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Integrated Pest Management of Tree Pathogens and Disease Vectors

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Abstract

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Throughout history, insect pests and diseases have had a devastating effect on ornamental and other economically important tree species. The classic example in forestry, Dutch Elm Disease, decimated elm trees throughout Europe, parts of Asia and in most of the temperate zones of North America and is still a problem in some countries. Symptoms induced in trees by disease-causing agents are often subtle and in order to make an accurate diagnosis experience in the field of tree pathology is essential. Stress either due to environmental factors, or insect infestations, often plays a crucial role in the manifestation of disease symptoms. A pathogen residing as an endophyte in healthy tissue will often induce symptoms of the disease when its host is physiologically weakened. Once the symptoms of the disease become noticeable, the tree is usually beyond saving. Management of tree diseases is complicated. The application of chemicals is usually not practical and often poses a risk to the environment. In this paper, two diseases, oak decline and wilt of *Quercus* spp., a species of some importance in the Arab regions, are discussed. Both oak decline and wilt have an association with insects and their management requires an integrated approach.

Introduction

Throughout the last century, insect pests and diseases have had a devastating effect on ornamental and economically important tree species. Two examples are *Ophiostoma ulmi*, the causal agent of Dutch Elm Disease, and *Cryphonectria parasitica*, the causal agent of Chestnut Blight, which destroyed all American elm trees and almost all American chestnut trees, respectively. Epidemics can be the result of introductions of disease-causing agents or pests into new environments. Alternatively, the introduction of exotic tree species can also led to serious disease outbreaks when these species are attacked by native pathogens or pests.

The introduction of pathogens or pests into new environments have been especially damaging because native trees have had no opportunity to evolve resistance to new disease-causing agents. In addition, indigenous natural enemies cannot rapidly adapt to new insect introductions (potential disease vectors) and rarely are natural enemies introduced along with the pest. The classic example in forestry of an introduction of a pathogen into a new environment is Dutch Elm Disease that decimated elm trees (*Ulmus* spp.) The causal agent, *Ophiostoma ulmi,* probably has its origin in Asia from where it spread to Europe and North America. Only the Chinese and Siberian elms are tolerant, all other species, especially those widely planted as shade trees and in urban forestry, have yielded to the onslaught of the disease which has drastically altered species composition in several natural ecosystems. Dutch Elm Disease is also reported as a problem in Iran causing death of elms north of Tehran (pers. comm. Dr M. Baia, Plant Pests and Disease Research Institute).

The introduction of exotic tree species into new environments has on a number of occasions resulted in unforeseen disease/pest problems from formerly unimportant native pathogens/pests. An example of an introduction of an exotic species, which subsequently succumbed to an indigenous pathogen, is the introduction of palm species into Florida, USA, in the mid-1950s which began dying in large numbers due to lethal yellowing disease. As the epidemic progressed, other introduced palms succumbed while those native to Florida remained unaffected. The second example that is related to forestry, is the introduction of *Pinus radiata* into new areas. *Dothistroma* needle blight caused severe epidemics especially when *P. radiata*, which is a naturally winter-rainfed species, was introduced into areas with summer-rainfed regimes.

Globally there is limited quantifiable data about pest incidence and their effects on forests and forest products. There is also scant information readily available on the impact of tree diseases in the Arab countries. Insect and disease outbreaks in developing countries are surveyed and reported mostly for plantations and planted trees, and corresponding surveys of forest declines and diebacks in native forests of these countries are relatively rare. Little has been done to quantify economic impacts and implications of pests and diseases, despite the fact that their presence sometimes results in the curtailment of plantation programmes, the abandonment of a given tree species in cultivation, or the necessity to clearcut large areas dominated by infested trees.

Disease not only exerts a threat to forest productivity but also acts in concert with other agents of forest destruction, in particular insects, fire and adverse weather conditions. Recent examples include dieback in north-eastern USA, the little leaf disease of short leaf pine (*Pinus echinata*) in the southern USA (4) and eucalypts (mainly *Eucalyptus tereticornis*) ravaged by pink disease, *Corticium salmonicolor* and leaf blight *Cylindrocladium* spp. in southern India. *Acacia mangium* plantations in Malaysia have been seriously affected by heart-rot disease of unknown aetiology (5).

