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Management Strategies of Forest Plant Diseases: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOO designed the study and wrote the first draft of the manuscript. Authors TOI and FAO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Forest serves as source of timber, fodder, fuel and forest produce to human along with conservation of soil and water, provision of food and shelter to wildlife and also adding to the aesthetic value and recreational need of human. A major injury to nursery seedlings is caused by pests (insects, mites, diseases and weeds) which has detrimental effect on the seedlings during nursery production by reducing plant growth and quality. Plant diseases are caused by insects, fungi, bacteria, nematodes, viruses and phytoplasmas. However, it is important to know the kind of diseases present in the nursery and the detrimental impact they cause on tree production. Basically, to reduce the risk of pest infestation (insects, mites, weeds, diseases) in the nursery it is important to first of all know the source of diseases in or around the nursery. Seedling production plays an important role in keeping the forest productive, it is therefore important that these disease causing organisms are carefully eradicated from the nursery through proper management strategies. In forest nurseries, different types of diseases such as damping off, root rot, powdery mildew, leaf curl, wilt, canker and rust among others could be found. Therefore, this review emphasizes on the causes and effective ways of managing and eradicating diseases in forest nursery.

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1. INTRODUCTION

Forest nurseries and the seedlings produced there play an important part in keeping this Nation's forest lands productive. Production of healthy and marketable plants in the nursery are the principal objectives to focus on the nursery of forest plants. Modern nurseries must optimize healthy conditions to maximize seedling production while minimizing the risk of a disease outbreak. Proper management of disease involves, spotting symptoms of key diseases, knowing environmental conditions that favor those diseases, knowing when pathogens might be introduced into the crop production cycle and knowing what products are effective [1]. Development of plant diseases in the nursery is affected by many factors, including biotic (living) agents, abiotic (nonliving) factors or a combination of both factors. The biotic agent which are the fungi, bacteria, viruses, nematodes and parasitic plants and abiotic factors such as nutrient deficiencies, lack of water, temperature stress and combinations of these problems as they associate with specific types of plants. Diseases cannot occur unless there is a susceptible plant host, a disease causing agent, and a favorable environment [1]. These plant diseases are carried through seeds into forest nurseries where they become established on seedlings which may cause stunted or malformed seedlings or even kill the seedlings resulting to heavy mortality in nurseries. Plant diseases emerges in necrotic areas, usually spots of various shapes and sizes on leaves, shoots, and fruit; as cankers on stems; as blights, wilts, and necrosis of shoots, branches and entire plants; as discolorations, malformations, galls, and root rots [2].

Pathogenic fungi are common in forest nurseries and they gain entrance to the host plant during periods of physiological pressure or through diseased tissue [3]. Most of these are varying in host specificity and responsible for most losses occurring from the time of sowing throughout planting period. Pathogens may hinder or stop seeds from germinating, cause the death of seedlings or give rise to malformation and stunted growth which result in seedling rejection or a reduction in field survival rate [4].

Since forest provides timber, fuel, fodder and minor forest produce to human as well as conserving soil and water, climate, offering food and shelter for wildlife and adding to the aesthetic value and recreational needs of man, it is therefore predominant to know the causes and effect of a disease outbreak in the nurseries of forest plants.

2. DISCUSSION

2.1 What Causes Plant Diseases?

A plant disease is defined as abnormal growth and/or dysfunction of a plant. Diseases are the result of some disturbance in the normal life process of the plant. Diseases may be the result of living and/or non-living causes [5-7]. Biotic diseases are caused by living organisms (e.g., fungi, bacteria, and viruses) while abiotic diseases are caused by non-living environmental conditions (e.g., soil compaction, wind, nutrient deficiencies, soil salt damage, temperature) [8-10]. Certain conditions must be met for biotic disease to develop. Almost all, if not all, familiar lower and higher plants have their organs attacked by one or more pathogens at different developmental stage [11]. Plant diseases can be classified into several types based on symptoms such as leafspots, wilts, cankers, declines, abnormal growth, reduced yield, dieback, chlorosis, necrosis, and soft rot, etc. They may occur in the field or in storage (pre and postharvest).

Plant pathologist talks about a combination of three crucial factors that must be present to have plant disease. There must be a susceptible host plant, the pathogen (fungi, bacteria, viruses, etc.), and environmental conditions conducive to disease development. These three factors make up what is called the Plant Disease Triangle [12-14].

