College Campus as a Living Laboratory:

Scrubbing Scales, Saving Trees, Engaging Students

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Opportunities for meaningful engagement of college students in their campus communities rarely focus on tree health, and even less frequently address insect pests. Tree Campus USA certification typically involves service-learning projects such as tree plantings (Arbor Day Foundation 2018), with little concern for issues associated with insect infestations. The Urban Forest Initiative (UFI), a consortium of urban tree interests centered at the University of Kentucky, saw a unique opportunity in a calico scale infestation that was leading to tree decline on campus. The outbreak presented a chance to blend pest management and tree health with student engagement to contribute to Tree Campus USA certification, for the greater good of both the campus tree canopy and the student volunteers (see sidebar on UFI).

Located in the heart of Lexington, the University of Kentucky (UK) strives to navigate tensions between developing facilities to keep pace with an ever-growing campus to support the needs of its student body while maintaining the beauty and ecosystem functions of its green infrastructure. Space and infrastructure are at a premium for both the university and for the city, which is situated in the geographically distinct Inner Bluegrass Region. The region has a unique geologic substrate that supports rich grasslands where large, open-grown trees persist. Development, urbanization, and sparse resources and long-range planning threaten the distinct landscape of the Bluegrass Region and its iconic trees, as does invasion by non-native organisms.

The UK main campus occupies 384 ha (948 ac) with nearly 350 distinct tree species. The beauty of the campus, and its sense of community and identity, is enhanced by its 8,400 trees; the tree canopy covers approximately 17% of the total area. Protection and expansion of the campus tree canopy is a priority for campus administrators. Substantial tree-centric efforts have been underway for the past decade, including a 2010 tree-planting initiative involving more than 500 trees on UK's campus. More recently, certified arborists were appointed as essential members of UK Facilities Management for improved tree maintenance and proactive engagement in infrastructure development to minimize tree–hardscape conflicts (that is, conflicts with pavement, wires, and structures).

In addition to these beautification efforts, UK is continually seeking ways to utilize its campus as a living laboratory, and several entities have developed multifaceted projects to increase student engagement in campus development, campus sustainability, and human health. Included in these ambitious ventures are support for farm-to-table projects for locally sourced food products, creative solutions for storm water management, and initiatives to expand, promote, and engage with the urban tree canopy. For UFI, transforming the UK campus into a living laboratory involves garnering student engagement and support to ensure the continued health and development of the campus tree canopy and to promote a sense of place for UK students. Providing a mechanism

for college students to engage in nature is proving critically important in students' emotional and physical well-being (Capaldi et al. 2015) and has become a major emphasis in UFI's work plan (see sidebar on UFI).

Hiding in Plain Sight

A significant portion of the 500 trees in UK's 2010 tree planting initiative were honey locust, *Gleditsia triacanthos* L., planted on main thoroughfares and as allées along pedestrian conduits. Honey locust are fast-growing trees tolerant of urban stresses. Their leaf morphology permits filtered light to penetrate, allowing grass or partial shade plants to grow, making them especially useful in urban landscapes. Unfortunately, a substantial number of the honey locust trees planted in 2010 arrived on campus with undetected infestations of the non-native calico scale, *Eulecanium cerasorum* (Cockerell).

Calico scale is polyphagous, univoltine, and parthenogenetic, with a remarkable reproductive potential that contributes to its pest status (Hubbard and Potter 2005). It is distributed throughout the U.S., with infestations reported on both the East and West Coast, but is reportedly a more severe pest in the central states of Ohio and Kentucky (USDA FS 2016). Calico scale overwinters on stems and main branches as nymphs, maturing rapidly in spring before producing >3,000 eggs per individual, which hatch into crawlers that migrate to newly expanding leaves. The feeding and settling behaviors of crawlers on abaxial leaf surfaces along the midvein make management with foliar sprays problematic, and the efficacy of stem/trunk injections is variable, apparently dependent on the translocation capacity of the host plant (Hubbard and Potter 2006). Calico scale infests numerous landscape trees such as maples, sweetgum, and crabapples, as well as honey locust, making the street and landscape trees of urban areas especially susceptible.

