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URBAN INTEGRATED PEST MANAGEMENT

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This paper discusses the need to establish urban integrated pest management (IPM) programs in cities, for the purpose of reducing pesticide use, and documents some of our experiences in developing such IPM programs in the north central California and San Francisco Bay areas.

One of the more important reasons to focus attention on urban areas is because that is where most people in the United States live. In 1970, 73.5% of the population (149 million) was classified as urban by the Bureau of the Census. These people lived in 7,061 communities, each with 2,500 or more people. Areas classified as rural may also have urban characteristics in relation to pest management.

Historically insect pest control has developed largely around agricultural, silvicultural and medical pest problems, while horticultural areas have been given relatively less attention. This general trend is also evident with the development and application of the new technology of integrated control (2,3,4,13). The revised edition of Urban Entomology (1) hardly considers horticultural problems. Those that it does consider are dealt with from a relatively narrow but widely accepted viewpoint that has predominated over the last few decades, i.e., chemical control. Only recently, in 1974, did the American Institute of Biological Sciences recognize the field of Urban Entomology by providing for a symposium on the subject. In 1976 the Internatonal Entomological Society also held a session devoted to this area. Very few researchers are available to focus on the problems of urban plant-insect relationships. Those working in this field are scattered and poorly organized, as is the literature of horticultural entomology. This situation exists despite the fact that most people live in the urban areas where such vegetation-pest systems are evident.

Urban Pesticide Use

One way to assess existing urban pest management activities is to examine pesticide use patterns. Urban and suburban pesticide users are: homeowners, public and private institutions and commercial establishments — in short, all sectors of the urban community.

Everywhere that man maintains vegetation or provides other food energy sources on which insects or other "pests" can survive, pesticide use occurs. The fact that most of these sources remain unassessed as to pesticide use rates indicates a serious flaw in overall pesticide monitoring programs, particularly since the potential of human exposure to toxic materials is great in such environments when compared to the use of these same substances in non-urbanized areas.

One attempt to ascertain the degree of pesticide usage in an "urban area" is a study commissioned by the Environmental Protection Agency (14). Total pesticide production for the nation in 1970 was 1.034 billion pounds, distributed as: 47% insecticides, 39% herbicides and 14% fungicides. This study estimated that over 750,000 lbs. of active ingredients were used in the three major metropolitan areas studied. This 750,000 lbs. was distributed as 68% insecticides, 17% herbicides and 16% fungicides. Thus, insecticides appear to find proportionally greater use in urban areas. Extrapolating from this assessment produces an estimate of 30 million pounds of total pesticide use for urban areas. Roughly 80% is used by homeowners. The von Rumker report (14) identified lawns as a major target category. However, two independent studies done by volunteers in California suggest other uses that appear substantial. They also provide data concerning user philosophy, background and source of information.

Pesticide User Surveys

The first report (16) was done in the City of Berkeley, California. Different areas of the city were sampled and 85, out of 130 homes approached, participated. Based on the value of the home, it appeared that people with higher incomes had fewer "pests," used more insecticide and had different "pests" than people with lower income. However, geographic and microclimatic differences could be partly responsible for this variation. Conversely, people with lower income had more "pests," but used less insecticides. Older people (over age 40) appeared to use more pesticides regularly, but sample size was too small to make definitive statements. Most of the people sampled fell into the age group 20 to 40, and interestingly, almost all (79%) said that recent concern with environmental matters had changed their attitude. (This study was done in 1971.) Still, the group reported that more than 25% used flea collars, 7% — snail pellets, 6% chlordane in the garden, and about 15% used aerosols for flies and roaches. Thus, although environmental concerns were expressed, pesticide use was still considerable.

In general, upper income homeowners either have a gardener whose job is viewed as keeping things tidy (*insects are untidy*), hire a commercial pest control company for a regular treatment (usually monthly), or do it themselves with advice from various sources. Homeowners hiring gardeners generally did not know what specific pesticides were being used on their premises.

The second study (17) was done in Livermore, California. One hundred sixty-one interviews were collected, 90% during February through April, 1972. Twenty-six percent reporting using "pest strips" — with dichlorvos. (About one-third of these were using the strip improperly.) Twenty-two percent of the total used flea collars (lindane was in use at this time). Fifty-seven people or 31% called in professional applicators.

