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Campus Landscape Management at the University of Pennsylvania

Scott Creary

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Author: **Scott Creary, Plant Protection Intern**

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Abstract:

As part of a consulting project with the Office of the University Architect (OUA) at the University of Pennsylvania, The Morris Arboretum was asked to provide several services to the University. The original contract called for Morris staff to create a tree and shrub inventory for the campus, evaluate tree health, provide ID tags for selected trees, create and IPM regime, offer suggestions for street tree and capitol project plantings, and train the landscape operations workers. I was asked to help with the shrub inventory and to create a pilot IPM program for the University to implement via an outside contract. After negotiating with the OUA, a in-depth IPM program was deemed unnecessary, so the project was pared down to offering suggestions on the care of the University's American elms, creating an advanced monitoring calendar, and completing the shrub inventory. Through extensive research of American elm management, suggestions were made as to their future maintenance and potential problems. The elms should be given special care to promote their overall health and longevity. A skilled arborist should monitor the elms and Dutch elm disease should be controlled by preventative and therapeutic pruning. The advanced monitoring calendar was compiled for the growing season for only plants of note in the campus landscape. The shrub inventory was scheduled to begin in April, once the plants have leafed out. This project should be used as a precursor to further work on the University of Pennsylvania's landscape, both collecting data and consulting.

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INTRODUCTION

The Morris Arboretum, falling into the Business Services Department of the University of Pennsylvania, often collaborates with other sectors of the University on a contractual basis. Our expertise in the fields of urban horticulture and integrated pest management makes us the perfect choice for consulting with the Division of Facilities and Real Estate Services about the trees and landscapes on the main campus of the University. The original request from the Division of Facilities and Real Estate Services Office of the University Architect (OUA) asked that the Morris:

- Provide identification tags for selected specimen trees
- Monitor and evaluate tree health to justify long-term care or removal
- Create an Integrated Pest Management regime to be performed by a hired contractor or University personnel
- Guide *Franklinia* installation for the Benjamin Franklin Anniversary celebration
- Give feedback and recommendations on street tree plantings
- Oversee a new landscape project, guiding plant selection and installation
- Train University landscape operations workers for specific tasks.

Jason Lubar and Bill Graham, Arboretum-employed arborists, have already completed an inventory and accession database for all the trees on the campus grounds, in addition to tagging a selected few. They have also evaluated the health and care of many trees on campus and offered suggestions on their maintenance. Upon presenting a proposal for an IPM program, the Office of the University Architect decided that pest pressures were not sufficient to justify an in-depth monitoring program. The IPM proposal was pared down into specific areas of concern, and a new proposal was drafted. This new list of priorities broke the IPM proposal into suggestions for the maintenance of the American elms on campus, identifying and creating a shrub inventory, and drafting an advanced monitoring calendar.

American elms (Ulmus americana) were once the predominant trees in the urban landscape. Largely due to Dutch elm disease (DED), non-hybrid American elms are virtually extinct, except in isolated locations. The American elms on the University of Pennsylvania's campus are such trees—remnants of gone-by era. As the trees are established, magnificent specimens, the emphasis is preservation rather than aiding growth and development. In addition to considering the factors involved in tree aging, an effective management strategy involves preventing and treating maladies as they occur. American elms are susceptible to a considerably more disastrous pest complex than many other shade trees, making monitoring more crucial. The most notable and potentially devastating infestations and infections are: Dutch elm disease

(Ophiostoma ulmi), elm yellows, elm leaf beetle (Xanthogaleruca luteola), and European fruit lecanium (Parthenolecanium corni). Through researching these issues, I can offer suggestions to help implement a program to ensure the health and longevity of the University's most notable trees.