By 2017, scale infestations on the honey locust on the UK campus had induced crown thinning and branch dieback; sooty mold growing on the honeydew excreted by the scales had blackened stems, branches, and twigs. The extent and location of the scale-infested trees (adjacent to a major automobile and pedestrian thoroughfare) necessitated some type of management action but precluded traditional insecticide sprays.

An Opportunity for Engagement

The high-profile, scale-infested trees presented UFI with an opportunity to engage UK college students in the care of their campus tree canopy while strengthening existing partnerships between UFI and UK Facilities Management. Because of prior success in working with the Alpha Phi Omega (APO) Service Fraternity, UFI reached out to their leadership to collaborate on a "Scale Scrub" event.

The Scale Scrub involved physically scrubbing calico scale off infested honey locust using some very basic tools, along with the APO students' enthusiasm and willingness to care for their campus trees. The project was designed to allow evaluation of the effectiveness of three treatments for suppression of scale populations:

1) insecticidal soap + scrubbing
2) water + scrubbing
3) dry scrub (scrubbing alone)

The results from these three treatments were compared with results from untreated controls. Additionally, we conducted pre- and post-assessments regarding the tree and pest knowledge of the APO volunteers, as well as their engagement with the campus tree canopy.

Our Approach

We recruited 42 APO student volunteers to scrub calico scale from trees on two consecutive days, 8 and 9 April 2017.

Experimental trees. Trees were even-aged, with an average diameter of 12.7 cm at 1.37 m above ground level (range 9–20 cm). We identified suitable trees and used a randomized block design with four trees per block and a total of 20 blocks to evaluate scale suppression treatments. Blocking was based on the trees' proximity to one another and their location relative to a major thoroughfare and sidewalk.

Treatments. Students were grouped into teams of three, and each team was equipped with a standard toilet brush, a standard toilet brush attached to a 1.8 m

Urban Forest Initiative

Since 2014, the Urban Forest Initiative (UFI) has championed the perception, value, and function of the urban forest on the University of Kentucky campus and beyond. These efforts, along with strong collaborations with campus and community partners, have achieved significant and positive impacts on public awareness of and active involvement in the support, care, and expansion of our local tree canopy. UFI provides a dynamic framework for opportunities to partner across organizational and community boundaries to enhance urban forests. Collaborators bring a wide array of skills and expertise from academia, government, private industry, and non-profits. UFI is heavily reliant on student interns, who support our activities and help drive our success. UFI's current efforts include:

- Development of a cross-disciplinary Urban and Community Forestry Certificate for UK undergraduates to help address the needs of a growing industry
- Support for Tree Campus USA efforts at UK and surrounding campuses to increase tree health and meaningfully engage students in connecting with their campus trees
- The Adopt-a-Tree Program for K–college students, which helps participants understand the ecosystem benefits that urban trees provide and provides a mechanism to connect with nature
- Free campus and community workshops and events that engage the broader community in a greater understanding of the value and care of urban trees
- Free public lectures highlighting nationally known urban and community forest experts to engage the general public and campus and create opportunities for community building

Fig. 1. With expertise and oversight from the Urban Forest Initiative and operational support from the University of Kentucky (UK) Facilities Management, teams of Alpha Phi Omega Service Fraternity student volunteers equipped with brushes were instructed to spend 20 minutes of consistent effort per tree scrubbing calico scale off infested honey locust on the UK campus.

extension pole, and a deck brush attached to a 1.8 m extension pole. We provided personal protective gear (eye protection, a dust mask, latex gloves, and a reflective vest) to each volunteer. Equipped with brushes (one of each type) and their assigned treatment (insecticidal soap [mixed to label rates] + scrubbing; water + scrubbing; dry scrub [scrubbing only]; or untreated control), teams were instructed to spend 20 minutes of consistent effort scrubbing a given tree. Each team was assigned to a specific treatment, and student teams moved from block to block focusing solely on those trees with their assigned treatment. Treatments were color-coded, equipment was color-coded, and the APO student volunteers wore color-coded flagging. Thus, a given team scrubbed only one tree per block and scrubbed only those trees within their assigned treatment to avoid cross-contamination (Fig. 1).