2.2 Sources of Plant Disease in Nurseries

2.2.1 Soil

The amount and species of microorganisms in a particular portion of soil are determined by a complex interaction of varying amounts of sunlight, temperature, moisture, soil pH, nutrients, and redox potential [15]. Various plant pathogens can be found in soil. Fungi such as Cylindrocladium, Pythium, Phytophthora, Fusarium, Rhizoctonia, and Thielaviopsis, crown gall bacteria (Agrobacterium) and most nematodes reside in the soil. Pythium species

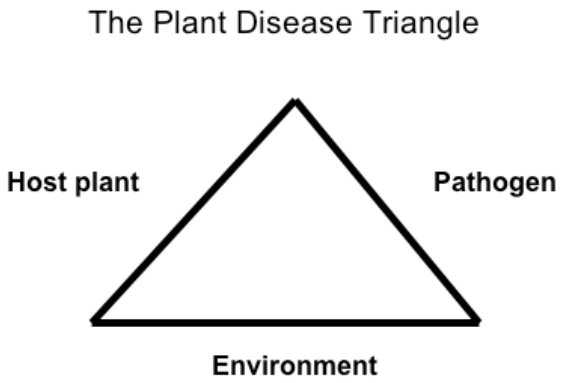

Fig. 1. Plant disease triangle

can be found in sand and peat as well. When nursery seedlings are planted into potting medium containing these pathogens, the pathogens are stimulated into activity by taking up all the nutrient from the plant root and disease may start to form. It is therefore important to sterilize soil or seed bed by steaming with a sterilizer or fumigating in other to have a pathogen free soil before planting to kill all the unwanted organisms [16-18]. Chemicals such as Formalin, Methyl bromide can also be used to treat the soil for two weeks before seeds are sown. Soil and seed can also be treated with chemicals. Soils from the environment can easily contaminate the potting mix, so care must be taken to avoid getting contaminated soil in the potting mix. Species which have hypogeal germination can be carefully treated with fungicide before sowing. It is highly important that equipment to be used are thoroughly disinfected to avoid contamination.

2.2.2 Plant

The first thing to do in other to reduce the risk of pests (e.g. insects, mites, weeds, nematodes diseases) is to ascertain plant sources and non-plant sources in or around the crop from which the pests can come [19]. All plants and plant material around the crops can be a source of pests. Plant materials from other nurseries (seed, cuttings, scion wood and rootstock) can harbor nursery pests, it is therefore necessary to quarantine seedlings coming from an outside nursery before it is introduced into your nursery. If possible, accept propagation material from nurseries only if it has a plant inspection certificate. If in doubt, surface sterilization should be carried out on all new and unknown material. Diseased plants in a nursery should be culled rigorously and burnt rather than composted. Composting diseased material can only be recommended if the compost temperatures are high enough to kill pests (above 60°C), and can be maintained at this level for several days [20, 21].

2.2.3 Water

Water for irrigating in nurseries often comes from a dam, a borehole or a tank filled with rain water. These stagnant reservoirs provide excellent conditions to breed water mold fungi species of Pythium and Phytophthora which are commonly associated with damping off. A small amount of chlorine to provide a 1 ppm concentration for at least 30 minutes can be added to the irrigation water to control damping off fungi.

2.2.4 Weed

Weeds are one of the most significant sources of insect pests and diseases [19]. There is a very high risk that pests will enter your crop from weeds in and around your crop. Weeds provide shelter and food for insect and mite pests and act as a host for diseases.

2.2.5 Crop debris

Crop debris can harbor a lot of pests, giving them a safe place to wait around before moving into another crop. Crop debris includes old plants that have been removed from the crop as well as pruning and other plant material taken from a crop during the growing period. Most plant pathogens have a stage in their life histories that can rest in a dormant state and survive periods of time when temperatures are extreme or moisture is not sufficient for growth. Some pathogens have evolved a strategy of becoming dormant in the dead leaves, stems, branches, and roots where they previously caused disease.