Although there are 18 live American elms on the campus, not all of them are necessarily in high profile areas, nor are they all of sufficient size or spread to include them in an intensive preservation initiative. The prized specimen elms are in front of College Hall facing Van Pelt Library, on the Spruce Street side of Houston Hall, on the east wall of Logan Hall, in the middle of the Quadrangle, a courtyard in the main dormitory complex, and lining the north side of Hamilton Walk. As per the recommendation of a contracted arborist, several of these trees were injected with Arbortect 20-S in May of 2004. The treated specimens are the two in front of College Hall, one on Hamilton Walk, one in the Quadrangle, and two specimens that died shortly after injection on the green south of Van Pelt Library

Table 1. Location and size of living American elms at the University of Pennsylvania

Grid Location	Inventory #	DBH (inches)	Spread (feet)	Injected?
N33.2	2	26	70	No
N34.1	32	41	79	Yes
N34.1	83	34	79	No
N34.1	85	33	60	No
N34.2	4	49	100	Yes
N34.4	13	27	72	No
N34.4	14	27	60	No
N40.4	26	40	70	No
N42.1	13	18	52	No
N42.1	14	19	52	No
O37.4	11	26	58	Yes
O37.4	28	31	94	Yes
O38.2	16	5	20	No
O38.3	6	27	51	No
O38.4	16	27	55	No
P37.2	39	38	58	No
R34.3	7	12	33	No

The shrub index is a facet of the Arboretum's consulting that builds upon the tree inventory. By identifying and mapping the shrubs in some high priority areas of the campus, I hope to give the OUA a better grasp of the landscapes on campus. In addition to creating an awareness of the campus plantings, this inventory will be an invaluable resource for future endeavors such as: predicting and monitoring pest outbreaks, transplanting initiatives, landscape renovations or replacements, selecting priority plantings, and general grounds maintenance.

The advanced monitoring calendar is intended to act as an alert to the key pests that might occur through the growing season. Although the University of Pennsylvania does not have the budget to allow for an entire contract to monitor and treat the campus plantings, identifying the key pests of the trees and shrubs will help to guide the landscape operations workers in troubleshooting ailing plants. Together with a comprehensive shrub inventory, a list of key pests will elucidate problem landscapes, pointing out overabundances of susceptible plants.

MATERIALS AND METHODS

Addressing the elms on the University of Pennsylvania campus began with speaking with Bob Lundgren and Debbie Gillespie at the Office of the University Architect. They pointed out the "sacred trees" on campus, and I looked at them individually. From there, I consulted Casey Sclar, the IPM coordinator at Longwood Gardens for his suggestions and literature on tree injections benefits and detriments. I looked at a number of papers from the *Journal of Arboriculture,* and spoke with Michael Raupp, a professor at the University of Maryland, who had experience working with the American elms in Central Park. After compiling this information, I spoke with the OUA again and gave suggestions for managing the prized American elms on campus.

The shrub inventory has not yet taken place, although all the materials are in place to begin as soon as the shrubs are in leaf, making identification easier and more reliable. The materials necessary for a shrub index and mapping are maps of the quadrants of the University of Pennsylvania campus both blank for mapping the shrubs and with the trees mapped, as many shrubs have already been included in the tree inventory. Anne Brennan, The Morris Arboretum Urban Forestry Intern, will work alongside me with mapping and identifying the shrubs. Considering how large the University's campus is and the density of the plantings, we will focus first on the highest profile quadrant, the landscapes that are between Spruce and Walnut Streets, east of 36th Street to 34th (Quadrants M34 and N34).

Using the maps provided by the OUA, Anne and I will draw the shrubs onto a paper copy using the buildings and trees on the map for scale. We will make comments on the health of the shrubs in addition to noting their size and spread. Rather than concentrating on counting individual plants in a grouping, we will note the size of the grouping and treat it as one mass. After placing the shrubs and shrub masses on the map, we will use ArcView to create a digital plan of the quadrants, which we will then send to Debbie Gillespie at the OUA. I will also create an Excel spreadsheet assigning both characteristics and accession numbers to all the shrubs and shrub masses.

The advanced monitoring calendar was created from a template drafted by Casey Sclar and Jackie Bergquist at Longwood Gardens cataloguing pest emergence dates and life stages. After making a brief overview of the most prevalent and important trees and shrubs on the heavily trafficked areas of the University of Pennsylvania campus, I took the data from Casey Sclar's findings to create a list of the key pest emergence dates for the priority plants on campus. I decided that both the Growing Degree Days (GDD's) and Plant Phenological Indicators were not germane to the University, having no capacity to accurately measure GDD's, and noting that the Plant Phenological Indicator listings in the Sclar and Bergquist report were either misplaced or inaccurate. However, I cross-referenced the emergence dates from the Sclar and Bergquist draft with the 2001 and 2003 reports of the Penn-Del IPM Research Group to verify them. This seemed odd as the list from Longwood was drafted from several years' data from the IPM group, but there were several discrepancies.