Calico scale. Five blocks (N = 20 trees) were randomly selected for pre- and post-Scale Scrub branch sampling to evaluate scale densities. At the time of our treatments (early April), the young adult scales were not yet fully swollen with eggs; no crawlers were present. We used pole pruners to remove six branches <6 cm in diameter from the south side of each tree (three from the upper canopy and three from the lower canopy), both pre- and post-treatment. Branches from each tree were bagged by stratum (upper or lower), returned to the laboratory, and stored at 4 °C until processing (about 4 weeks). We measured the excised branches and determined their surface area using the formula for a tapered cylinder. Scales were counted, and the density per branch (number of scales/cm^2) was determined. Scale density values represent the mean of three branches for the upper and lower samples from each designated tree.

We evaluated scale density pre- and post-Scale Scrub, and also evaluated the change in scale density by subtracting post-Scale Scrub from pre-Scale Scrub densities for each tree. We used a general linear mixed model analysis of variance (GLIMMIX) to assess differences in scale density across treatments, evaluating the effects of block, road, tree, and canopy level (upper versus lower canopy; SAS Institute 2011).

Additionally, we conducted a one-minute scale count on six randomly selected blocks of trees (N = 24) three weeks after the Scale Scrub event. Two independently trained observers counted scales at accessible heights on each tree for a one-minute period. The mean of the two counts was calculated, and a general linear model (GLM) was used to assess differences in density across treatments, incorporating the effects of road and canopy level.

Student engagement. APO volunteers received a 10-minute orientation before the Scale Scrub to introduce the tree species, the pest, and the problem, as well as the pest management strategies under evaluation. Students were asked to complete a short paper questionnaire before and after the Scale Scrub to evaluate their understanding of the project, but also (importantly) to assess their level of enthusiasm and interest in the process of caring for their campus trees. Nine months later (January 2018), we followed up with an electronic survey to APO volunteers involved in the Scale Scrub to determine whether participating in this project had a lasting effect on their sense of place and their connection to UK and its campus tree canopy.

Scrubbing Scales Reduces Densities

Branch sampling before treatment revealed a weakly significant block effect ($P = 0.08$), confirming observations that trees in some locations were more heavily infested than in others. Similarly, there was a trend indicating that trees close to the main thoroughfare had lower scale densities than trees adjacent to the sidewalk; sidewalk trees were more sheltered and had less exposure to winds and road splash (Fig. 2). There were no differences in scale population density in the upper versus lower canopies for either pre- or post-Scale Scrub measurements, though variability was high.

Analysis of our pre- and post-Scale Scrub branch sampling demonstrated no differences in scale density among

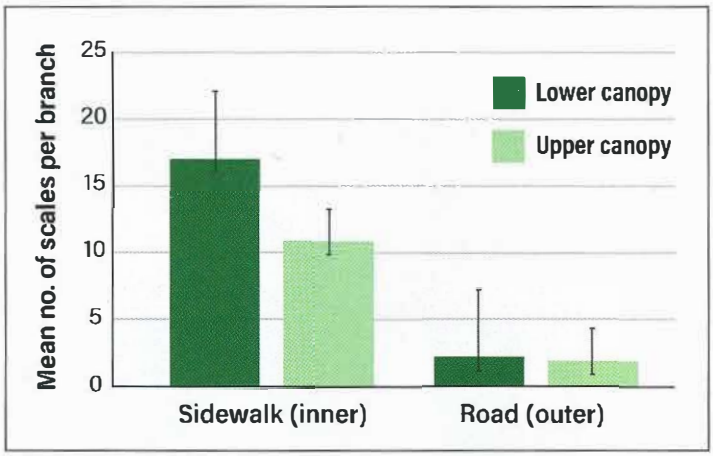


Fig. 2. Though there is no statistical difference (P = 0.08), honey locust trees adjacent to the sidewalk and away from the road appear to support higher calico scale densities (mean ± s.e.) than those adjacent to the roadway, which are subjected to harsher conditions.