Specific symptoms of plant diseases can be classified under three major types of tissue alteration, namely necrosis, hypertrophy and atrophy. These symptoms are often subtle and in order to make an accurate diagnosis, experience in the field of tree pathology is essential. Stress, either due to

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environmental factors or insect infestations, often plays a crucial role in the manifestation of disease symptoms. A pathogen residing, as an endophyte in healthy tissue may induce symptoms of the disease when its host is physiologically weakened. Once the symptoms of the disease become noticeable, the tree is usually lost. The effect of disease on the tree is also often hidden from view or initially not readily evident, for example, heart decay contributes 73% of total disease impact in forest trees but its effect in destroying the internal heartwood column goes unnoticed until harvest, unless increment core samples are taken to monitor the situation (16). Management of tree diseases is thus complicated.

Management Strategies

Forest protection is an integral part of sustainable forest management. Good management including the use of appropriate species and provenances to meet prevailing environmental conditions and end use requirements, and planting materials of optimal physiological and genetic quality, coupled with good silviculture, is thus the key to a healthy forest. The best line of defence in forest protection is prevention through international and national phytosanitary legislation. The International Plant Protection Convention (IPPC) is a multilateral treaty for cooperation in plant protection, approved and deposited in 1951 with FAO in Rome. The IPPC came into force in 1952 and was amended in 1979 ("the Revised Text") and 1997 ("the New Revised Text"). At this present time, 111 countries have adhered to the Convention. The purpose of the IPPC is to secure common and effective action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control. The new revised text of the IPPC provides the framework for international phytosanitary standard-setting, and makes provision for a Secretariat of the IPPC and for a Commission on Phytosanitary Measures to support structures to facilitate implementation of the Convention. A number of international standards for phytosanitary measures have been endorsed through this system. (http://www.fao.org/waicent/faoinfo/agricult/agp/agpp/pq/Default.htm)

Despite phytosanitary measures and exchange of official information, pests still continue to move between and within countries and regions of the world and given suitable climatic conditions and the absence of indigenous natural enemies, are quick to establish. Health monitoring is important to ensure that pest activity is discovered before it spreads widely and extensive damage occurs, and to provide data to support decisions on appropriate strategies of control once a problem has been detected. Frequently, however, by the time an undesirable exotic forest insect or disease is discovered, the problem is already widespread, and will necessitate urgent integrated interventions.

The concept of Integrated Pest Management (IPM) in forestry is still evolving. Too often pest outbreaks are still treated as a crisis situation once they are already widespread, when it is too late to prevent major damage to the forest or plantation resources. Promotion of IPM in forestry is an urgent priority. The use of IPM implies that pest management programmes are designed as an integral part of forest management, and that they include both prevention and suppression strategies. Emphasis should be on understanding the underlying causes of outbreaks, pest monitoring and maintaining or gradually improving the overall health of forests, rather than on controlling pests once they have occurred. Development of an IPM system to address damage caused by a newly established and damaging forest pest will require accelerated research and vigorous action programmes to establish host/ pest interactions, identify site and stand conditions that favour the pest, evaluate effects of local natural enemies, and predict potential resource damage (6).

The establishment of single species plantations may/can increase the susceptibility of plantations to insects and diseases. In cases where it is feasible, mixed stands may be part of the management solution, along with attention to an appropriate genetic base in forest plantations, and the application of adequate silvicultural measures. Selection and breeding programmes rely on variation found in natural populations to confer genetically based resistance to pests and disease. An example of a disease in which tree breeding together with the implementation of sound forest management may offer a solution is that of the introduced white pine blister rust to North America (*Cronartium ribicola*), on sugar pine (*Pinus lambertiana*) and western white pine (*Pinus monticola*), where major-dominant gene resistance has been found and is currently in use in seed orchard and reforestation programmes (9). Virulent races of the rust have evolved over the years, but the major gene resistance, combined with selection for other minor resistance genes, provide adequate protection to forest tree plantations of these species.

Specific Examples

In this paper, two diseases, oak decline and oak wilt of *Quercus* spp., a species of some importance in the Arab region, are discussed. Both oak decline and wilt have an association with insects and their management requires an integrated approach. Whilst oak decline is of localised importance, oak wilt is of potential international importance.

Oak is of importance to the Arab region with fifteen species of oak described for nine countries (Table l). These species are mainly managed in natural stands.

Table 1. Distribution of *Quercus* species in the Arab Region.