When asked to name the particular problems, 22 people (14%) said it was an insect. Twenty-nine people (18%) specifically mentioned either one or more of the following as an indication of the extent of their knowledge of why pesticides were used in and around their homes: dormant sprays — no insect named (5 people), earwigs (4), spiders (3), ants (2), aphids (2), rust fungi (3), moths (2), cutworms (1), sap bug (1), weeds (1), lawn — no insect named (1), bugs (3), fleas (2), carpet beetles (1), termites (1), and miscellaneous such as spider mites, pine beetles, walnut bugs, elm tree beetles (4). Eleven people (6.8%) had their homes fumigated (presumably for termites). Two people specified that the treatments were precautionary and could not name an insect pest they hoped to prevent from appearing.

The conclusions derived from these assessments and studies are:

1. Existing data on urban pesticide use is mostly non-existent, and what exists is poor.
2. The urban area, from a pesticide-use viewpoint, is a vast complex of users, problems and information sources.

In general, urban insect populations and pesticides would seem to be affected by:

1. Plant species, their locations and existing management practices.
2. The home, its structure, upkeep, location and surrounding vegetation.
3. Life style of occupants: e.g. food production, waste storage management practices, presence and care of pets and/or other domestic animals.
4. Income, age and attitude of users toward insects, pesticides, and environmental and human health concerns.
5. Area of city, meso- and microclimate, soils, native vegetation, industrial pollutants, etc.

Integrated Pest Management

Given the complexity of the urban area with its multitude of users, pest problems, belief in the chemical cure, widespread fear of insects (8), and vested interest groups, where can one start in order to bring the IPM approach to urban populations? Urban shade trees were selected initially because they are highly visible, are responsible already for substantial budgets devoted to pest control, and are frequently the concern of vocal, politically active citizen constituencies interested in bringing "new" ideas into the community. The microgeographical location of street-side shade trees, located on the interface between private and public domain, gives them a very critical position within the city vegetation complex as a whole. Shade trees also provide very practical advantages to people (e.g. shade and humidity, reducing the need for air conditioners), as well as improving the livability of crowded urban areas through aesthetic enhancement.

By setting up IPM programs for city governments, models are created which can offer viable alternatives to the homeowner if properly represented to the public through existing mass media. This represents an energy and cost effective way to disseminate IPM concepts and technology, which would otherwise be most difficult to accomplish given the nature of the urban user complex with its large number of individuals unfamiliar with the agricultural context of IPM.

Initially, when work was started in 1969, the usual approach to pest control research was followed: focusing on a particular pest problem, investigating its natural history, and conducting field and laboratory studies that further elucidate the biology in relation to the existing theory used in the particular sub-field (e.g. physiology, taxonomy, morphology, ecology, ethology, etc.). However, soon after the start of the project, it became obvious that the traditional approach was inadequate and that a systems view of the problem would be required that would include the human community within which the pest problem had arisen.

The project began with a focus on just biological control efforts against the linden aphid, *Eucallipterus tiliae* L. (10). After the first year, city crews and citizens, aware of the initial work that reduced and eventually eliminated insecticide use, pressured for further study of still other pest problems. It became apparent that some of the problems were related to horticultural maintenance practices, some were a function of the pest control treatments themselves, and many were related to each other. The realization came that the primary problem was with the pest management delivery system itself and its need for an ecosystem perspective. Only occasionally was the problem due to lack of information about the specific pest (with the exception of information on biological control agents). Results of this discovery process have been reported elsewhere (5), but some initial observations on the necessary difference from the usual approach to pest management research as originally developed in agricultural areas are important to record here.

Urban IPM

Urban IPM (especially but not exclusively shade tree IPM) requires attention to more pest problems than are usually encountered in a particular crop. In the San Francisco Bay area, there are in excess of 100 species of shade trees commonly planted. This diversity of plant materials, and consequently of insect pests, is much greater than one would find in any particular agricultural locality. Table 1 is a list of the shade tree pest problems

Table 1. A list of the pest problems under study by the Urban Biological Control project, University of California, Berkeley, California, 1977 and requests for pest management advice from cities participating in the program during 1976.

