Fungal Plant Pathogens Associated with Emerging Crops in North America: A Challenge for Plant Health Professionals

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Abstract

“Emerging crops” is a term typically applied to ethnic food plants or to plants used in traditional or ethnic medicine, some of which are becoming viable niche markets in North America. Information on crop protection of these plants is often scarce to lacking. Literature on diagnosis and management of fungal diseases of these crops in North America is concisely reviewed, with information gaps identified. Emphasis is placed on crops comprising recent niche

markets for Asian, African, Oceanian, or Latino immigrants. Emerging crops are often tied to economic activities of immigrant populations. Crops of immigrants from Asia, Africa, Latin America, and Oceania are contrasted with crops established by immigrants of European origins, plants usually familiar to North American plant health professionals, and with Native American food and medicinal plants, some of which are experiencing a renaissance as emerging crops.

In the United States, recent immigrants and those to whom they have imparted their culinary tastes have created demand for new crops. Various prefaced by the descriptors “ethnic,” “specialty,” or “emerging,” these crops represent growing niche markets (Govindasamy et al. 2010; Molinar 2012; Wang and Cerkaskas 1999). Some such crops are primarily food crops, whereas others are primarily medicinal, although the distinction is not invariant for many ethnic groups (e.g., Corlett et al. 2003). For some crops, such as chili peppers, use is now widespread and the fruit highly familiar (“mainstream”). This familiarity can be partly attributed to increases in the populations of Asian and Hispanic immigrants but also to acceptance within the general population (Gandonou and Waliczek 2013). Other emerging crops have been initiated from agricultural activities or culinary preferences of recent Oceanian or African immigrants, or a smaller number from European immigrants or Native American populations as discussed later.

The introduction of plants as specialty crops or as breeding materials for American agriculture is facilitated by the U.S. Department of Agriculture’s National Plant Germplasm System (NPGS, <https://www.ars-grin.gov/npgs/>), which comprises regional plant introduction stations and crop-specific genebanks or repositories. Crop curators for the NPGS are currently building collections of tef (*Eragrostis tef*), quinoa (*Chenopodium quinoa*), faba bean (*Vicia faba*), chia (*Salvia hispanica*), amaranth (*Amaranthus* spp.), fennel (*Foeniculum vulgare*), and other plants (New Crops Report, https://www.ars-grin.gov/npgs/cgc_reports/newcrops2.htm). Such efforts can result in firm establishment of crops once regarded as emerging.

The USDA-ARS Western Regional Plant Introduction Station (WRPIS, part of the NPGS) and the USDA-ARS Grain Legume Genetics unit long collaborated on introduction of chickpea (*Cicer arietinum*) as an alternative regional crop in rotation with wheat and

barley (Muehlbauer et al. 1982), but the crop’s primary disease, Ascochyta blight (causal agent, *Ascochyta rabiei*), followed in 1983 (Kaiser and Muehlbauer 1984). The sexual state of the pathogen was soon detected and its role in disease transmission explained (Kaiser and Hannan 1987). Today the crop is an established, major contributor to regional agriculture in the Pacific Northwest (PNW), in the high plains of the United States and Canada, and in California (NASS 2017). Diseases are well described, and cost-effective management of *A. rabiei* is achieved via seed treatment, cultural practices, and partial resistance (Chen et al. 2011; Harveson et al. 2011). In strong contrast, crop protection information on many crops still regarded as emerging continues to lag.

The objectives of this review are to concisely summarize available information on fungal plant pathogens of specific emerging crops by provision of cited literature (Table 1) and to provide further examples and status reports for “ethnic” vegetables and for faba bean, an emerging crop in the U.S. PNW. Situations pertinent to different groups of emerging crops, each such group being affiliated with one or more immigrant or native populations, are briefly contrasted.

INFORMATION DEFICITS AND PHYTOSANITARY RISKS

As with all crops, emerging crops have disease problems. These problems are conveniently, if somewhat artificially, divided into two categories: (i) deficits in phytopathological information and (ii) phytosanitary risks associated with movement of propagative material. Even when suitable crops and cultivars are available, inadequate information on diseases may limit crop production (Kim 2016). A recent detailed economic analysis of ethnic crops referred to crop protection only by stating “more applied studies are needed” (Sciarrappa et al. 2016). Moreover, there have been concerns that seeds of specialty crops, imported in the absence of a phytosanitary certificate, may contain pests or pathogens that pose a threat to production (Wang and Cerkaskas 1999). Interception of pests (including pathogens) associated with seeds and other propagation materials illicitly transported to the United States comprises 7% of interception records in the USDA Animal and Plant Health Inspection Service Port Information Network database (McCullough et al.

