transgenic chestnut, currently under regulatory review. These trees have also been included in the development of genetic mapping tools and grafting experiments. In addition, several specimens have contributed to the exploration of landscape scale diversity of the species.

Publications:

- Sandercock, Alexander M., Jared W Westbrook, Qian Zhang, Hayley Johnson, Thomas M Saielli, John A Scrivani, Sara Fitzsimmons, Kendra Collins, Jeremy Schmutz, Jane Grimwood, Jason A Holliday. Whole-genome resequencing reveals the population structure, genomic diversity, and demographic history of American chestnut (*Castanea dentata*). (BioRxiv). Submitted February 2022.

Linking above and belowground interactions in highbush blueberry.
Sponsor: NSF Division of Environmental Biology, $199,528
Effective Dates: Spring 2019- Fall 2021
PIs: A.K. Brody (Biology), J. Harris (Plant Biology), and Taylor Ricketts (Gund Institute)

The vast majority of all angiosperms engage in multiple mutualisms and do so simultaneously. Most form symbioses with mycorrhizal fungi to gain nutrients in exchange for carbohydrates and most rely on animals for pollination. However, most often plant interactions with these mutualists is studied separately, but knowledge of their links is important. Why? From a basic science perspective, understanding how selection is operating is a fundamental question of evolutionary ecology. Traditional studies of selection on floral phenotypes link pollinators with selection on floral traits. However, plant-mycorrhizal symbiosis may affect floral trait expression but be under different selection pressures. Ignoring third-party interactions, like those with mycorrhizae, may lead to erroneous conclusions about how selection is operating. From the perspective of applied science, maximizing yield in an animal-pollinated plant may require attention not only to supporting local pollinator populations but also to enhancing root symbionts.

Our objectives are to 1) quantify how mycorrhizae affect floral traits important to pollination and fruit production; 2) examine if plants respond in similar or different ways to inoculation with commercially available mycorrhizal spore mixtures versus raw soils from a nearby farm; 3) measure the effects of differences in pollinator abundance and diversity on the links between mycorrhizal colonization—floral traits—pollinator visitation—reproductive success in highbush blueberry; 4) introduce school-aged children to the importance of pollinators in food systems. Plants were randomly assigned to three treatments: 1) control plants potted a standard mix of peat, sand and vermiculite (“soil mix”); 2) plants inoculated with commercial fungi and potted in soil mix; 3) plants inoculated with local farm soil from the rhizosphere of the same blueberry cultivar and potted in soil mix. These plants were then grown and overwintered at the University of Vermont’s Horticultural Research Center.

Population Dynamics of Asian Invasive Earthworms
PI: J. Gorres, PSS
Sponsor: Vermont Agriculture Experiment Station Hatch Grants Program.
Status: On-going

Asian Earthworms of genus *Amynthas Kinber*g are relatively new arrivals in Vermont but have already begun to invade sugar bush and riparian forests. At the HRC there are three annual species in this genus: *A. agrestis*, A. *tokioensis* and *A. hilgendorfii*. This study aims to understand the climatic factors that cause interannual variations in population size for *A. tokioensis* and *A. agresteis*, the two species that are present throughout the eastern forest

at the HRC. The study has found large variations in population size within a year and between years. Drought and frost resistant egg-casings (cocoons) persist late into the year potentially mitigating the effect of drought on population size. The study is now in its 8th year and gives a meaningful long term record of these populations.

Immediate and Future Facility Needs

The HREC hosts multiple research, teaching, and outreach programs, yet its core facilities have not been significantly upgraded since the 1970s. Buildings and infrastructure at the farm are in fair to poor shape and despite this, are used beyond their capacity by multiple research and teaching programs. As summer instructional programs and applied research projects have increased in recent years, conflicts over space have developed at the same time that enrollment has been difficult in some classes because of institutional barriers that make summer instruction less appealing to undergraduates. Immediate and mid-term needs to support present and future growth in programs include:

- Investment in utilities, classroom, food processing, and laboratory facilities as outlined in the 2022 Horticulture Research and Education Center Master Plan developed with UVM CALS; UVM Planning Design and Construction, and Black River Design Architects, .

- Removal of institutional burdens on undergraduates who wish to enroll in summer classes by enhancing scholarships and developing an optional summer semester which students can finance similar to academic year semesters.

- Site redevelopment in coordination with the city of South Burlington to address community stormwater runoff issues and provide a new supply of irrigation for the eastern portion of the property.

Black River Design Architects, Montpelier, VT