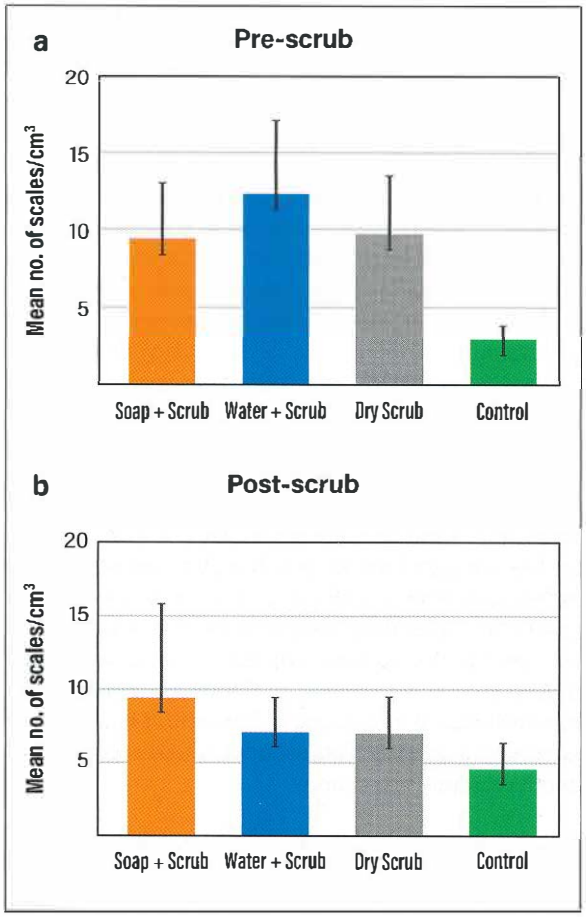


Fig. 3. Branch sampling (a) pre- and (b) post-Scale Scrub showed no differences among treatments (mean ± s.e.); variability was high.

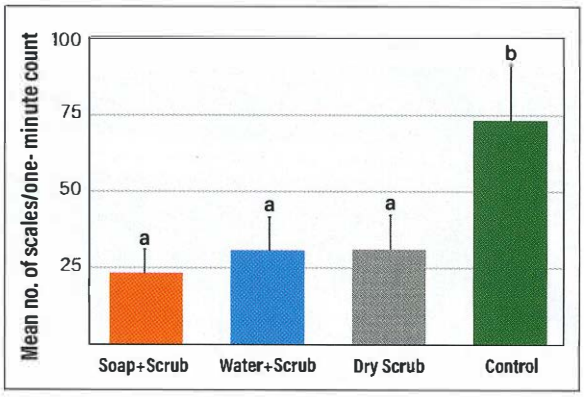


Fig. 4. One-minute counts post-Scale Scrub showed lower densities of calico scale relative to untreated controls ($F_{8,23} = 3.21$; $P = 0.025$), but there were no differences among scrub treatments.

