Potential Range of *Phymatotrichum omnivorum* as Determined by Edaphic Factors

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ABSTRACT
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Based on a search of the literature, a potential range distribution for *P. omnivorum* has been developed using edaphic factors. Soil base exchange capacity, pH, sodium content, calcium content, and clay fraction were determined to be factors delimiting occurrence and survival of the fungus. A nonedaphic factor considered was mean annual air temperature. Soil types possessing the necessary characteristics were identified using the FAO-UNESCO soil-classification system. A map of the potential distribution of *P. omnivorum* in North America was produced and a comparison made with the known distribution of Phymatotrichum root rot disease. The two distributions were coterminous. Distribution of *P. omnivorum*-conducive soils in South America, Africa, and India was also examined.

The soilborne fungus *Phymatotrichum omnivorum* causes a major root rot disease of several economic crops of southwestern North America. As the species name implies, the pathogen has a very broad host range, totaling more than 2,000 species of dicotyledonous plants. Although some native plant species can harbor *P. omnivorum* with few apparent symptoms, many cultivated crops are quite susceptible. Control of this pathogen by chemical and other management strategies is difficult because of the resistant nature of its sclerotial survival structure. The fungus is a very poor competitive saphrophyte, however, and some control has been obtained by use of green manuring and deep plowing.

Examination of the edaphic ecology of *P. omnivorum* indicates the pathogen has rather specific environmental requirements. The fungus is often associated with alkaline calcareous soils that readily shrink and swell with water content because of a montmorillonite clay fraction. A strong relationship exists between soil basicity and occurrence of the pathogen (3). *P. omnivorum* is seldom found in soils with base exchange capacities below 50 meq/100 g soil or calcium carbonate contents lower than 1% (8). Exchangeable sodium in soils is negatively correlated with the sclerotial producing potential of the fungus (9). Therefore, survival of *P. omnivorum* is reduced in sodic soils. Generally, the pathogen is not found in soils with a sodium content greater than 2–3 meq/100 g soil (S. D. Lyda, *personal communication*).

P. omnivorum is greatly influenced by soil pH (9,12). Although the fungus can grow in acidic soils, it does not produce sclerotia in soils below pH 4.8 (8). The optimal soil pH for growth and survival is between 7.2 and 8.0. Soil and air temperature also affect survival of *P. omnivorum*. It has been postulated that the fungus will not persist in regions where the annual mean air temperature is lower than 16 C or where temperatures lower than −23 C occur (1). Therefore, *P. omnivorum* is considered an inhabitant of thermic or hyperthermic soils.

P. omnivorum is indigenous to the United States and northern Mexico (8,11). The pathogen has been reported in Texas, Arizona, New Mexico, California, Louisiana, Nevada, Utah, Oklahoma, Arkansas, and several states of Mexico (5–7). It causes severe economic losses in Texas and Arizona (8,11). A disease similar to that caused by *P. omnivorum* has been reported in Hawaii, India, Pakistan, and the USSR (11). These reports require confirmation.

MATERIALS AND METHODS

An attempt was made to determine the range potential of *P. omnivorum* using its environmental requirements and to compare this theoretical range with the known distribution of the pathogen. The available literature was consulted and environmental factors thought to be definitive in determining a theoretical range of *P. omnivorum* were identified. Factors determined relevant included base exchange capacity, Ca and Na content, pH, clay content, and annual mean air temperature. Soil types possessing the necessary characteristics were identified using the FAO-UNESCO *Soil Map of the World* and soil classification system (2). This map series had the detail and precision of definition necessary for translating the chemical and physical requirements of *P. omnivorum* into soil-unit types.

Thirty-three of the 106 soil units of the FAO-UNESCO system were identified as potential harbors of *P. omnivorum* by a process of elimination (Table 1). A basic assumption in selecting these soil units was that the corresponding soils

Table 1. FAO-UNESCO soil classification units proposed to be supportive to *Phymatotrichum omnivorum*[a]

Soil unit	Symbol
Vertisols	V
Pellic	Vp
Chromic	Vc
Fluvisols	J
Calcaric	Jc
Gleysols	G
Calcaric	Gc
Andosols	T
Mollic	Tm
Regosols	R
Calcaric	Rc
Eutric	Re
Rendzinas	E
Greyzems	M
Gleyic	Mg
Orthic	Mo
Chernozems	C
Luvic	Cl
Glossic	Cg
Calcic	Ck
Kastanozems	K
Luvic	Kl
Calcic	Kk
Haplic	Kh
Phaeozems	H
Gleyic	Hg
Calcaric	Hc
Haplic	Hh
Podzoluvisols	D
Gleyic	Dg
Eutric	De
Xerosols	X
Luvic	Xl
Calcic	Xk
Haplic	Xh
Yermosols	Y
Luvic	Yl
Calcic	Yk
Haplic	Yh
Nitrosols	N
Eutric	Ne
Lubisols	L
Gleyic	Lg
Calcic	Lk
Vertic	Lv
Cambisols	B
Gleyic	Bg
Vertic	Bv
Calcic	Bk

[a] The assumption has been made that these soils contain 35–40% clay where such criterion is not implicit in the soil-unit definition.