Species	Country
Quercus suber (cork oak)	Algeria*****, Morocco, Tunisia
Q. ilex (holm oak)	Algeria, Morocco, Syria, Tunisia
Q. coccifera	Algeria, Jordan*****, Libya, Morocco, Syria, Tunisia
Q. faginea (zen oak)	Algeria, Morocco, Tunisia
Q. afares	Algeria,
Q. calliprinos	Egypt , Lebanon, Syria
Q. boissieri	Iraq
Q. cedrorum	Lebanon
Q. cerris (or *pseudocerris*)	Lebanon, Syria
Q. aegilops	Iraq, Jordan*****, Lebanon, Syria
Q. libani	Lebanon, Syria
Q. infectoria	Iraq, Jordan, Lebanon, Morocco, Syria
Q. pyrenaica	Morocco
Q. rotundifolia	Morocco
Q. ithaburensis	Jordan

***** grown in plantations

Source: M. Malagnoux FAO (pers.comm) and REFORGEN, FAO-World Wide Information System on Forest Genetic Resources (Forest Resources Division, FAO, Rome)

Oak Decline

Oak decline is a term not used for any single disorder of symptom (13). Oak trees experience decline for many reasons and the most common causes of decline varies with region, site condition, forest type, oak species and year (14). A multitude of predisposing environmental factors such as genetic characteristics, climatic factors and age, may result in oak trees becoming susceptible to decline and premature death (10). Mortality usually results from initial injury caused by biotic, climatic, or edaphic predisposing factors followed by invasion of the weakened trees by secondary fungi and insects. Trees are weakened by environmental stresses such as drought, frost and water logging and are then invaded and killed by insects and diseases that cannot successfully attack healthy trees (17). According to Tainter and Baker (16) the most important predisposing agent to oak decline is defoliating insects. In excess of 20 oak-defoliating insect species have been identified, but those primarily associated with oak mortality are oak leaf tier (*Croesia semipurpurana*), fall canker worm (*Alsophila pometaria*), forest tent caterpillar (*Malacosoma disstria*) and gypsy moth (*Lymantria dispar*). Secondary invaders include *Armillaria* root decay (2), *Phytophthora* root rot (8) and various stem and branch decay fungi such as *Botryosphaeria, Sphaeropsis* and *Endothia* spp. (16).

Biology

The geographical range of decline coincides more or less with the natural range of oaks (3). Rarely do isolated or scattered trees suffer from decline, it is far more common where many trees over a large area are affected usually in almost pure stands. Trees attacked by leaf-feeding insects may succumb after several years of defoliation or they may be weakened by one severe or several partial defoliations. Droughts, early spring frosts, or ice and hail damage may have similar effects. Trees thus weakened show depleted carbohydrate reserves, reduced increment, root mortality and crown die-back.

Diagnosis

The visible symptoms of decline in oaks are slow growth, sparse, undersized, sometimes distorted, often chlorotic leaves, death of scattered twigs, die-back of branches and major limbs and often occurrence of adventitious sprouts (epicormic shoots) along the trunk and large limbs following die-back (13). In the case of insect attack, die-back symptoms are preceded by defoliation. If drought-induced, the gradual crown die-back is preceded by root mortality and in some cases stem cankers are evident.

Control strategy

Efforts to control oak decline should focus on reducing or preventing predisposing stress factors (17). However in forests, environmental conditions such as drought and frost cannot be controlled but management can reduce their effects. For example, thinning can reduce competition for moisture and nutrients and silvicultural practices designed to encourage development of species best adapted to the site can help reduce the effects of environmental stress. Stress from insect defoliation can be reduced or eliminated in high value forest stands by spraying the trees with selective insecticides or biopesticides. Generally, however, direct control of the defoliating insects is not economically feasible in forests.

Regulation of species composition appears to be the only feasible means of avoiding oak mortality. Species in the red oak group (including *Quercus rubra*) appear to be more susceptible than members of the white oak group (including *Q. alba*) to decline and mortality associated with defoliation and drought (13). To minimise susceptibility of oaks to decline, forest management should favour the use of appropriate species, provenances or targeted seed collection from non-infected trees for use in plantation programmes (15).

Oak Wilt

Oak wilt is one of the most destructive diseases of oaks. It currently only occurs in the United States of America but it is found in 21 States, with considerable damage in the Midwest. The causal agent of the disease is *Ceratocystis fagacearum*. Oak wilt is especially serious in coppice stands where there are a large number of stems per hectare and few other tree species present (13). Plantation grown Chinese chestnuts can also be naturally infected and symptoms have been induced artificially in over 35 native and exotic oaks and in American and European chestnuts, chinkapin species, tanoak and several varieties of apple (11).

Biology

Ceratocystis fagacearum can spread among oak trees through root grafts or by spores transmitted by insects. The fungus grows between the bark and cambium forming fungal mats that form cushions under the bark of infected trees. This fungal growth ultimately forces a break in the bark. Insects are attracted to the fruity odour produced by the fungus and they enter through the cracks to feed on the fungus. Sap-feeding beetles in the family Nitidulidae and oak bark beetles such as species of *Pseudopityophthorus* spp. are reported to be vectors of *C. fagacearum* (12). When the insects feed on the fungal mats within infected trees, fungal spores adhere to their bodies. As the insects move from diseased trees to wounds on healthy oaks, the fungal spores are transmitted to a new host. Once inside the tree, the fungus can spread rapidly through the vascular system. The tree is stimulated to produce gums and tyloses that plug the water conducting tissues and thus prevent water and nutrients from reaching the foliage. This causes the tree to wilt.

