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Involvement of Soilborne *Phytophthora* Species in Northeast Illinois Rapid Oak Decline and the Effect of Site Factors on the Disease

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Abstract. Background: Mature oaks across Northeastern Illinois declined unusually rapidly, and many died, starting in 2019 and 2020. Investigation into the cause was initiated in 2021. In the absence of signs of disease or insect infestations aboveground, site soil characteristics and precipitation history that could facilitate root problems were investigated. Methods: Eighteen sites with rapidly declining oaks were identified. Root samples were collected and tested for the presence of *Phytophthora* spp. using DAS-ELISA. An investigation of soil conditions was conducted on one of the sites with declining and healthy trees growing on lower and slightly elevated ground, respectively. Results: DAS-ELISA results were positive in 87% of the samples. All sites had fine textured soils classified as moderately to poorly drained, with high spring water tables. Topography was always very flat. The water table was near the surface for most of the spring on poorly drained sites with declining trees, and significantly higher than in the slightly elevated sites with better drainage and healthy trees. From 2018 to 2020, the region experienced the highest average spring rainfall for any 3 consecutive years in the last 70 years. This created soil conditions conducive to root disease development. Conclusions: Predominantly positive ELISA results on fine roots indicated that *Phytophthora* species are present in root systems when growing in moderately to poorly drained, fine textured soils across the Chicago region. The consecutive years of above-normal rainfall and poor soil drainage appears to have facilitated the development of root disease leading to rapid decline of oaks in the region.

Keywords. *Quercus* spp.; Root Rot; Waterlogged Soil.

INTRODUCTION

Groups of mature oaks (*Quercus* spp.)(> 50 cm DBH) across the Northeast Illinois area began to decline unusually rapidly starting in 2019 and 2020. Native *Quercus alba*, *Q. rubra*, *and Q. macrocarpa* all appeared to be declining with similar symptom progression. Descriptions from arborists managing the trees, and comparison of historical aerial photographs, indicated that most of these trees died in 2 to 3 years. The symptoms in the first year of the decline would typically be a death of a major portion of the crown in mid- to late-summer. In the subsequent year or two, remaining live branches, which often were only smaller laterals on main structural branches, would die. These symptoms were distinct from the more typical slower decline of mature oak trees that is more common in urban and suburban landscapes of the region.

Reed et al. (2017) reported a similar rapid decline of white and red oaks (*Quercus alba* and *Q. rubra*) in forested stands in Missouri. Mortality patterns included the deaths of entire tree crowns following rapid bronzing of foliage often during late summer. Mortality spiked during 2012 and declined during the subsequent years. Mortality in stands ranged from fewer than 25% to nearly complete mortality. Tree mortality occurred in pockets on lower slopes and drainages where trees may also have been affected by root pathogens, such as *Phytophthora* spp., that are favored by these conditions (Corcobado et al. 2014; Reed et al. 2017).

This work was initiated as a regional survey of rapidly declining oaks to assess the extent of the observed decline. This led to a more detailed assessment of soil conditions and pathogen presence on a

large site that was well suited for it, with declining and healthy trees and soils characteristic of sites with rapidly declining oaks throughout the region.

MATERIALS AND METHODS

Initial Regional Declining Oak Survey

In summer of 2021, 18 sites across the Chicago metropolitan region with oaks that had recently declined unusually rapidly were identified through contacts with local arborists and property owners (Figure 1). Soil series, texture, drainage class, and slope were identified for each site (Natural Resources Conservation Service [NRCS] 2024).

Fine root samples were collected from 87 declining trees on the 18 different sites to test for the presence of *Phytophthora* spp. Since all 3 tree species appeared to be declining similarly, there appeared to be no need to investigate beyond the *Quercus* genus level. Samples were taken from the upper 15 cm of soil near the base of the trunk to be as confident as possible that the roots were from that tree. The qualitative Phyt (*Phytophthora*) double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) PathoScreen® Kit (Agdia, Inc., Elkhart, IN, USA) (referred to as ELISA, hereafter) was used following the manufacturer's protocol.