Scrubbing Scales Engages Students

Forty-two APO Service Fraternity members voluntarily engaged with their campus tree canopy through the Scale Scrub project. Sixty-eight of the 80 scale-infested trees were treated over two weekend mornings (9:00 a.m.–12:00 p.m.); 12 trees remained untreated due to time constraints. Through paper and electronic surveys, APO student volunteers demonstrated their understanding of the study (Figs. 6a and 6b) and indicated that, if the opportunity arose, they would be willing and able to adopt this unconventional approach to pest management (Figs. 7a and 7b). Importantly, the electronic survey conducted nine months post-Scale Scrub demonstrated that the experience generated positive self-perception in volunteers, and increased their awareness of, and sense of ownership in, their campus trees (Figs. 8 and 9).

the scrubbing treatments, though again, variability was high (Fig. 3). Similarly, the change in scale density (post-Scale Scrub densities subtracted from pre-Scale Scrub densities) showed no differences among treatments ($F_{1,22} = 1.86$; $P = 0.19$). However, in our one-minute counts conducted three weeks post-Scale Scrub, we found substantially and significantly lower densities of calico scale attributable to the scrubbing treatments; but again, there were no differences among the scrub treatments themselves (Figs. 4 and 5).

Student Engagement Enhances Tree Health and the Campus Community

Street trees on a main thoroughfare through the University of Kentucky campus were heavily infested by calico scale, causing canopy thinning and tree decline. This provided a unique opportunity for the Urban Forest Initiative to employ their expertise and partner with UK Facilities Management to utilize the college campus as a living laboratory, engaging students in a practical volunteer project to enhance their campus canopy. Thus,

Fig. 5. Calico scale populations (a) pre- and (b) post-Scale Scrub. The effects of the Scale Scrub are visible months after the event.

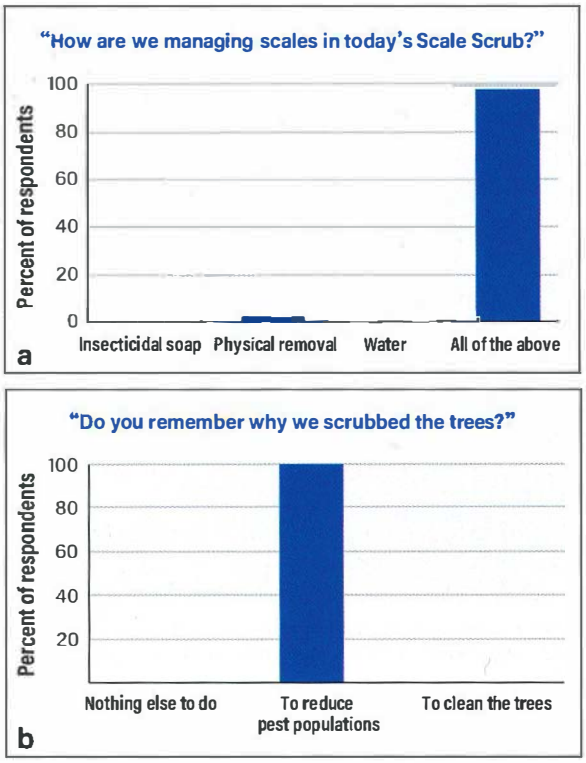


Fig. 6. Volunteers demonstrated their understanding of the project through (a) a paper survey administered during the event and (b) nine months later through an electronic survey.