RESULTS

Plant Health Care

As a tree ages, many vigorous processes in younger trees become slower and more complicated in older trees due to a number of factors. Older trees are increasingly subjected to environmental constraints as their ability to acquire resources and react to stress reaches its limit. Old trees have been mining the soil for resources for many years and these resources grow scarce, other organisms compete for them, pests become more numerous, disturbance increases in the limited growing space, and stresses like heat and drought become more pertinent. Much of this is strictly environmental, but much is also a result of internal processes becoming less efficient and effective (Coder, 2005).

As a tree ages, its transport system becomes more complicated and is less able to supply water and nutrients to the various places that require them. Every node in the tree represents a constriction of vascular tissue and an increase in transport resistance. The water columns grow longer, adding to both downward tension and cavitation. This causes a reduction in the net photosynthesis of the leaves from stomatal closure and insufficient nutrient supply to photosynthetic areas. The amount of living tissue in trees increases with age. Thus, the tree needs to allocate more resources to maintaining its biomass all the while doing so with a net photosynthesis decline. Soil resources decline as trees mine essential elements out of existing root spaces, but the trees are less able, with less food production and transport complications, to devote energy to root production. Older trees generate more secondary defense compounds, leaving less energy for growth (Coder, 2005).

Therapeutic measures include a number of common sense strategies and more technical treatments that require highly trained personnel. Providing the tree with ample resources falls into the first category. Supplying the soil with organic matter, whether through mulching or compost application is one step toward ensuring tree health from the ground up. Organic matter improves the drainage, water retention, aeration, and nutrient content of the soil. Avoiding soil compaction is one of the best and easiest methods of maintaining proper aeration and water infiltration. Combining the two aforementioned strategies is as simple as providing the tree with a mulch ring as large as the drip line of the tree, thereby increasing organic matter and reducing compaction by discouraging people and vehicles from passing over the root zone. In addition, lawnmowers are less likely to damage the trunk of the trees. Furthermore, a mulch ring increases the water available to the tree by limiting competition with grass or surrounding plantings. Water availability accounts for approximately 80 percent of the variation in tree growth (Coder, 2005). Therefore, ensuring its steady supply is the most important facet of ensuring the health and longevity of venerable, sacred trees like the American elms at the University of Pennsylvania.

Reduction of branch weight and extent can reduce the risk of structural failure and improve vascular transport problems. Occasional crown reductions with emphasis on reducing branch length and lessening the weight of the branch helps to avoid breakage and shortens the water column, thus lessening the resistance to vascular flow. Pruning events should be timed several years apart to allow the tree a chance to recover (Codey 2005).

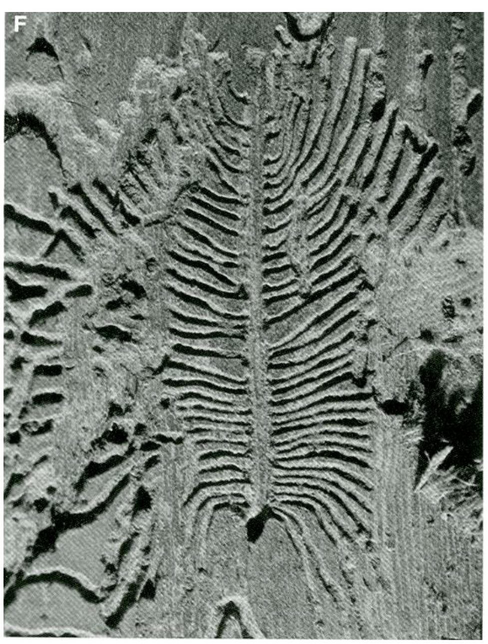
Ensuring the overall health of the tree serves to alleviate both the severity and occurrence of any potential pest infestations. Because the threats to American elms are especially weighty, they will be discussed separately.