Soil Moisture and *Phytophthora* Distribution

Further investigation was conducted on an approximately 6 ha site with both healthy and rapidly declining oaks. The majority of the site was Ozaukee silt loam, with one small area, approximately 0.25 ha, of Beecher silt loam. The site was flat with less than 25 cm change in elevation over most of the site. A small portion, approximately 0.25 ha, was as much as 60 cm higher, with a 1% slope over 60 m. The healthiest oaks on the site were in this area.

Soil moisture was monitored throughout the spring of 2022 at 14 locations across the site in areas of good and poor drainage. The depth of the seasonal perched water table and percent soil moisture were measured on 2022 April 10, 15, and 29, May 17, June 7 and 28, and July 13 (day of year 100, 105, 119, 137, 158, 179, 197, respectively). The water table was measured to a depth of 35 cm using a pipe installed vertically in the soil and measuring the depth to standing water in the pipe. Volumetric soil water content was measured in the upper 20 cm of soil using FieldScout TDR (Time Domain Reflectometry) 350 Soil Moisture Meter (Spectrum Technologies, Inc., Aurora, IL, USA). Measurements were taken at least 2 days after rainfall to allow time for the soil to drain to field capacity.

To test for the presence of *Phytophthora* spp. in roots growing in topsoil (0 to 20 cm deep) and subsoil (20 to 40 cm deep), fine root samples were collected near 3 trees each in areas with good and poor drainage, and ELISA tested during September 2023. The topsoils were more organic and dark in color. Subsoils were high in clay content and denser compared to the topsoils.

RESULTS AND DISCUSSION

Initial Regional Declining Oak Survey

The declining oaks were typically in pockets on each site, with no declining oaks in adjacent areas. There were no signs of disease or insect infestations aboveground. Site characteristics that could facilitate root problems were investigated. All rapidly declining trees were on sites that had fine textured soils classified as moderately to poorly drained with high seasonal (spring) water tables as described by the NRCS (2024). Future work could benefit from more extensive soil analysis. Topography was always very flat and often lower than surrounding areas (Table 1).

Northeast Illinois's normal spring rainfall, in combination with cooler temperatures limiting evaporation and foliage that has not yet fully emerged limiting transpiration, result in wet, potentially saturated, soils for extended periods in the spring. Native hardwoods, including oaks, naturally occur on these soils, and these mature oaks can clearly tolerate occasional wetter than normal springs.

In 2018 through 2020, the seasonal spring (April to June) rainfall was 65% to 77% above normal (Table 2). This was the highest average spring rainfall for any 3 consecutive years in the last 70 years (National Weather Service 2024). This rare 3 consecutive years of high spring rainfall would create persistent, unfavorable conditions for oak roots, and favor soil-borne pathogens that are favored by the presence of free-water, such as *Phytophthora* spp., which can cause root rot diseases (Corcobado et al. 2013; de Sampaio e Paiva Camilo-Alves et al. 2013; Corcobado et al. 2014) resulting in crown decline, as seen on these 18 sites.

Eighty-seven percent of the ELISA tests on root samples from declining trees were positive. All sites with more than one declining tree sampled had at least