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TABLE 1
North American^a records for fungal diseases of selected ethnic and specialty food and medicinal crops

Crop	Disease, agent	Ethnic affiliation(s) of crop	References
<i>Aloe vera</i>	Leaf spot, <i>Alternaria alternata</i> Root rot, <i>Rhizoctonia solani</i> Southern blight, <i>Sclerotium rolfsii</i>	Multiple, Latino	da Silva and Singh (2012); Farr and Rossman (n.d.) ^b
Arugula, <i>Eruca sativa</i>	Anthracnose, <i>Colletotrichum higginsianum</i> Downy mildew, <i>Peronospora parasitica</i> White rust, <i>Albugo candida</i>	Mediterranean	Koike (1998); Patel et al. (2014); Scheck and Koike (1999)
Bok choy, <i>Brassica campestris</i> , <i>Chinensis</i> group var. <i>communis</i> ^c	Alternaria leaf spot <i>Alternaria brassicae</i> , <i>A. brassicola</i> Club root, <i>Plasmodiophora brassicae</i> Downy mildew, <i>Peronospora parasitica</i> Foliar blight, <i>Rhizoctonia solani</i> Verticillium wilt, <i>Verticillium</i> sp. White leaf spot, <i>Pseudocercospora capsellae</i> White rust, <i>Albugo candida</i>	East Asian	Cerkauskas et al. (1998); Koike et al. (2007); Zhang et al. (2013)
Chervil, <i>Anthriscus cerefolium</i>	Powdery mildew, <i>Erysiphe heraclei</i> Stem and crown rot, <i>Sclerotinia sclerotiorum</i>	European, French	Koike (1999); Koike and Saenz (2004)
Chickory, Italian dandelion, radicchio, <i>Cichorium intybus</i>	Downy mildew, <i>Bremia lactucae</i> Leaf spots, <i>Alternaria cichorii</i> , <i>A. sonchi</i> , <i>A. tenuissima</i> , <i>Cercospora cichorii</i> , <i>Ramularia inaequale</i> Powdery mildew, <i>Golovinomyces (Erysiphe) cichoracearum</i> Root rots, <i>Phymatotrichum omnivorum</i> , <i>Phytophthora cryptogea</i> , <i>Sclerotinia sclerotiorum</i> , <i>S. minor</i> Rust, <i>Puccinia hieracii</i> , <i>Puccinia littoralis</i> Southern blight, <i>Sclerotium rolfsii</i>	European, Italian	Farr and Rossman (n.d.); Koike and Butler (1998)
Chinese and Napa cabbage, <i>Brassica campestris</i> , <i>Pekinensis</i> group var. <i>cephalata</i> ^c	Alternaria leaf spot, <i>Alternaria brassicae</i> , <i>A. brassicola</i> Downy mildew, <i>Peronospora parasitica</i> Foliar blight, <i>Rhizoctonia solani</i> Verticillium wilt, <i>Verticillium</i> sp. White leaf spot, <i>Pseudocercospora capsellae</i> White rust, <i>Albugo candida</i>	East Asian	Cerkauskas et al. (1998); Koike et al. (2007)
Chinese broccoli, Chinese kale, <i>Brassica alboglabra</i> (<i>Brassica oleracea</i> var. <i>alboglabra</i> ^c)	Downy mildew, <i>Peronospora parasitica</i> White leaf spot, <i>Pseudocercospora capsellae</i> White rust, <i>Albugo candida</i>	East Asian	Cerkauskas et al. (1998)
Chinese leaf mustard <i>Brassica juncea</i> var. <i>foliosa</i> ^c	Alternaria leaf spot, <i>Alternaria brassicae</i> Club root, <i>Plasmodiophora brassicae</i> White rust, <i>Albugo candida</i>	East Asian	Cerkauskas et al. (1998)

(Continued on next page)

^a Including the state of Hawaii.

^b Records in Farr and Rossman (n.d.) are not restricted to pathogens. Only records from unequivocally pathogenic fungi are here included, although other records, not shown, may indicate the origin as "leaf spot" or other symptoms on a given host. Records of special importance are individually listed in spite of inclusion in Farr and Rossman (n.d.).

^c Records in Farr and Rossman (n.d.) seldom pertain to cultivars (which can vary greatly in susceptibility) but are recorded at the level of host species.