Dutch Elm Disease

Dutch elm disease is the sole reason for the all but eradication of American elms from the landscape. It is caused by *Ophiostoma ulmi*, a fungus that kills the xylem cells of members of the elm family by secreting a toxin into infected vessel cells. Mortality is a result of extensive loss of water conduction. While many members of the family exhibit strong resistance to the disease, American elms are highly susceptible. Root grafts and bark beetles are vectors of the disease. Root grafts were once a common method of infection, but as elms become scarcer and more isolated opportunities for root grafting decrease (Stipes and Campana, 1981). However, bark beetles, primarily the European species (*Scolytus multistriatus*), are ubiquitous and most commonly transmit the disease.

The life cycle of DED varies by mode of infection, but the only vector of note is bark beetle. Logically, one must then look to the life cycle of the beetle to predict the occurrence of DED. The adult beetles are shiny, reddish-brown and about 3mm in length. The beetles overwinter as adults and nearly full-grown larvae. The larvae emerge through several weeks in early May. The adults feed at twig crotches of 1-3 year old branches. The adults congregate at dead and dying elm branches and trunks, where they mate and lay their eggs. If the branch is infected with DED, as many dead elm branches are, the fungus grows saprophitically, producing spores in the galleries created by the feeding larvae (Figure 1). The fungus creates a mucilaginous secretion containing spores in these galleries. The beetles become coated with the secretion, and transport the spores it contains after they emerge. As they feed, the spores rub off into the wounds, thereby infecting a new branch.

Figure 1. Bark beetle larval gallery (Johnson and Lyon, 1991)



Adult females can also contaminate already dead branches while excavating a site for oviposition (Johnson and Lyon, 1991).

The disease most noticeably manifests itself as a yellowing of the leaves of one or a few localized branches, usually after the leaves have reached their full size if the infection is via bark beetle. In Philadelphia, this would be around the end of May and beginning of June, when the bark beetles are feeding and mating. Symptoms that occur within 8 weeks of leaf expansion are indicative of infection via either root grafts or an infection from the previous year. The browning, yellowing leaves and branch death are often mistaken for drought stress. As the xylem is the area primarily infected, inspection of the wood of the suspect branch will show dark brown streaks where the fungus is established. The disease spreads rapidly both laterally and vertically to neighboring branches and downward to the roots within the first 4-6 weeks (Sinclair et al., 1987).

Management strategies vary, but the literature and skilled community suggests that DED can be completely controlled without the use of chemicals. This strategy involves close monitoring of the tree canopy for the earliest signs of DED and pruning the infected branch to 3 meters below the lowest noticeable streaking (Lanier, 1988). Close attention to pruning dead, dying, and weak branches to avoid sites for bark beetle breeding is crucial. Every historically successful strategy has depended almost solely upon sanitation to reduce bark beetle activity and available inoculum of the DED fungus (Haugen and Stennes, 1999). Keeping the overall health of the tree at optimum level helps to keep the risk at a minimum.

As Michael Raupp, PhD., a professor at the University of Maryland put it, "This is not rocket science." Reliance on pruning does have its drawbacks as it depends upon having a skilled technician inspect the tree(s) frequently. Furthermore, the infected tissue must be removed immediately, despite the branch being 50 feet from the ground. Pruning one branch out of large trees can be a daunting task. Assuming that the disease is caught before 10% of the canopy is affected, and the fungus has not progressed into the trunk, therapeutic pruning has been shown to be completely effective in eliminating the disease (Lanier, 1988). Removing infected tissue is a necessary step in any DED program, so therapeutic pruning seems to cover all the bases of disease management. Despite pruning being an effective treatment, some tree care companies recommend fungicide injection as a preventative measure.