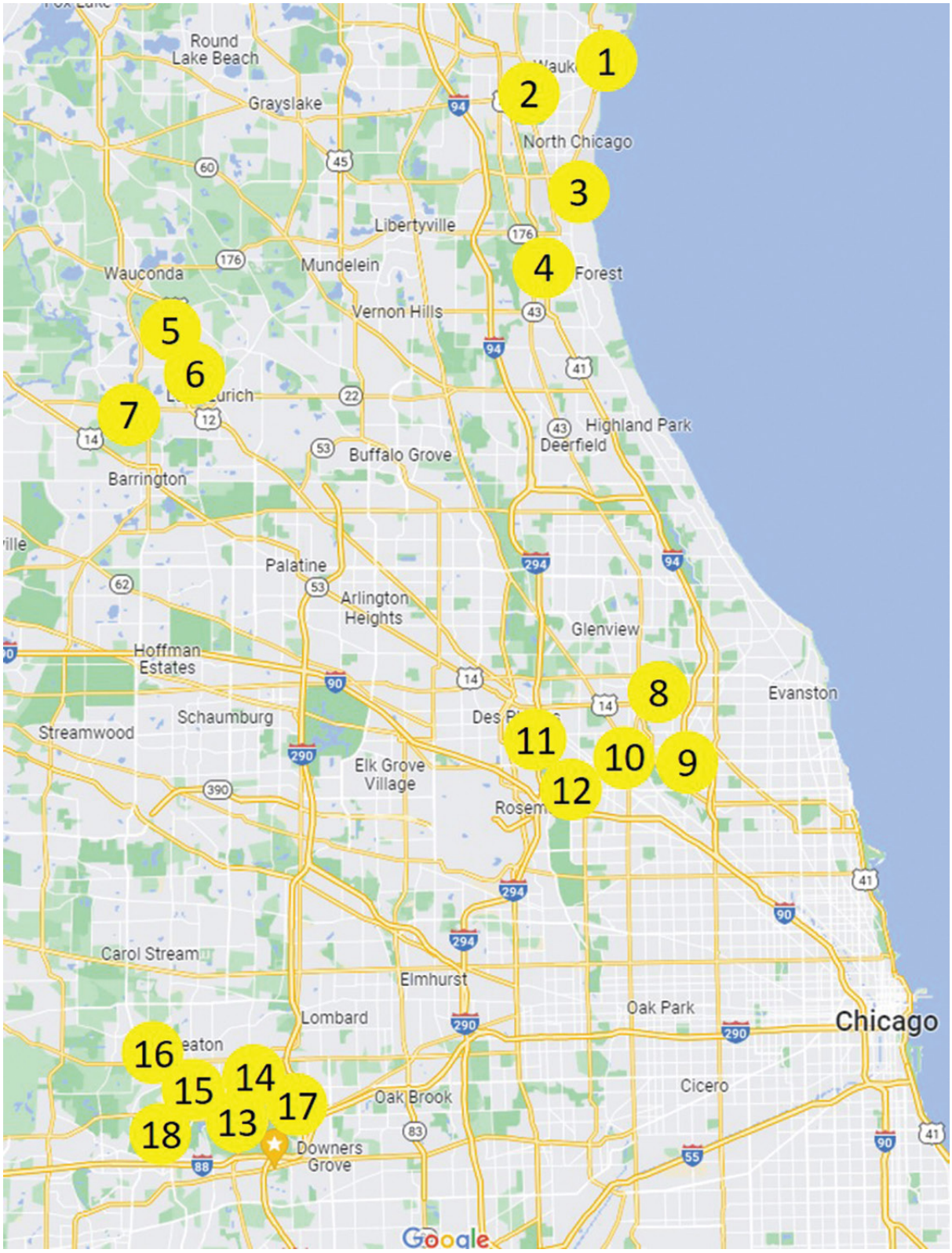

Figure 1. Locations of the 18 study sites in the Chicago region with rapidly declining trees. Numbers refer to Table 3.

Table 1. Soil series, slope, and drainage class of soils occurring on sites with rapidly declining oaks (Natural Resources Conservation Service [NRCS] 2024).

Soil series	Slope (%)	NRCS drainage class
Blount silt loam	0 to 2	Somewhat poorly drained
Del Rey silt loam	0 to 2	Somewhat poorly drained
Nappanee silt loam	0 to 2	Somewhat poorly drained
Ashkum silty clay loam	0 to 2	Poorly drained
Beecher silt loam	0 to 2	Somewhat poorly drained
Kane silt loam	0 to 2	Somewhat poorly drained
Ozaukee silt loam	2 to 4	Moderately drained
Zurich silt loam	0 to 4	Moderately drained
Grays silt loam	2 to 4	Moderately drained

Table 2. April to June rainfall (cm) at O'Hare airport (ORD), the official station for the Chicago area (NOAA National Centers for Environmental Information Climate Data Online Search).

Year	ORD	% change from normal
Normal	26.7	—
2018	47.2	177%
2019	44.0	165%
2020	45.0	169%

one tree that tested positive (Table 3). There is a small chance of false positive results for *Phytophthora* spp. Per the manufacturer's validation report, 7 other Oomycete species can also be detected by the test, though none have been reported as pathogens on oak roots.