Pest Species	Importance Total	%
Phryganidia californica, California oakmoth	575	46.0
Hyphantria cunea, Fall webworm	123	9.8
Pyrrhalta luteola, Elm leaf beetle	98	7.8
Drepanaphis acerifolii, Silver maple aphid	72	5.8
Illinoia liriodendri, Tulip tree aphid	65	5.2
Archips argyrospilus, Fruit tree leaf roller *Lithophane attenata*, Green fruit worm	57	4.6
Prociphilus fraxinfolii, Modesto ash aphid	38	3.0
Euceraphis punctipennis and *Callipterinella calliptera*, Birch aphids	23	1.8
Schizura concinna, Red-hump caterpillar	23	1.8
Myzocallis sp., *Tuberculoides* sp. and *Tuberculatus* sp. Oak aphids	18	1.4
Orgyia vetusta, White faced tussock moth	17	1.4
Hyalopterus pruni, Plum aphid	14	1.1
Gossyparia spuria, European elm scale	12	1.0
Malacosoma sp., Tent caterpillar	11	.9
Periphyllus lyropictus, Norway maple aphid	10	.8
Eucallipterus tiliae, Linden aphid	10	.8
Tropidosteptes illitus, Ash bug	10	.8
Saissetia oleae, Black scale	8	.6
Leptocorris rubrolineatus, Western box elder bug	7	.6
Scolytus rugulosis, Shot hole borer	5	.4
Tinocallis platani, Elm aphid	5	.4
?, Hackberry aphid	4	.3
Trialeurodes sp., Whiteflies	4	.3
Calico sp., Sweetgum scale	3	.2
Hordnia circellata, Blue-Green sharpshooter	3	.2
Muscellaneous aphids	21	1.7

now being studied in our project. It shows one season's distribution of requests for pest management advice that we received from the communities which support this work.

The proximity to people of the pest-vegetation complex is another difference between urban and agricultural or silvicultural pest management. Thus, from the very first efforts, public education necessarily became a basic component of all our activities. This factor also dictated extreme caution in the use of toxic materials, and whenever possible, substituting alternative strategies, e.g., physical, cultural and biological controls.

Another basic characteristic of many urban vegetation systems is that they are maintained for primarily aesthetic purposes. Thus economic pressures to treat an insect population are frequently not a factor in decision making. There are exceptions, of course, but these are more easily found in dealing with plant pathogens than with insects, for example Dutch Elm Disease.

The Injury Level Concept

The existence of a hypothetical aesthetic injury level has been assumed (5,6,10) because it helps to explain treatment of insect populations when no economic damage is apparent. Application of this concept to field situations can greatly reduce pesticide treatments.

An example is found in the work on the California oakmoth, *Phryganidia californica* Packard, occasionally a defoliator of the California live oak, *Quercus agrifolia* (12). Periodic defoliation of this native tree by this native insect is not permanently damaging. The temporary loss of leaves is regarded as distasteful by many people, however. This study utilized measurements of 10 larvae per 25 shoots as the level above which excessive defoliation would occur. Thus, although no extensive population data were correlated with various damage levels, this level of insect abundance was useful in deciding on *Bacillus thuringiensis* treatments.

In 1976, 40 European holly oak trees, *Q. ilex*, in Berkeley, California were monitored by our urban IPM group using the monitoring system previously mentioned but with a reduction of the aesthetic injury level to 8 larvae per 25 shoots. This reduction was determined to be desirable because in this case not only were we dealing with a native insect on an exotic plant species, but the trees were generally young, small and so situated that defoliation was extremely noticeable. Only 30% (12 out of 40) of the trees exceeded the theoretical injury level and were treated to prevent possible defoliation. Thus, although determining an absolute injury level that will work precisely in all locations appears implausible if not impossible; the concept can be applied in a relative way within a range of values.

In the spring of 1977 this injury level was applied on a larger scale; 5,680 oaks (mostly *Q. ilex*) were monitored in San Jose. Due to the scale of the system and limited time for decision-making the oakmoth larval populations were classified into high, medium and low. High and medium trees were those that exceeded the injury level and were consequently sprayed with *Bacillus thuringiensis*. A total of 2,300 or 5% of the trees were treated. Thus, through application of the aesthetic injury level concept, 45% of the trees were eliminated from the treatments. Under non-IPM conditions all oaks would routinely receive pesticide applications at considerable cost to the city.