Fungicide macroinjection (as opposed to risky and unproven microinjection) involves drilling a number of holes into the root flare of the tree and injecting (under pressure) or infusing (utilizing the tree's own capillary action) a large amount of fungicide solution into the vascular stream of the tree (Haugen and Stennes, 1999). Different technicians use either method, although which method is more effective remains unknown. The most uniform distribution is obtained by injecting into excavated roots, but most often the root flare is injected. The treatments are proven effective, although not 100% effective without a proper pruning regime (Lanier, 1988). Should the tree become infected, the source of inoculation must be removed to minimize disease pressure even if the tree has been injected (Haugen and Stennes, 1999). Arbortect 20-S acts by interfering with fugal cell division. If present in small concentrations, it is fungistatic, halting cell division; at higher quantities, it is fungicidal (Haugen and Stennes, 1999)

In order to be useful, the fungicide must reach all points of possible infection and be present in sufficient amounts to kill the fungus or prevent its spread (Stipes, 1988). The two leading products (Arbortect 20-S and Alamo) on the market are proven to be effective both as a preventative and therapeutic treatment post-infection. Injection should only be considered for high value trees as one facet of an overall management strategy (Haugen and Stennes, 1999).

Injection (both macroinjection and infusion) techniques are fraught with uncertainty. One must carefully consider the costs of injection before engaging in any injection regime. Virtually no studies are devoted to the physiological side effects of fungicide *in vitro*, and long-term studies of the effects of fungicide injection on tree health are just as rare (Anderson et al., 1985). Injection exposes trees to a score of pathogens, whose action within the tree are little understood. Once in the tree, diffusion rates and uniformity of coverage are variable to the point of meaninglessness, compounded by testing methods being prohibitively expensive and technical. To be effective, the fungicide must move to the infection site in sufficient amounts to inhibit the fungus, but translocation in the tree and amount of fungicide injected affect concentration in the plant tissue as do a host of uncontrollable environmental conditions. Trees of roughly the same size and age in the same area differ in their translocation rates. The dosage calculations are based on the DBH of the tree, but elms vary so much in morphology that a dose based on DBH is not sufficient (Stipes, 1988). Lanier suggests that the amount of fungicide should depend upon the estimated crown surface area. Lanier's study showed that Arbortect 20-

S is completely effective and less toxic when prescribed according to crown surface area or bark surface area, as this type of calculation often cuts the amount of fungicide injected by 75% (1987). However, most arborists still use trunk diameter to administer injections. Studies have not established the best dilution of the fungicide in water prior to injection, and a higher dilution does not lead to better diffusion within the tree. To complicate matters, the label rates vary one hundred fold for the same product. The diffusion gradient within the tree is unknown and judging from all the other variables interacting, will remain so. As with all the other facets of injection, persistence is little understood and dependent on a number of factors. Pesticide resistance develops most quickly with systemic chemicals, like those for DED. Although no resistant strains have been observed in the field, they have been observed in a laboratory setting. To compound the problem historically, arborists have left little or no records to aid research (Stipes 1988).

While a seemingly infinite array of unknowns haunt injection techniques, we do know that they have adverse effects on the health of the tree. In order to inject the tree, the technician must first drill a hole into the cambium of the tree, and although this port becomes smaller as the technology improves, this wound is an open invitation for a number of opportunistic pathogens. Assuming the wound is small enough, the tree can wall off the invaded portion, thereby cutting off a potential pathogen's oxygen supply. Repeated wounding, however, can reintroduce oxygen to the existing pathogens, resulting in a spike in decay in the interior wood (Perry et a, 1991). Few, if any arborists sterilize their tools from injection to injection, which may aid the spread of disease (Stipes, 1988). Simply responding to the injury utilizes a tree's limited energy resources, helping to predispose it to infestation and infection.

While most healthy trees are capable of healing small wounds, especially those as small as injection ports, the bigger issue is that DED fungicides are toxic compounds forced into the vascular system of the tree. Arbortect 20-S, the fungicide used on the Penn elms, is typically formulated as acid salts (2-[4-thiazolyl] benzimidazole hypophosphite) (TBZ), dissolved in water (Anderson et al, 1985). While it is indeed effective both as therapy and prophylactic, the deleterious side effects need to be considered carefully before engaging in any injection regime.