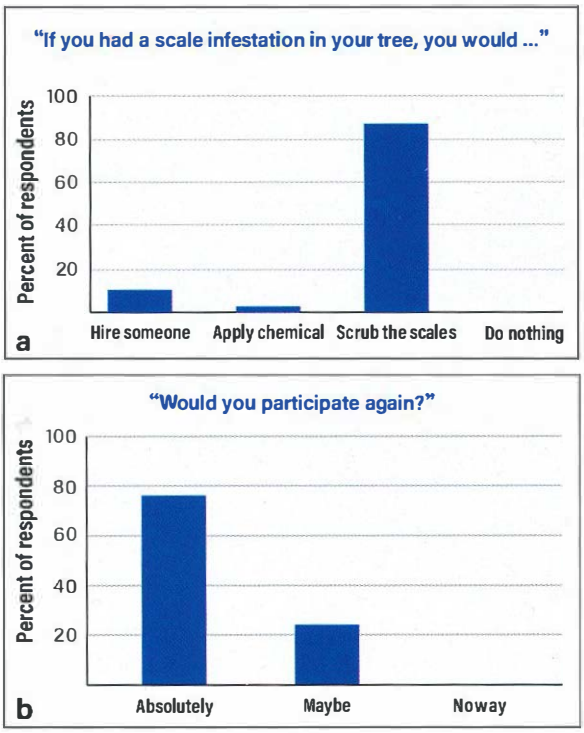
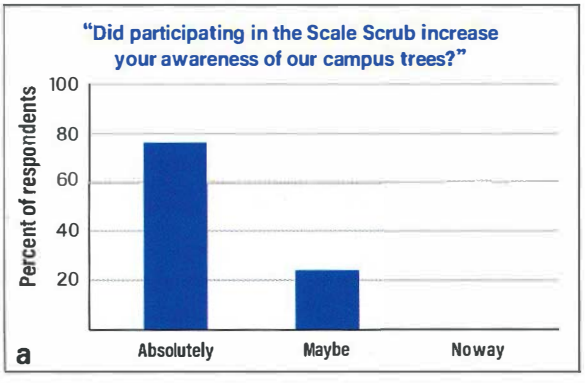
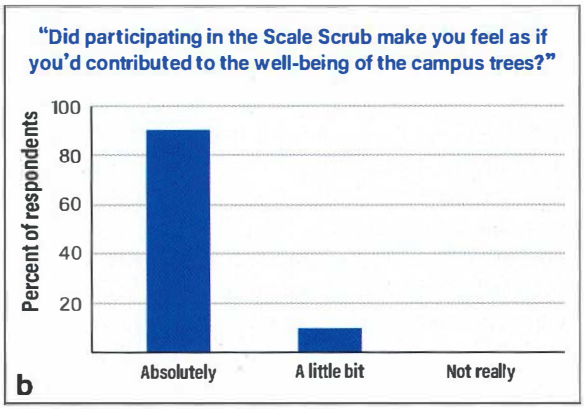


Fig. 7. Survey responses suggested that the majority of volunteers would be willing to adopt this unconventional means of scale suppression (a) immediately after the event, and (b) nine months later.

our objectives were twofold: contribute to necessary suppression of a pest infestation on some highly visible trees on the UK campus and foster student interest and engagement in their campus tree canopy.

As a group, scale insects are common on street and landscape trees and thrive in heavily urbanized areas, due in part to plant stress in the urban environment, the inability of natural enemies to reduce scale densities (Raupp et al. 2010), and/or to urban heat island effects (Meineke et al. 2013). Not surprisingly, we found that scales were not evenly distributed either within or between study trees. Those adjacent to the main thoroughfare had lower scale population densities and were more exposed to road splash, wind, and noise, all of which can influence pest distribution (Raupp et al. 2010, Bunkley et al. 2017), whereas trees adjacent to the sidewalk were more sheltered, had less exposure, and harbored higher scale densities.





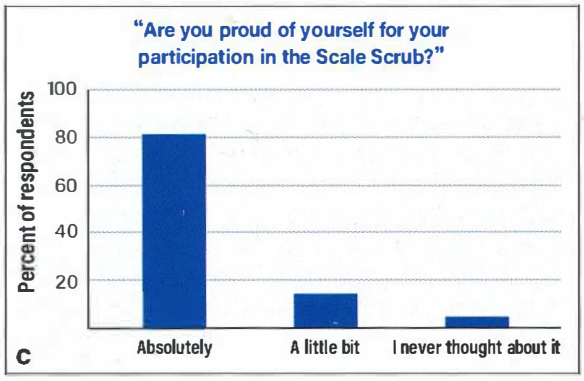


Fig. 8. Respondents to the electronic survey nine months post-Scale Scrub reported (a) a greater awareness of their campus trees, (b) a feeling that they had contributed to the well-being of their campus trees, and (c) pride in having made this contribution.