The blue spruce aphids, *Elatobium abieinum* Walker, provides an example of a pest that can cause economic damage since successive defoliations of its host plant *Picea* sp. is believed to kill the tree (15). This aphid, which occurs on blue spruce plantings in a highly visible median strip in the City of Palo Alto, was regularly treated with a series of different compounds over the years. Just prior to beginning IPM work, pyrethroids were the material being used on all 30 trees in the three major blocks. In 1976 we started detailed studies that documented the population sizes on all trees. Through weekly monitoring, alternating between even and odd numbered specimens, aphid populations were sampled in the middle canopy of each tree. Four branches from the north, south, east and west were each tapped four times with a stick and the aphids collected on a beating cloth, counted and recorded. Population size was plotted through the period of highest abundance and the lowest aphid counts correlated with the initiation of defoliation established a tentative working injury level of a mean or 34 aphids per tree sample. During this first study season only 17% (5 out of 30) of the trees studied showed sample means above the injury level and thus might be recommended for treatment. We expect to study this situation in subsequent seasons to discover if the individual trees observed to be susceptible to excessive aphid populations remain susceptible over a series of seasons as well as to test the appropriateness of this proposed injury level.

Spot Treatments

Some horticultural personnel have observed the wide variation in pest numbers on adjacent trees of the same species. Those trees that repeatedly each season show excessive pest populations are called "host trees." We have observed this "host tree" phenomena for a series of species (9) and pest herbivore populations, but the actual mechanisms that produce the phenomena are still unknown. However, the fact that a similar phenomena has been observed with the plant pathogen (*Gleosporium aridium* Ell. and Holw.) on Modesto ash trees (*Fraxinus velutina* 'Modesto') which are all genetically identical, having been vegetatively propagated from a single tree from Modesto, California, indicates that variations in the environmental conditions or causal agent, and not genetic variations, may account for the differences observed. Even without knowing the mechanism of the "host trees" phenomena, confining treatments to those individual specimens is also a valuable strategy for reducing pesticide use.

Delivery System Research

It is a mistake to assume that delivery system strategies commonly employed in agricultural IPM projects can be simply transposed to urban areas. These systems are extremely complex socially and politically in ways that impinge directly upon the pest management decision-making. Where citizens are used as "advance" scouts to alert pest management advisors of presumed potential problem areas, and entomologically untrained municipal personnel are relied upon to interpret and carry out necessary strategies, all manner of management devices must be invented. Each type of institution has its own idiosyncracies, and as we have learned in our project, a school district requires quite different approaches from that of a city public works department. It is also most important that economically viable IPM models be developed for use by the private pest control industry that services the homeowners, for here the potential for misuse of materials is particularly great.

Biological Control in IPM Studies

Elsewhere we have described some of the many alternatives to toxic pesticides, i.e. physical, cultural and biological, that we have employed in our urban IPM project (6,7,8,11). We would like to stress here the importance of integrating classical biological control research into IPM delivery system studies.

Current IPM programs that do not have importation capabilities, particularly those that deal with non-native pest species, tend to focus just on servicing problems rather than the possibility of permanent solutions. If IPM programs are organized under one institutional framework and biological control importation programs under another, as has developed here in the California agricultural sector, each organizational approach develops independently. The result is that the more field-oriented IPM people become totally concerned with and forget about the possibilities and importance of nurturing importation projects while the biological control experts become somewhat isolated and are apt to disdain research into the development of delivery systems. The resultant situation creates unnecessary lags in support for the initiation of natural enemy studies and introduction programs and, obviously in some cases, in pest management strategies. Biological control research is particularly applicable in urban areas where permissible levels of herbivorous insect abundance may be much higher than in agriculture, thus providing an ideal setting for the use of parasites and predators to suppress pest population numbers.

Conclusions

Integrated pest management programs in urban areas can significantly reduce pesticide use in these environments. To accomplish this it is essential that aesthetic and economic injury levels be determined for horticultural and other urban pests wherever pesticides are used. To provide the greatest possible range of alternative strategies, biological control research should be incorporated into these programs along with educational efforts and delivery system studies.

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ABSTRACT

Linderman, R.G. 1978. **Mycorrhizae—indispensable aids to profitable plant production.** American Nurseryman 147(4): 17, 129-133.

Healthy rootlets of most vascular plants grown in natural soil are inhabited by nonpathogenic, probably beneficial, fungi called mycorrhizae. In ornamental horticulture, we have not paid attention to these associations that many feel are indispensable for the survival and well being of the host plant. There are two major groups of mycorrhizae based on the anatomical nature of their root infections: ectomycorrhizae and endomycorrhizae. Plants benefit from mycorrhizae in several categories: (1) water and nutrient uptake; (2) detoxification of soils; (3) altered root morphology and physiology; and (4) protection against root pathogens. Our recent studies on enhanced rooting of bearberry (*Arctostaphylos uva-ursi*) when ectomycorrhizal inoculum is added to the rooting medium demonstrate the great potential significance to the nursery industry, because so much plant material is vegetatively propagated.