TBZ solution is extremely acidic and immediately kills the plant cells it comes in contact with until it dilutes sufficiently within the tree's vasculature. The damage manifests itself as a column of discolored, dead wood within the trunk, spreading up toward the canopy, sometimes as high as 15 feet from the point of injection and several feet down into the roots (Anderson et al, 1985). Eventually, the tree is able to compartmentalize this area to stop the spread of necrotic wood, but the woundwood hides the fact that roughly twenty percent of the tree's transport system can be blocked by the injections spaced every eight inches along the trunk (Perry et al, 1991). However, TBZ slows the tree's response to wounding. Several compounds that a tree creates to halt the spread of necrosis laterally and vertically were lacking in TBZ injected trees as opposed to those injected with water (Anderson et al, 1985). Callus formation slows considerably after fungicide injection, and the lag in healing time may foster the establishment of pathogens within the tree. The internal damage appears externally as bleeding from the wounds, especially one year after injection (Anderson et al, 1985).

While preventative injection is questionable, therapeutic injection is a powerful tool in cases of advanced or residual infection. Lanier found that among trees with a residual (last year's) infection, 71% survived when both pruned and injected (1988). Furthermore, injection of a supposedly unsalvageable tree at both the branch collar and root flare after pruning was effective in preserving the tree. Sometimes the DED streaks are found well into a branch such that therapeutic pruning would be disfiguring for a specimen tree, and injection could be used as a mediating factor in pruning.

Preventative injections are largely unnecessary according to all of my sources, however, therapeutic injections may be warranted in some occasions. Monitoring from the ground level is completely reliable, and the monitor should be able catch the disease with sufficient time to employ proper sanitation measures, assuming that the monitor is qualified and inspects the trees regularly (Canon et al, 1985). Injections should be implemented only after careful consideration of the costs and benefits of the procedure, and even then, only in special circumstances.

Elm Yellows

Elm yellows is a systemic, incurable, lethal infection of the phloem elements of the vascular system, rather than the xylem as in DED. A little understood organism called a mollicute causes the condition, also known as phloem necrosis. It disrupts transport of photosynthate to the roots, essentially starving them. With few healthy roots, the elm cannot absorb sufficient water to maintain the canopy. The end result is the drought-stress symptoms widespread throughout the canopy such as wilt, browning, and premature leaf drop in late summer, indicating an already fatal condition in the roots (Sinclair et al, 1989). As a response to the infection, in addition to DED-like streaking, the elm creates methyl salicylate, oil of wintergreen, which allows for a handy diagnosis by sealing a bark sample in a jar for a few minutes. Treatment with antibiotics does slow the progression of the disease, but it does not cure it. Insects serve as the primary vectors by infecting new hosts after feeding on infected plants (Stipes and Campana 1981).

Despite its deadly nature, elm yellows spreads slowly, and typically occurs as very localized epidemics among dense stands of elms. Although it has been reported in the Philadelphia area, it has yet to become established (Stipes and Campana, 1981).

Insect Pests

European fruit lecanium (*Parthenolecanium corni*) is the one of the most economically important scale pests of shade trees. Outbreaks are typically held in check by a number of natural enemies, but some years can be problematic. Mature females, the most apparent life stage of the pest, appear on the twigs from fall to late spring as hemispherical light to dark brown bumps. The eggs hatch from under the females around June and July and migrate to the leaves, where they will spend the summer until moving back to the twigs in early fall. Lecanium only have one generation per year (Cranshaw, 2004). The most noticeable damage to the tree occurs in spring and early summer. The scales only rarely reach damaging levels, and these are usually not sufficient to warrant expensive treatment measures for large trees (Johson and Lyons, 1991). However, should the infestation be sufficient to compromise the health of the tree, a systemic soil drench of imadicloprid may be warranted. Pesticides should only be used to rescue trees, as many will kill beneficials, leading to outbreaks of secondary pests like spider mites. Systemic pesticides are recommended for a well-used public location as spraying is not a feasible option on campus. Injections need to be timed so that they will be active in the tree when the insects are feeding, i.e. May and June. Regular monitoring is important to note the scale population and whether treatment may be necessary.