Fig. 9. Alpha Phi Omega Service Fraternity members who wrapped up a morning of scrubbing scales from their campus trees reported a greater connection with their campus tree canopy after the experience. This stronger sense of place could pay dividends into the future.

We found that scrubbing scales reduced scale densities relative to un-scrubbed controls, but there were no differences among scrub treatments (insecticidal soap, water, and dry scrub). Physical removal was not enhanced by addition of insecticidal soap or water. The lack of efficacy of the insecticidal soap is not indicative of product efficacy, but rather is likely an artifact of timing (treatments were applied before the appearance of crawlers) and/or our inability to apply according to label directions (applying to runoff).

Branch sampling proved ineffective for our study; it was labor-intensive and generated highly variable results. The post-Scale Scrub one-minute counts, however, generated data that reflected visual observations of reduced scale densities on treated trees relative to untreated controls. Future Scale Scrubs could enlist student volunteers in pre-Scale Scrub one-minute counts, greatly reducing organizers' pre-Scale Scrub preparations and significantly increasing sample size.

The Scale Scrub project demonstrated a successful collaboration across entities within a university setting, something that is often not attempted and difficult to achieve. Volunteers from the APO Service Fraternity were engaged learners and provided enthusiastic labor; UK Facilities Management provided institutional support with water hoses and lane closures; the UK departments of Entomology and Forestry provided sampling personnel and personal protective equipment for volunteers; and UFI provided the organizational framework, expertise, and oversight.

The Scale Scrub provided an opportunity for service fraternity members to fulfill their service requirements in a fun, physically active, collegial way, while also providing a much-needed mechanism for volunteers to develop a sense of place and connect with urban nature through their campus trees. Comments solicited through the electronic post-Scale Scrub survey indicated that volunteers appreciated the opportunity to contribute to campus tree care:

What did you like best about the Scale Scrub?

- "The novelty of using a toilet brush to get bugs off a tree—learning about the scales and perfecting techniques to destroy them. Rewarding."
- "I love trees. I got to help some trees fight off pests, and further the knowledge of the best method to remove and fight the scale."
- "I knew I was not only helping with a research project, but I was potentially helping find a way to eliminate the pest problem on campus and better our environment."
- "I like trees, and it was educational about what affects them."
- "Helping the trees."

Volunteers clearly appreciated the opportunity for camaraderie that the event provided:

- "Bonding with others."
- "The interactions between my friends and fellow brothers made the work enjoyable."

Survey responses were not always positive.

What did you like least about the Scale Scrub?

- "Black particles, bugs, and other stuff would just fall in your hair and face and that was a little gross."
- "Bugs on my face."
- "It was cold out."

Interestingly, more than one volunteer requested that we follow up by sharing our research findings.

The UFI Scale Scrub helped transform our campus into a living laboratory and contributed to suppression of a pest infestation causing the decline of some highly visible trees on the UK campus. The Scale Scrub provided

a mechanism that allowed students to actively engage in their campus tree canopy, helping to develop a long-lasting sense of place that should pay dividends well into the future for both the students and the university.

Acknowledgments

The authors appreciate the awesome volunteers from the APO Service Fraternity. We thank Grace Coy, Millie Hamilton, Hannah Moore, Dave Olson, and Sam Rivers for assistance, Jerry Hart (UK Facilities Management) for administrative support, and Eric Roemmele for statistical assistance. Daniel Potter and Lee Townsend provided technical advice and reviewed an early version of this manuscript. This project was supported by the Urban Forest Initiative Working Group, the UK Sustainability Challenge Grant program, the Tracy Farmer Institute for Sustainability and the Environment, and the UK Office of Sustainability. This is publication No. 18-08-024 of the Kentucky Agricultural Experiment Station and is published with the approval of the Director.

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DOI: 10.1093/ae/tmz010