2.3 Types of Plant Pathogens

2.3.1 Fungi

Amongst the types of plant pathogens, fungi, rather than bacteria are the most widespread and are accountable for the most damage to plants in both agricultural and natural ecosystems. Fungi are part of the dominant causal agents of plant diseases. In order to occupy the plants and cause diseases, pathogenic fungi use diverse approaches [22]. Some fungi obtain their nutrients from a living host (plant or animal) and are called biotrophs, others obtain their nutrients from dead plants or animals and are called saprotrophs (saprophytes, saprobes). Some fungi infect a living host, but kill host cells in order to obtain their nutrients; these are called necrotrophs [23]. Fungal plant pathogens often have complex life/ disease cycles involving multiple (as many as five) phases, each of which occurs on a different plant host and is characterized by different reproductive strategies. Most fungi exist as threadlike hyphae made up of cells surrounded by chitin-rich cell walls [11]. These organisms produce enzymes and use physical pressure to create entry points through which the hyphae may invade plant interiors, where they colonize and take over plant nutrients.

2.3.2 Bacteria

Plant associated bacteria may be favorable or destructive. All plant surfaces have microbes on them (epiphytes) and some microbes live inside plants (endophytes). They are single-celled microorganisms, generally ranging from 1-2 µm in size that cannot be seen with the unaided eye [24]. Bacteria are among the microbes that successively colonize plants as they mature. Most plant pathogenic bacteria belong to the following genera: *Erwinia, Pectobacterium, Pantoea, Agrobacterium, Pseudomonas, Ralstonia, Burkholderia, Acidovorax, Xanthomonas, Clavibacter, Streptomyces, Xylella, Spiroplasma,* and *Phytoplasma* [25]. Plant pathogenic bacteria cause many different kinds of symptoms that include galls and overgrowths, wilts, leaf spots, specks and blights, soft rots, as well as scabs and cankers. Unlike fungi, which enter plants through direct penetration, bacteria require a natural opening or wound, such as stomata or insect feeding site to enter a plant host.

2.3.3 Virus

Viruses are infectious pathogens that are too small to be seen with a light microscope, but in spite of their small size they can cause a lot of havoc. The simplest viruses are composed of a small piece of nucleic acid surrounded by a protein coat. As is the case with other organisms, viruses carry genetic information in their nucleic acid which typically specifies two or more proteins [26]. Viruses cannot replicate outside a susceptible hosts. Most plant viruses are transmitted by insect, and the epidemiology of these pathogens is dependent upon the range and behavior of the specific insects that disseminate them. Infected plants may show a range of symptoms depending on the disease but often there is leaf yellowing (either on the whole leaf or in a pattern of stripes or blotches), leaf distortion (leaf curling) and/or other growth distortions (stunting of the whole plant, abnormalities in flower or fruit formation).

2.3.4 Nematodes

Most nematode species that attack plants are microscopic and live in soil. They are worm-like in appearance, but are taxonomically distinct from earthworms, wireworms or flatworms. They are bilaterally symmetrical, soft-bodied (no skeleton), non-segmented round worms [27].

Some of them cause disease in plants either by puncturing the plant cuticles with their stylets to feed or by physically invading the plant's interior spaces, where they stimulate plant cell division, resulting in cysts or galls [11]. Some of the most damaging nematodes are: Root knot (*Meloidogyne* spp.); Cyst (*Heterodera* and *Globodera* spp.); Root lesion (*Pratylenchus* spp.); Spiral (*Helicotylenchus* spp.); Burrowing (*Radopholus similis*); Bulb and stem (*Ditylenchus dipsac*i); Reniform (*Rotylenchulus reniformis*); Dagger (*Xiphinema* spp.); Bud and leaf (*Aphelenchoides* spp.) and Pine Wilt Disease (*Bursaphelenchus xylophilus*).

2.3.5 Protozoa

There are a few protozoa that are considered pathogenic to plants, some, such as Phytomonas spp., cause serious impacts. Members of this genus inhabit the xylem vessels of palms, causing a wilting disease.

2.4 Diseases Associated with Nursery Plants

The soil is a favorable habitat for microorganisms which is inhabited by a wide range of bacteria, fungi, algae, viruses and protozoa. The soil contains large number of microorganisms, usually between one and ten million per gram of soil, with fungi and bacteria being the most prevalent. This review focuses on fungi associated microorganisms that are found in forest tree nurseries.

2.4.1 Damping-off

Damping-off is a fungal disease which causes the death of young seedlings during the first week after germination [3]. This disease is a widespread disease of forest tree seedlings caused by certain soil borne fungi. Damping off disease affects seedlings during the early stages of development. All southern hardwood species are susceptible to this disease [28]. The soil or seed borne fungi associated with the disease are not host specific and they cause rapid decay and mortality of germinating seeds and developing seedlings.