Elm Leaf Beetle (*Xanthogaleruca* [*Pyrrhalta*] *luteola*) is another largely cosmetic problem for an established American elm. Adult leaf beetles are generally a dull olive green with yellow markings appearing as they become more active. The overwintering adults emerge in late April to feed on the expanding leaves. They cut round holes in the foliage. They lay their eggs underneath the leaves within several weeks of emergence, which hatch in another two weeks. The larvae match the adults in coloration: yellow with olive markings. The larvae feed on leaf tissue, but leave the veins intact, creating a skeletonized leaf pattern. As they age, they will crawl down to the base of the tree to pupate (Cranshaw, 2004). The pest typically has two generations in Philadelphia.

Control measures are rarely justified on American elms, as this tree is not the favored host of the leaf beetle. Infestations can reach disfiguring levels, but established trees can tolerant substantial defoliation. Chemical controls involve spraying an insecticide (Sevin) around the trunk to kill the immatures as they crawl down the tree to pupate, spraying the canopy with Ornazin, Atazin, or *Bacillis thuringiensis* to kill the young larvae, or systemic injections of imidacloprid or another comparable chemical (Dreistadt et al, 2004). Any chemical control regime requires diligent monitoring to ensure the proper time for treatment.

Advanced Monitoring Calendar

The following table is not a complete list of all the pest problems that may arise over the course of a year, nor is it intended to be. This is a list of only those pest problems particularly troublesome for the landscapes at the main campus of the University of Pennsylvania. Furthermore, the entries on this list are only those pests and life stages that can be controlled once discovered. The decision to enact a control measure should be based upon careful observation of the life stage, degree of infestation, damage, and cost of control. Chemical control measures in an area like a college campus are complicated by the possible health hazards to pedestrians. I would advise that this list be used as a reference for monitoring the campus plantings with the amassing a data set specific to the University of Pennsylvania.

Table 2. Pest Emergence dates, noting life stages and hosts (Sclar and Bergquist, 2005)

Time	Pest/Pathogen	Life Stage	Earliest Observed Date	Hosts of Importance	Comments
March	Eriophyid Mites	E, N, A	February	Pines, Firs	
	Spruce Spider Mite	E, N, A	February	Conifers	
	Eastern Tent Caterpillar	L	14 March	Hawthorn, Cherry, Crabapple	First Hatch
	Obscure Scale	N	17 March	Oaks	Dormant
April	Eastern Tent Caterpillar	L	14 March	Hawthorne, Cherry, Crabapple	
	Pine Sawfly	L	25 March	Pines	Hatching
	Eriophyid Mites	E, N, A	February	Pines, Firs	
	Spruce Spider Mite	Hatching, E, N, A	February	Conifers	
	Southern Red Mite	E, N, A	1 April	Broadleaved Evergreens	

	Azalea Whitefly	N, A	6 April	Azaleas	
	Honeylocust Plant Bug	N	14 April	Honeylocust	
	Dogwood Anthracnose				Prune out
May	Spruce Spider Mite	E, N, A	February	Conifers	Spring Peak
	Southern Red Mite	E, N, A	1 April	Broadleaved Evergreens	Spring Peak
	Privet Rust Mite	E, N, A	4 April	Privet	
	Azalea Whitefly	A	6 April	Azalea	
	Honeylocust Spidermite	A, E	27 April	Honeylocust	Egg Laying
	Lace Bugs	E, N	30 April	Azalea, Oak, Hawthorn, Amelanchier, Crabapple,Cotoneaster	
	Privet Rust Mite	E, N, A	4 May	Privet	
	Honeylocust Plant Bug	A	6 May	Honeylocust	
	Boxwood Psyllid	A	6 May	Boxwood	
	Taxus Mealybug	C	Late May	Yew, Dogwood	Scout for egg cases
	Cottony Maple Scale	C	Late May	Maple, Honeylocust, Linden	Scout for egg cases
June	Privet Rust Mite	E, N, A	4 May	Privet	Most damaging in hot weather
	Honeylocust Plant Bug	N, A	6 May	Honeylocust	
	Honeylocust Spider Mite	E, N, A		Honeylocust	Most damaging in hot weather
	Lace Bugs	E, N, A		Azalea, Oak, Hawthorn, Amelanchier, Crabapple, Cotoneaster	
	Boxwood Psyllid	N, A	6 May	Boxwood	
	Taxus	E, N, C	May	Yew, Dogwood	