Since root disease can be unevenly distributed in the root system, and only 330 mg of roots from a small portion of the tree root system were used for the ELISA test, a positive or negative result may not be a complete reflection of overall root health. Other roots on the trees may have been infected even if the results on the sampled roots were negative. The shallow sampling depth may also have been limiting. In Western Australia, *Phytophthora* infection has been shown to infect roots in deeper, moister soils, leading to the decline of Eucalyptus trees with drier surface soils (Shearer and Tippett 1989).

Overall, the ELISA data provide a good indication that at least one of the detectable species of Oomycetes, most likely *Phytophthora* spp., is present in the roots of these rapidly declining trees. Further evidence that *Phytophthora* spp. are associated with rapidly declining trees is the sudden browning of large portions of the crown seen in late summer of the first year of the decline. This is a characteristic symptom of *Phytophthora* root rot infection because the damaged root system cannot keep up with transpiration demand of the crown (Forest *Phytophthoras* of the World 2024).

Soil Moisture and *Phytophthora* Distribution

A further study was undertaken to better understand the involvement of *Phytophthora* spp. with pockets of rapidly declining trees across the region. This pattern of widespread decline could be a result of a cosmopolitan presence of pathogens in soils and oak roots in the region, compounded with unusually wet soils, which promotes disease development.

Phytophthora species have been isolated from soils near both declining and healthy *Quercus alba* in mid-Atlantic forests (McConnell and Balci 2014). This study site included pockets of rapidly declining (symptomatic) trees and healthy (asymptomatic) trees adjacent to them. The declining trees were on level ground and the healthy trees were growing on a gentle upslope (1%). This resulted in measurable differences in drainage.

Water table depth was measured during spring of 2022 to help understand the spring soil moisture content on the site. The rainfall was only 2.4 cm above normal during the period, with all of the above normal rainfall occurring in April. Even with more

Table 3. ELISA test results from the 18 oak decline survey sites.

Site #	Site character	Soil series	# Tested	# Positive
1	Park-like	Grays	7	4
2	Park-like	Ozaukee, Ashkum	8	6
3	Park-like	Ozaukee, Beecher	10	10
4	Residential	Nappanee	3	3
5	Residential	Ozaukee	1	1
6	Natural	Ozaukee	3	3
7	Park-like	Zurich	1	0
8	Park-like	Zurich	4	4
9	Park-like	Del Rey	3	3
10	Park-like	Ozaukee, Kane	5	5
11	Residential	Urban land	6	5
12	Park-like	Fox	2	1
13	Park-like	Ashkum	3	3
14	Park-like	Ozaukee	2	1
15	Park-like	Ozaukee	4	4
16	Park-like	Ozaukee	5	5
17	Park-like	Beecher, Blount	9	7
18	Park-like	Ozaukee	11	11
		Total	87	76
			% Positive	87%

normal rainfall, at sites where trees had declined rapidly, the seasonally perched water table was significantly closer to the surface until early June (Figure 2). In early April, the water table averaged less than 5 cm below the surface, with surface water present for extended periods on some sites. By the end of April, the water table had lowered to 10 cm below the surface. In contrast, on well drained sites which had a slightly higher elevation and gentle slope, the water table was always 30 cm below the surface.

Volumetric soil water content was significantly higher in the soils with poorer drainage and rapidly declining trees for the entire April to July measurement period (Figure 3). At one measurement period (2022 May 17, day 137), the volumetric soil water content had remained above field capacity 11 days after a 7 mm rainfall. Even after the water table receded to 30 cm below the surface on the poorly drained sites, and water content of both soils were below field capacity, water content of the more poorly drained soil was still significantly higher than the soil with good drainage.