Causal Agent: *Pythium* sp, *Rhizoctonia* sp., Phytophthora sp and Fusarium sp.

Area and distribution: Damping-off is an important disease during nursery stage which causes about 60 -75% damage to the plant. The disease is more prevalent during rainy season and causes delayed seedling emergence in addition to root and basal rots [29].

Symptomatology: Two types of symptoms are observed;

1. **Pre-emergence damping-off:** This symptom of damping-off result in seed and seedling rot before it emerges out of the soil [29].
2. **Post emergence damping off:** Here, the pathogen attacks the collar region of seedlings on the surface of the soil. Damping-off can occur on seed before germination, or on young seedlings. When this happens, the stem of the seedling becomes constricted just above the surface of the germination substrate, and then the seedling falls over and dies. The factors favoring infection are moist soils, poor drainage, 90-100% relative humidity, high temperature of the propagation medium. The affected seedlings are seen to have light brownish color.

Preventive Measures:

1. Healthy seeds should be selected for sowing.
2. Maintain optimum growing conditions and soil amendments such as composted tree bark when added to potting mixtures have shown to suppress damping off.
3. The seed should be treated with Thiram or captan at 2g/kg of seed before sowing and nursery should be drenched with Copper oxychloride 0.25% at fortnight interval.
4. *Trichoderma viride* in soil at 4 to 5kg/ha is also found effective to control damping off to a considerable extent.
5. Avoid waterlogged soils, water seedlings only as necessary with pre-warmed water, ensuring adequate drainage.

Picture/Caption

Fig. 2. Infected plant with damping off

2.4.2 Fusiform rust

This fungal disease attacks several southern pine species, but is most damaging on slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*). Oaks, such as water oak (*Quercus nigra*), willow oak (*Q. phellos*) and southern red oak (*Q. falcata*), serve as important alternate hosts for this disease, but do not sustain any damage.

Causal Agent: *Cronartium quercuum f.* sp. *fusiforme*

Area and Distribution: Fusiform rust infection typically results in definitive swellings called galls on infected branches and stems. Galls vary in appearance, but are most often spindle or fusiform in shape. Fusiform rust infections of first year nursery seedlings appear as distinct knots or elongated swelling (galls) at or near the base of seedlings. Stem galls are often associated

with branches or branch stubs as a result of the rust fungus growing from infected branches into the main stems. Sometimes branches and stems are killed beyond the point of the galls. Stem breakage at galls is common.

Symptomatology: On pine, the most obvious symptom of infection is the formation of a spindle shaped gall on a branch or main stem. The gall may be pitch soaked and occasionally exude sap. During cool spring months, bright orange spores are often produced on the gall surface. These aeciospores are blown off by the wind and serve to infect oak leaves. On oak, symptoms are limited to small leaf spots that may be chlorotic or necrotic. A key diagnostic characteristic on oaks are the bright orange spores (urediospores) produced on the underside of the leaf.

Picture/Caption:

Fig. 3. Gall of fusiform rust on the stem of an infected pine

Preventive Measures:

1. Plant resistant pine species, Shortleaf pine (*P. echinata*) is highly resistant and longleaf pine (*P. palustris*) is relatively resistant.
2. Avoid planting susceptible species in areas with historically high incidence of fusiform rust.
3. Prune out galls within 8 inches of the main stem.
4. Fusiform rust is readily controlled in seedling nurseries with the careful application of appropriately registered fungicides. Avoid practices that over stimulate growth such as fertilization, as this has been shown to increase the incidence of rust.
5. Destroy severely infected young stands and reestablish stands with either less susceptible species, or genetically resistant planting stock.

2.4.3 Anthracnose

Causal Agent: *Gloeosporium* spp., *Gnomonia* spp., and *Apiognomonia* spp.

Area and Distribution: Anthracnose is a general term for a group of diseases on hard woods that cause lesions on leaves, twigs, and fruits. Hosts include a wide variety of hardwoods.