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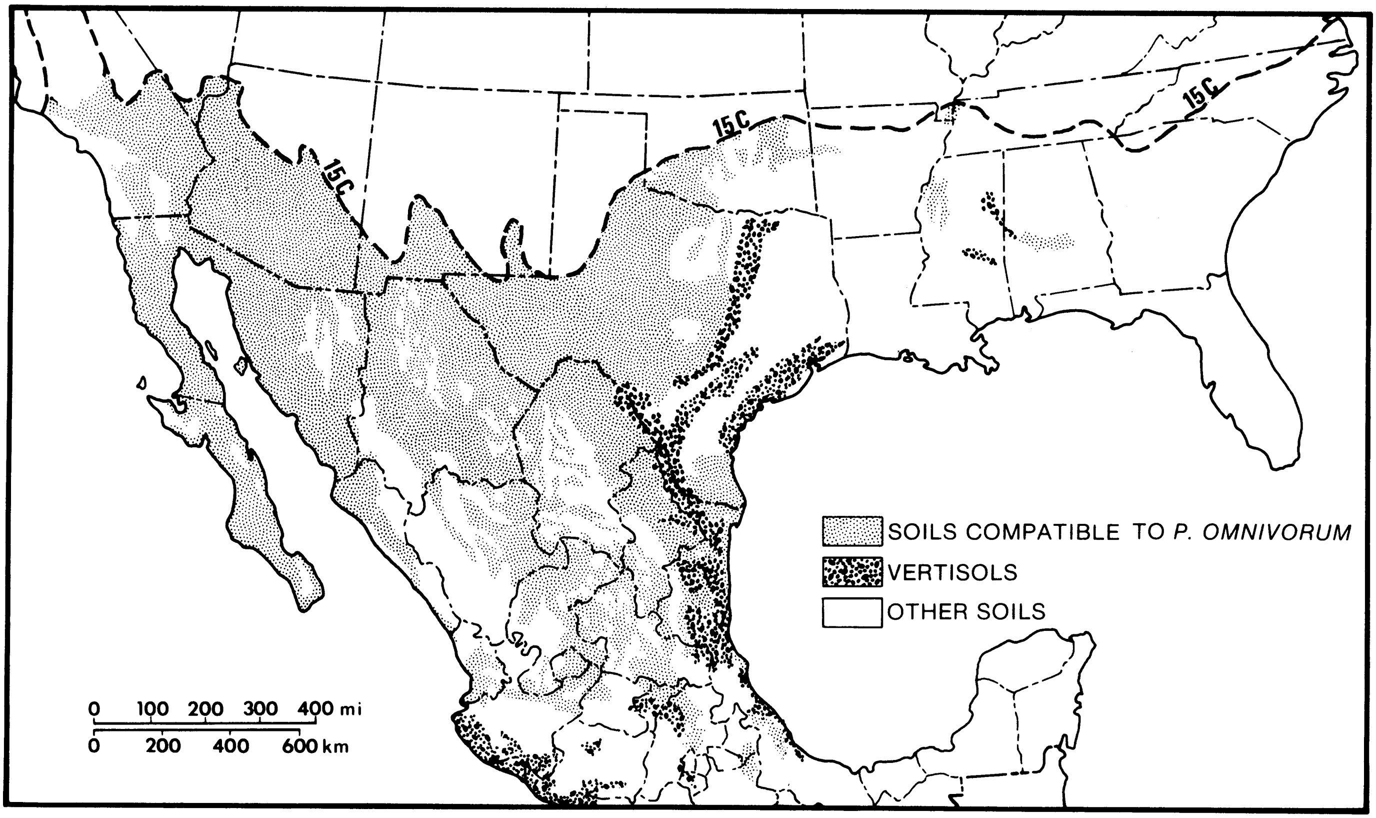

Fig. 1. Theoretical North American range potential of *Phymatotrichum omnivorum.*