The ELISA tests on the roots were positive in 2 of 3 samples from all depth and drainage combinations, except the topsoil with good drainage, despite the well below average rainfall that growing season (Table 4). The topsoils with good drainage would have been the least favorable of the 4 situations for root disease development. Positive test results on deeper root samples of at the same locations may be due to wetter soil conditions. It should be noted that these 3 non-declining trees all had bleeding trunk cankers on the lower trunk consistent with, but not unique to, *Phytophthora* infection. Woody tissues throughout the root system and lower trunk may have retained their *Phytophthora* infection from previous years through a dry growing season, while the annual growth of the small, shallow roots was free of infection. Though the sample size was small, the positive ELISA tests on roots growing in soils with both good

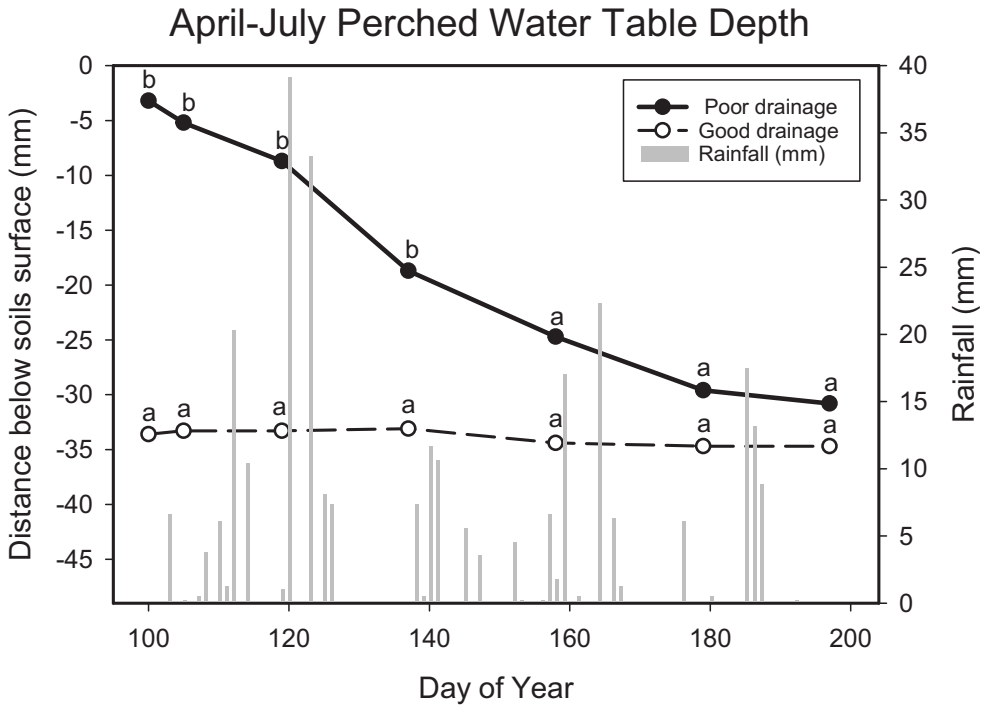

Figure 2. Depth of the perched water table on soils with good and poor drainage, and daily rainfall, during the spring months of 2022. Measurement calendar dates were 2022 April 10, 15, and 29, May 17, June 7 and 28, and July 13.