Symptomatology: Anthracnose is the name given to a group of fungal diseases that infect a wide variety of herbaceous and woody plants. The infections of anthracnose diseases are distinctive and appear as limited lesions on the leaves, stem and/or fruit. It also attacks developing shoots and expanding leaves. In leaves and in some fruit, the lesions are often angular and follow the vein pattern. Lesions often begin as pale green or greenish-grey blotches, but then turn yellow, tan, reddish-brown, or brown. Lesions tend to begin along leaf veins (because the depressions along veins hold water for a longer period of time and spores tend to collect there), but often rapidly expand. Severely infected leaves may have a scorched appearance, becoming almost completely brown, wilted, or cupped.

Preventive Measures:

1. Management for anthracnose is usually not necessary as it causes no serious harm to the tree; however aesthetic concerns may warrant an attempt to reduce disease severity.
2. Plant trees on a wide spacing, keep the surrounding area clear of vegetation, and prune properly to improve air circulation within the crown.

2.4.4 Powdery mildew

Causal Agent: There are many different species of the fungal disease powdery mildew, and each species attacks a variety of different plants.

Area and Distribution: Powdery mildew is one of the most common and easily recognized plant diseases. Almost no type of plant is immune, however, some are more susceptible than others [30].

Symptomatology: Unlike many other fungal diseases, powdery mildew does not require moisture to infect plants. It also survives well in warmth. This means that it can infect your plants under a wide variety of conditions. Injury commonly seen on infected plants includes stunting and distortion of leaves, buds, growing tips, and fruit. The presence of white to gray fungal growth over leaf surfaces is the most common sign of the disease. Powdery mildew begins as circular, powdery white spots and expands to coat the entire leaf surface. In most cases this fungal growth can be removed by rubbing the leaves.

Picture/Caption:

Fig. 4. Leaf infected with Anthracnose

Preventive Measures:

1. Try to find a powdery mildew-resistant cultivar, if your area is susceptible.
2. Don't plant non-resistant varieties in the shade.
3. Choose healthy plants and keep them growing healthy.
4. Plant trees on a wide spacing and prune properly to improve air circulation within the crown. The use of fungicides is rarely warranted in a land scape situation.

Picture/Caption:

Fig. 5. Leaves infected with powdery mildew

2.4.5 Verticillium wilt

Verticillium wilt is a serious disease that affects over 300 host plants in numerous plant families. Symptoms of Verticillium wilt are easily confused with two other widespread diseases, Fusarium wilt or yellows and bacterial wilt. The fungus produces toxins that cause tyloses or gums to form in the vascular (water-conducting) tissues, resulting in a greatly decreased flow of water from the roots to the foliage. This lack of water results in wilting, the characteristic symptom of the disease and often death of the host.

Causal Agent: *Verticillium albo-atrum* and *Verticillium dahliae*.

Area and Distribution: The host range includes trees, shrubs, ground covers and vines, vegetables, field crops, fruits, herbaceous ornamentals, and many weeds.

Symptomatology: Vascular discoloration or streaking, consisting of dark-colored, elongated, necrotic tissue, occurs in both woody and herbaceous stems. This streaking may be accompanied by external symptoms, such as wilting, the yellowing and death of leaves, and the death of branches or entire plants. Chronic symptoms may follow, including stunted, chlorotic, and deformed foliage; leaf scorch; slow growth; abnormally heavy seed crops; and the dieback of shoots and branches.

Picture/Caption:

Fig. 6. Plant infected with Verticillium wilt disease

Preventive Measures:

1. Steam the soil used for potted plants or for bench crops in the greenhouse and nursery at 180°F (82°C) for 30 minutes or 160°F (71°C) for one hour.

2. Do not grow susceptible plants on land where crops previously have been killed by Verticillium wilt.
3. Control weeds that can act as inoculum reservoirs in and around planting sites.
4. Fertilize to promote vigorous growth and maintain a balance of nitrogen, phosphorus, and potassium. Fertilizing can help reduce symptoms in nursery, field, and landscape plantings.

3. CONCLUSION

Every nursery establishment has high hopes for healthy and disease free seedlings, only to have those hopes dashed as the seedlings suffers pests (insects, mites, weeds, diseases) attack which results into slow and stunted growth of seedlings. Although plant diseases generally do not cause immediate, acute, or lethal consequences for humans, they can and do result in significant economic harm, as market is affected and rural communities and downstream industries experience the impacts of these losses. The strategies and management for disease control has been clearly stated in this review which is ultimately important in nurseries in other to ensure the stability of the nation's forest.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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