Diagnosis

In the case where red (for example, Q. *rubra*) and black (for example, *Q. velutina*) oaks are infected with *C. fagacearum*, the leaves turn a dull green or bronze colour, which rapidly progresses from the margins to the base, shortly after which the leaf is shed. Leaf symptoms of white oaks (for example *Q. alba*) on the other hand tend to be more localised and most of the crown may remain healthy. Defoliation may occur any time after the symptoms appear. Twig die-back occurs in the early stages of the disease followed by branch die-back and eventual death of the tree (14). Vascular discoloration may be present in the form of brown streaks that develops in the outer sapwood. White oaks may survive for years after infestation whereas red or black oaks die within weeks (7). No species of oak is known to be immune to this vascular disease and infections have been found in 16 native oak species including most of those of commercial importance (11)

Control strategy

The most essential part of a control programme against oak wilt is to disrupt natural root grafting. This can be achieved chemically or mechanically by killing a portion of the root system halfway between infected and the surrounding healthy trees. Restricting pruning and other wounding activities during the time when new wood is being formed eliminates much insect spread of the disease. Injection with systemic fungicides such as propiconizole may be effective if used as protectants or in the very early stages of infection in high value trees (1).

Conclusions

During the past century, human activities, especially international travel and trade, have circumvented natural barriers and species are invading new continents at an alarming rate. The introduction of a new disease or insect pest or exotic tree species causes substantial disturbance to forest ecosystems as well as having a severe socio-economic impact. Management of the resulting epidemics is fraught with difficulty and successful elimination or control of the problem is rarely achieved.

In this paper, two diseases are discussed. Oak decline is widespread worldwide whereas oak wilt is presently limited to a single continent. The diseases also differ with respect to the causative agent. Oak wilt is caused by a single pathogen whereas oak decline is the result of an association of a number of factors including insects, pathogens and environmental factors. Each country should evaluate the risks associated with the introduction of oak wilt into new environments. It is the sovereign right of each country to determine their own phytosanitary regulations. However, it is important that decisions in this regard are based on adequate information and acknowledgement of potential risks.

Oak decline and wilt are both associated with insect vectors albeit in different manners. Their management relies on the integration of various control measures which attempts to prevent the spread of the pathogen (in the case of oak wilt) such as genetic resistance, if available, favouring species mixtures, root trenching (once infected trees have been identified) and maintaining healthy oak trees. In a number of tree diseases, integrated pest management is the only option to preventing large-scale losses of valuable resources.

الملخص

الارد، جيليان وتيريزا كوتينهو. 2000. الإدارة المتكاملة لممرضات أشجار الغابات ونواقلها. مجلة وقاية النبات العربية. 18: 124-127.

عبر التاريخ، كان للآفات الحشرية والأمراض دوراً مدمراً لأشجار الزينة وغيرها من الأنواع الشجرية المهمة اقتصادياً. ويعتبر مرض (Dutch elm)، الذي أتلف شجر العرعر في كافة أوروبا، وأجزاء من آسيا وفي معظم المناطق المعتدلة من أمريكا الشمالية ولا زال من المشكلات القائمة في بعض الدول، المثال الكلاسيكي في علم الغابات. فالأعراض التي تحدثها العوامل المسببة للشجرة تكون فجائية، ولا بد من مراس في مجال أمراض الغابات للقيام بتشخيص دقيق. وتسهم الإجهادات سواءً البيئية منها أو تلك التي تحدثها الإصابة بالحشرات بدور فاعل في ظهور الأعراض المرضية. ومن الممكن لممرض، موجود في الشجرة على هيئة فطر داخلي، أن يظهر أعراض المرض على عائله عندما يكون هذا الأخير ضعيف فيزيولوجياً. وعندما تضحي أعراض المرض واضحة، تكون حماية الشجرة غير ممكنة. وتعدّ إدارة هذا المرض معقّدة، إذ من غير العملي استخدام المبيدات والتي تشكل، من ناحية أخرى، مخاطر بيئية. وسيناقش الباحثان مرضين، تدهور البلوط وذبول السنديانات، المهمين في بعض الدول العربية. ولكلا المرضين علاقة بالحشرات وتتطلب إدارتهما اتجاهاً متكاملاً.

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