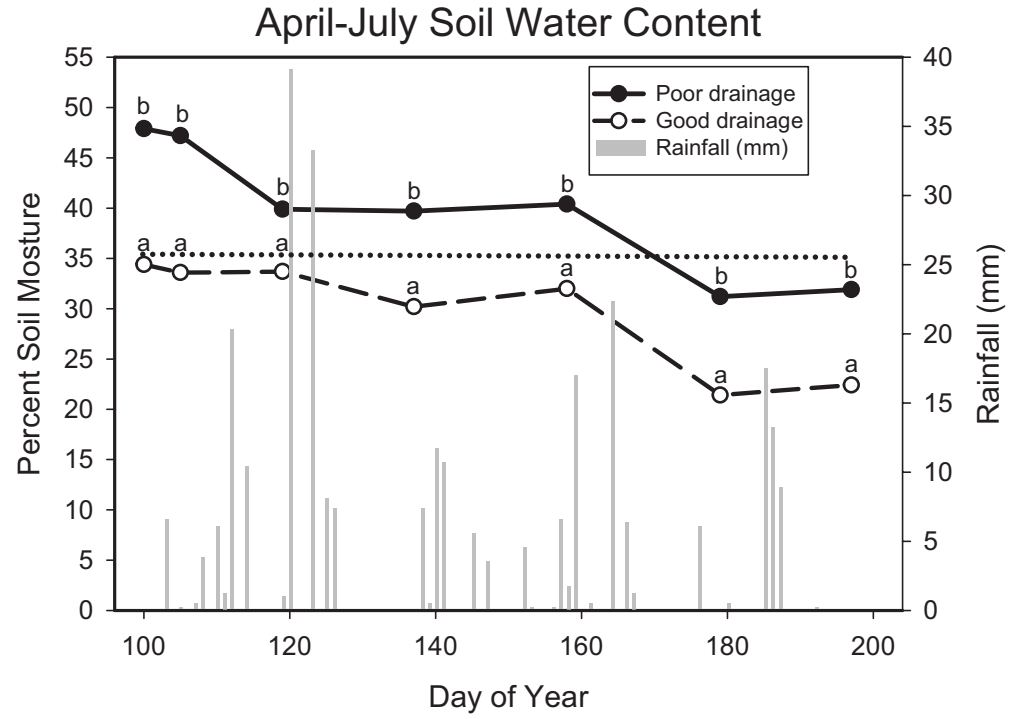

Figure 3. Soil water content in the upper 20 cm on soils with good and poor drainage, and daily rainfall, during the spring months of 2022. On poorly drained sites, soil moisture content was consistently above field capacity (horizontal dashed line) even after the water table had receded to as much as 25 cm below the surface (Table 2). Measurement calendar dates were 2022 April 10, 15, and 29, May 17, June 7 and 28, and July 13.

Table 4. Results of ELISA tests on oak roots in topsoil and subsoil with good drainage and poor drainage.

	# Tested	# Positive
Good drainage		
0 to 20 cm	3	0
20 to 40 cm	3	2
Poor drainage		
0 to 20 cm	3	2
20 to 40 cm	3	2

and poor drainage, and after a long dry period, is evidence that *Phytophthora* spp. may be present in oak roots in most soils under most conditions.

CONCLUSIONS

Predominantly positive ELISA test results on fine roots of declining oaks demonstrates a connection between Oomycetes, likely *Phytophthora* spp., a known pathogen of oaks, and oak decline when growing in fine textured soils with moderate to poor drainage, across the Chicago region. Soil types with better drainage were not investigated. The multiple consecutive years (2018 to 2020) of far above normal rainfall appear to have facilitated the development of root disease leading to rapid decline of oaks in the region. A better understanding of the soil and environmental conditions that can cause rapid decline and death of oaks is needed.

Additional Research Needed

If *Phytophthora* spp., and perhaps other soil-borne pathogens, are widely present in soils and oak root systems, a better understanding of the conditions that will lead to serious disease would help us to anticipate it in the future and treat trees to control disease before the infection kills trees. Unusually high rainfall that is conducive to root disease development is becoming a consistent trend in Illinois in the last century. Over the last 120 years, mean precipitation has increased by 5% to 20% across the state (Wuebbles et al. 2021). Understanding this pathosystem will increase in importance in the future as Northern Illinois is expected to see further increases in winter and spring precipitation in the coming decades as the climate warms (Wuebbles et al. 2021).

Positive ELISA test results indicate that species of *Phytophthora* is present in the root systems, but identification of pathogenic species can only be confirmed by isolating them into culture from the roots, morphological or molecular identification, and completing Koch's postulates. Species identification work is currently underway. Preliminary results have identified several species of *Phyophthora*, *Pythium*, and *Phytopythium*. Most of them have previously been reported to cause root disease on different hosts, but not necessarily oaks.

Roots of non-declining trees growing on soils with better drainage also ELISA tested positive. During sampling, the fine roots appeared healthy, though sometimes sparse in density. Do *Phytophthora* or other Oomycete species have a role in oak root growth life cycle under normal conditions that are not severe enough to cause rapid decline? Could root pathogens like *Phytophthora* spp. be contributing to normal fine root turnover?

A slow decline over several years is not uncommon on mature oaks in the built environment. Is a less severe infection of *Phytophthora* spp. contributing to this decline under less extreme soil conditions? If better understood, could that disease be managed to reverse or prevent decline?

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The authors reported no conflicts of interest.