The impact of resources availability on *phytophthora* population dynamics and ecosystem health

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Abstract. The relationship between resource availability and the population dynamics of Phytophthora species plays a critical role in shaping ecosystem health. Phytophthora is a genus of oomycetes that known for their impact on agricultural and natural ecosystems. Resource availability, encompassing both abiotic factors like soil nutrients and moisture, and biotic factors such as host plant density and diversity, influences Phytophthora populations and their pathogenicity. This interaction often results in complex feedback loops where shifts in resource availability can worsen or mitigate the spread of Phytophthora infections. For instance, high soil moisture levels and nutrient availability can enhance pathogen growth and sporulation, leading to increased disease incidence and severity. Conversely, resource limitations may suppress pathogen populations but can also lead to reduced host plant vigor, indirectly affecting ecosystem health. Understanding these dynamics is crucial for effective management strategies, as it helps in predicting disease outbreaks and implementing measures to sustain ecosystem functionality and resilience. This study highlights the need for integrated approaches that consider both the ecological impacts of Phytophthora and the broader implications for ecosystem health, emphasizing the importance of resource management in mitigating pathogen-related disruptions.

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1 Introduction

The genus *Phytophthora* get its name from ancient Greek for 'plant destroyer' most species were known as primary plant pathogens, although some aquatic Phytophthora species were saprophyte [1]. *Phytophthora* species, are notorious for causing plant diseases such as root rot in soybean [2], stem blight of Easter lily and lettuce crown rot [3], and sudden oak death [4], affecting both natural ecosystems and agricultural production.

The globalization era and human-mediated dispersal of organisms have led to the increasing homogenization of natural environments. The proliferation of Phytophthora species is a significant global concern for ecological conservation, given the outbreaks of diseases like sudden oak death, ramorum blight, Phytophthora dieback, and protea root rot [5]. The exotic Phytophthora species that are non-native can have a devastating impact on trees and natural ecosystems. These species often go undetected in their native habitats but become invasive when introduced to other regions. The lack of co-evolution between these Phytophthora and the local flora results in a high number of susceptible plant species, leading to widespread ecological declines [6].

A study in 1977 reported that, the soil moisture levels have significant impact on disease development caused by the chlamydospores and mycelium of *P. cinnamomi* is primarily attributed to the effects of matric potential on nutrient availability. This contributes to the current understanding of why diseases such as avocado root rot associated with *P. cinnamomi* typically manifest in a severe and rapid manner in fine-textured soils with poor drainage or soils subjected to excessive irrigation [7]. This fact was supported with more recent study revealed that improvement in soil physicochemical properties, increase in soil enzyme activity could alter soil bacterial community structure diversity and enhance soil pepper Phytophthora disease resistance ability. Which helped to promote the sustainable development of agriculture [8].

The complex relationship between resource availability and the dynamics of *Phytophthora* populations is essential for understanding how ecosystems can remain resilient under pathogen pressure. This review addresses how specific environmental resource such as nutrients, moisture levels, and host plant availability impact the behavior and spread of *Phytophthora* populations.

2 Influence of Nutrient Availability on Phytophthora Growth

Nutrient-rich environments, particularly those with excess nitrogen or phosphorus, have been shown to enhance the growth and reproduction of *Phytophthora* species. Nursery practices of applying high levels of nitrogen to stimulate rapid plant growth have been shown to worsen root rot when the Phytophthora pathogens *P. cinnamomi* or *P. plurivora* are present [9]. Higher soil nutrient levels lead to faster colonization rates, increasing the likelihood of outbreaks in susceptible host populations. Conversely, nutrient-deprived soils may slow pathogen development but also reduce plant health, making plants more susceptible to infection.

Modification of nutrient availability in the plant media can be used as disease control. Increase in copper ion concentration can significantly reduce ivy root rot incidence caused by *P. cinnamomi* at all inoculum levels [10]. The presence of manganese and zinc could inhibit the growth and development of the *P. nicotianae*. A potential mechanism underlying the inhibitory impact on sporangiogenesis of *P. nicotianae* is that Mn and Zn may act by suppressing the expression levels of the csn4 and csn7 genes, as well as by influencing the activity of antioxidant enzymes within the sporangium of *P. nicotianae* [11].