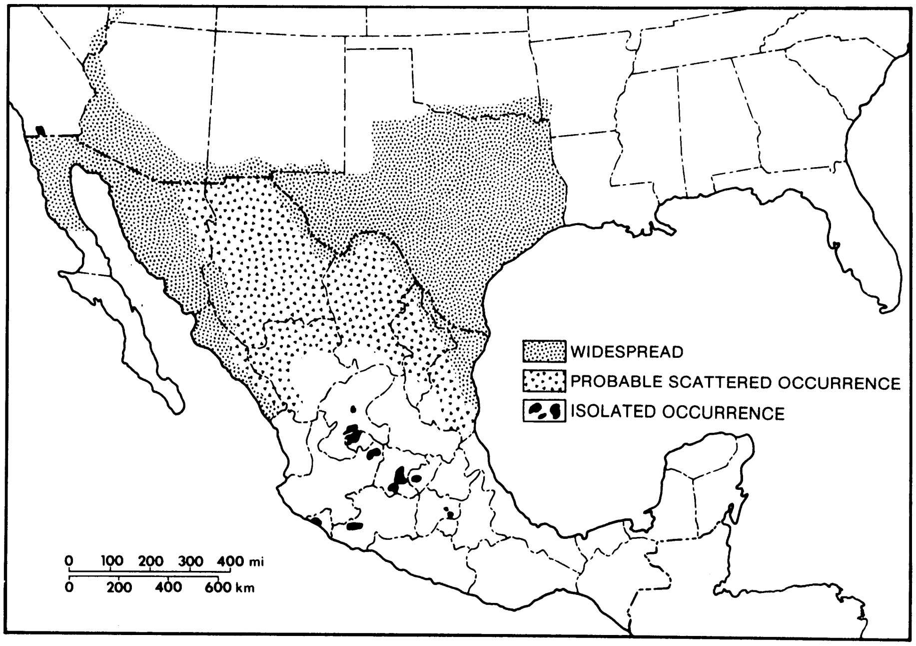

Fig. 2. Reported distribution of *Phymatotrichum omnivorum* in North America. Adapted from map by Streets and Bloss (11).

contained 35–40% clay in one of their horizons or that this criterion was met by the soil-unit definition. Having identified soil units, a map of the potential distribution of *P. omnivorum* in North America was produced. Soil units in phases incompatible with *P. omnivorum* (ie, saline, sodic, lithic, etc.) were excluded from the distribution. Soil units outside of the 15 C annual mean temperature isotherm minimum were also excluded (4,10,13). The resulting map of the North American range potential of *P. omnivorum* was compared with a map of the range of Phymatotrichum root rot disease produced by Streets and Bloss (11). Also examined were the distributions of potential *P. omnivorum*-conducive soils in South America, Africa, and India.

RESULTS AND DISCUSSION

A cursory comparison of the map of the theoretical range potential of *P. omnivorum* in North America (Fig. 1) with a map of its range as reported by Streets and Bloss (11) (Fig. 2) indicates a good fit. The northern boundaries of the potential range of the fungus and the known extent of the pathogen are in good accord. Likewise, the scattered occurrence of the pathogen reported in north central Mexico by Streets and Bloss (11) concurs with the scattered nature of compatible soils in Figure 1. An apparent one-to-one correspondence exists between the vertisols of southern Mexico (Fig. 1) and the isolated occurrence of the pathogen reported in that region (Fig. 2). Vertisols have been singled out for emphasis on the range potential map because of their highly conducive nature and the historic severity of the disease in these soils.

Some discrepancies are also noted between the two maps. Although the pathogen distribution map indicates the presence of *P. omnivorum* in eastern Texas and its absence on the Baja Peninsula, the theoretical range-potential map indicates the fungus should not occur in eastern Texas but can occur on the Baja Peninsula. This discrepancy can be partially explained by the tendency of Streets and Bloss (11) to follow political boundaries on their map. *P. omnivorum* has been reported to occur scatteringly in eastern Texas river flood plains. The overall agreement of the range of *P. omnivorum* depicted by the reported pathogen distribution and the range-potential maps support speculations that the range is delimited on its northern boundary by temperature and on its eastern boundary by soil type. Considering the known variation between individual soils within a soil-classification unit, the close fit of the two maps indicates the applicability of the soil-mapping scheme for prediction.

With this assurance, a cursory examination has been made of the distribution of conducive soils on various continents. An examination of South America reveals that continent to be generally devoid of soil types compatible with the fungus. One-third of the continent is too cold to sustain *P. omnivorum*. In contrast, Africa, appears fairly rich in compatible soil types. Large areas of vertisols occur in the Transvaal, Lake Victoria, and Upper Nile regions. The Indian subcontinent and Australia also appear to have an abundance of vertisols and other favorable soil types. Temperature isotherms for these land masses have not been examined, however. Central America and several islands of the Caribbean also possess areas of vertisols and temperatures favorable for the fungus. European soil types have not been examined because most of that continent is too cold for the pathogen to survive. With the exception of the unsubstantiated report from the Indian subcontinent, *P. omnivorum* has never been reported in any of these areas (11).

The discrepency between the postulated range potential of *P. omnivorum* outside of North America and its reported range raises several interesting questions. Disregarding for a moment the report from India, the question arises as to why the fungus is restricted to North America when other continents appear to possess suitable environments for the pathogen. It may be that the environmental factors used to define the range potential of *P. omnivorum* in this study are incomplete and not definitive. The factors used appear, however, to have adequately delimited the North American range. More work may be needed to define the edaphic requirements of *P. omnivorum*. Another possibility is that the fungus may occur in areas outside of its known range but has never been reported. This is especially true for certain areas such as African savannahs.

Another distinct possibility is that the range for *P. omnivorum* is an artifact of evolution. Perhaps the fungus evolved in the western hemisphere and, until the advent of man's technology, has never had the ability to fill its range potential. Having no known viable spore stage, the fungus is singularly lacking in any efficient long-range dispersal mechanism. A consideration perhaps of more immediate importance than the evolutionary history of *P. omnivorum* is its fate should it be introduced into areas of conducive soil types. With transcontinental transport of plants, this is a distinct possibility and consequences should be considered and precautions taken.

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