	Mealybug				
	Cottony Maple Scale	E, N, C	May	Maple, Honeylocust, Linden	
	Aphids	N, A		Tulip Tree, Abelia, Prunus	
	Fall Webworm	L	3 June	Shade/Fruit Trees	Hatching
	2-Spotted Spider Mite	E, N, A	4 June	Dogwood, Viburnum, many others	Huge Host Range
	Elm Leaf Beetle	L	10 June	Elm	
	Japanese/Maple Mealybug	C, N	Mid June	Azalea, Witch Hazel, Fothergilla, Winterhazel	Hatching; early disfigurement on azaleas
July	As Above				
	Red Headed Pine Sawfly	L	27 Jun	Pines	
	Dogwood Sawfly	L	28 Jun	Dogwoods	
August	As Above				
	Tulip Tree Scale	C	8 Aug	Tulip Tree, Linden, Magnolia	
	Magnolia Scale	C, N	Mid Aug	Magnolia	
September	Red Headed Pine Sawfly	L	27 Jun	Pines	Second generation
	Tulip Tree Scale	N	8 Aug	Tulip Tree, Linden, Magnolia	
	Magnolia Scale	C, N	Mid Aug	Magnolia	
	Southern Red Mite	E, N, A	24 Aug	Broadleaved Evergreens	Fall recurrence
	Spruce Spider Mite	E, N, A	26 Aug	Conifers	Fall recurrence
	Eriophyid Mites	E, N, A		Pines, Firs	
October	Southern Red Mite	E, N, A	24 Aug	Broadleaved Evergreens	
	Spruce Spider Mite	E, N, A	26 Aug	Conifers	
	Eriophyid Mites	E, N, A	Sept	Pines, Firs	

Shrub Inventory

As the shrub inventory has not been completed, it has not been added to the results section. However, the findings will be reported to both the arboretum and the University of Pennsylvania Division of Facilities and Real Estate Services for addition to the tree inventory and map records.

DISCUSSION

This report is far from comprehensive. Many gaps in the information need to be addressed and honed to ensure the efficacy of these findings. The report does not address all the issues raised by the OUA either. Such an undertaking would have been too vast for one year's project. The shrub inventory is too large an undertaking for the time left with this year's interns, but could easily be expanded in years to come.

This project does, however, break ground for future topics of study in the years to come. Future studies involving street tree maintenance, planting, and environments would be beneficial for both the University and the Morris, as it would help in planting choices, techniques and management, and possessing such information could be extrapolated to many other sites and circumstances in future consultations. The OUA was concerned with the training of their landscape operations workers and was interested in initiating a program directed by the trained professionals at the Arboretum. The turnover rate is very fast in University landscape workers, and over qualification could lead to an increased wage for the largely unionized workers. These issues should be addressed delicately, and the Arboretum's ties with the University make us the ideal candidate for such dealings.

Recommendations for future plantings, pest management, and American elm specifications are based upon having a body of historical data for the plantings. The OUA does not have comprehensive records of the services provided by contracted arborists, and future interns could monitor their work, keep records of said work and its quality to help ensure that the University remains informed in these matters. For instance, two American elms were removed after their death shortly after injection. The arborist did not leave any record of the cause of death or any complications in the injections, nor would such a record remain credible if unchecked by an unbiased source. Furthermore, Bill Graham and Jason Lubar noted several trees that needed pruning or were improperly pruned shortly after an outside arborist performed such services. These situations could be avoided in the future if the Arboretum were consulted before engaging in any contract with an outside source and to verify the quality of the services.

Many discrepancies and vagaries could be elucidated by future monitoring of pest emergences and their relative importance. The calendar above is intended to be used as a reference for scouting the plantings and refining the dates and life stages. Future plant protection interns are well suited for collecting and recording regarding pest infestation at the University. Once collected, this information could be used to guide planting choices and cultural control methods to minimize pest impact on the health and aesthetics of the campus landscapes. A completed shrub inventory will be a useful tool to guide monitoring.

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