The soil characteristics also plays important role in the *Phytophthora* infection. Soils with fine textures and thick Ah horizons were found to be unfavorable if *P. cinnamomi* was present. These soil characteristics are often linked to higher soil moisture levels, which increase the pathogen's inoculum and promote root infection [12]. Another study [13] also reported that the *P. nicotianae* infection in pineapple field were strongly related to the soil physical and chemical properties. The infested soil had higher clay content and higher pH as well compared to the uninfected soil. In this case, maintaining soil pH below 5 can significantly decrease the pineapple heart rot incidence caused by *P. nicotianae*.

3 Water Availability and Disease Proliferation

Phytophthora species thrive in moist environments, with water availability being a critical factor for zoospore production and dispersal. Prolonged periods of wet conditions, such as those caused by climate change-driven shifts in precipitation patterns, have been associated with increased disease severity. In riparian ecosystems, *Phytophthora* infections are often more aggressive, highlighting the pathogen's dependence on water for movement between host plants.

Soil saturation serves as a crucial prerequisite for substantial disease progression among numerous soil-dwelling Phytophthora species. During wet seasons, pooling of water in low-lying field regions can lead to waterlogged conditions, which, when coupled with the presence of Phytophthora root rot, can significantly impact the yield of Australian chickpea cultivars [14].

Water availability also hold significant role in the spread of Phytophthora species from agricultural area to nature. The dispersal of *P. boodjera* from out-planting sites to revegetation areas demonstrating its capacity to spread into the surrounding natural environment. This dissemination through the transplantation of nursery stock to native vegetation may disrupt the establishment of seedlings and result in long-term changes in the species composition of indigenous plant communities [15].

4 Host Availability and Genetic Diversity

The availability of susceptible hosts significantly shapes *Phytophthora* population dynamics. Monoculture systems, whether in agriculture or forestry, provide ideal conditions for pathogen proliferation, leading to severe outbreaks. In contrast, ecosystems with high plant diversity show greater resilience to *Phytophthora* infection, as the pathogen faces barriers to spreading among less-susceptible species. Host diversity also influences the genetic diversity of *Phytophthora* populations, which can affect the pathogen's ability to adapt to environmental changes.

Analysis of host ranges and geographic distributions allowed for the characterization of Phytophthora's invasive potential. The number of described Phytophthora species grew rapidly from 86 in 2000 to over 180 today, driven largely by advances in molecular identification techniques, resulting in an estimated total of 326 species. Countries with diverse ecosystems and well-established agricultural and forestry sectors supported by extensive research programs reported the highest Phytophthora diversity. Examining environmental and socioeconomic factors revealed gaps in national-level data, with two-thirds of trading nations reporting lower-than-expected Phytophthora species counts. The Phytophthora species fell into two main groups: widespread generalists and specialists historically associated with agriculture. As global trade continues to expand, particularly in developing and emerging economies, further spread and detection of these pathogens are inevitable. Implementing best diagnostic practices and enhancing resource and data sharing are critical for coordinated global surveillance and biosecurity efforts [16].

Different host species dominating an area also create different pathogen genotypes. Study on the *P. ramorum* in California and Southern Oregon (USA) revealed that different population structure of bay laurel, oak, and tanoak contributes to dominance of different pathogen genotypes. Some genotypes were widespread, while others were limited to a subset of the plots. Sites with higher bay laurel densities sustained a higher genotypic diversity of the pathogen [17].

5 Conclusion

Resource availability plays a pivotal role in shaping the dynamics of *Phytophthora* populations and their impact on ecosystems. Balanced resource levels, including water, nutrients, and host diversity, are essential for minimizing the risk of pathogen outbreaks and preserving ecosystem health. Integrating knowledge of resource-pathogen interactions into management practices can enhance the resilience of ecosystems against *Phytophthora* and other emerging pathogens.

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