TABLE 1
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Crop	Disease, agent	Ethnic affiliation(s) of crop	References
Chinese radish, daikon, <i>Raphanus sativus</i> , <i>Longipinnatus</i> group	White leaf spot, <i>Pseudocercospora capsellae</i>	East Asian	Cerkauskas et al. (1998); Koike and Molinar (1997)
Chinese winter melon <i>Benincasa hispida</i>	Anthrachnose, <i>Colletotrichum</i> spp. Downy mildew, <i>Pseudoperonospora cubensis</i> Root rot, <i>Fusarium solani</i> Verticillium wilt, <i>Verticillium dahliae</i>	East Asian	Farr and Rossman (n.d.); Ji et al. (2012); Koike et al. (2007)
Cilantro (Chinese parsley, Mexican parsley), <i>Coriandrum sativum</i>	Fusarium wilt, <i>Fusarium oxysporum</i> f. sp. <i>corianderii</i> Root rots, <i>Phytophthora parasitica</i> , <i>Rhizoctonia</i> sp.	East Asian, Latino, Southern European	Koike and Gordon (2005); Koike et al. (2007); Raabe et al. (1981)
Corn-salad, lamb's lettuce, <i>Valerianella locusta</i>	Downy mildew, <i>Peronospora valerianellae</i> Powdery mildew, <i>Golovinomyces orontii</i> Root rot, <i>Thielaviopsis basicola</i> Stem and crown rot, <i>Sclerotinia minor</i>	European	Koike (2003, 2008); Koike and Saenz (2004); Stanghellini et al. (1990)
Echinacea, coneflower, <i>Echinacea angustifolia</i> , <i>E. pallida</i> , <i>E. purpurea</i>	Alternaria leaf spot, <i>Alternaria</i> spp. Damping off, <i>Alternaria</i> spp., <i>Fusarium</i> spp., <i>Pythium</i> spp., <i>Rhizoctonia solani</i> <i>Fusarium</i> root and crown rot, <i>Fusarium oxysporum</i> , <i>Fusarium</i> spp. Gray mold, <i>Botrytis cinerea</i> Leaf spot, <i>Septoria</i> spp. Powdery mildew, <i>Golovinomyces cichoracearum</i> Sclerotinia blight, <i>Sclerotinia</i> and root rot, <i>Sclerotinia sclerotiorum</i> Smut, <i>Entyloma</i> spp.	Native American	Chang et al. (1999); Farr and Rossman (n.d.); Peichowski et al. (1997); Sholberg and Li (1999).
Faba bean, fava bean, horse bean, <i>Vicia faba</i>	Anthrachnose, <i>Colletotrichum villosum</i> Ascochyta blight, <i>Ascochyta fabae</i> (Canada) Chocolate spot, <i>Botrytis cinerea</i> , <i>B. fabae</i> Leaf spot, <i>Ascochyta pisi</i> Powdery mildew, <i>Erysiphe trifoliorum</i> (artificial inoculation) Root rots, <i>Phymatotrichum omniforum</i> , <i>Phytophthora cactorum</i> , <i>Phytophthora capsici</i> , <i>Rhizoctonia solani</i> Rust, <i>Uromyces fabae</i> Southern blight, <i>Sclerotium rolfsii</i> Stem rot, <i>Sclerotinia sclerotiorum</i>	Mediterranean, Middle Eastern, Asian	Attanayake et al. (2010); Erwin and Ribeiro (1996); Farr and Rossman (n.d.)
Fennel, <i>Foeniculum vulgare</i>	Fusarium stem and crown rot, <i>Fusarium avenaceum</i> Gray mold, <i>Botrytis cinerea</i> Leaf spot, <i>Cercosporidium punctum</i> Root rot, <i>Phymatotrichum omnivorum</i> , <i>Rhizoctonia solani</i> Stem rot, <i>Sclerotinia minor</i>	Multiple, especially South Asian, Middle Eastern, Mediterranean	Farr and Rossman (n.d.); Koike (1994); Koike et al. (1992, 2012)

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TABLE 1
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Crop	Disease, agent	Ethnic affiliation(s) of crop	References
Fenugreek, <i>Trigonella foenum-graecum</i>	Ascochyta blight, <i>Peyronellaea pinodes</i> Downy mildew, <i>Peronospora trigonellae</i> Gray mold, <i>Botrytis cinerea</i> Leaf spot, <i>Cercospora transversiana</i> Powdery mildew, <i>Erysiphe pisi</i> Smut, <i>Entyloma</i> spp.	Mediterranean, South Asian	Farr and Rossman (n.d.); Habibi et al. (2016); Richardson (1990); Rooney-Latham et al. (2009)
Ginseng, <i>Panax quinquefolius</i>	Alternaria blight, <i>Alternaria panax</i> Anthracnose, <i>Colletotricum</i> spp. Black root, <i>Thielaviopsis basicola</i> Damping off, <i>Pythium</i> sp., <i>Rhizoctonia solani</i> Gray mold, <i>Botrytis cinerea</i> Root rot, <i>Cylindrocarpon destructans</i> , <i>Phytophthora</i> spp., <i>Sclerotinia panacis</i> , <i>S. sclerotiorum</i> Rusted root, <i>Rhexocercosporidium panacis</i> Wilt, <i>Verticillium albo-atrum</i>	East Asian	Farr and Rossman (n.d.); McPartland and Hosoya (1998); Punja (1997); Putnam and du Toit (2003); Reeleder (2007)
Japanese mustard, <i>Brassica campestris</i> subsp. <i>nipposinica</i> ^c	White rust, <i>Albugo candida</i>	East Asian	Koike (1996)
Malabar spinach, <i>Basella alba</i>	Leaf spot, <i>Bipolaris</i> sp., <i>Cercospora</i> sp.	African, Asian	Farr and Rossman (n.d.); Zhang et al. (2011)
Noni, <i>Morinda citrifolia</i>	Fruit rot, <i>Mucor circinelloides</i>	East Asian	Nishijima et al. (2011)
Pak choy, <i>Brassica campestris</i> , <i>Chinensis</i> group var. <i>communis</i> ^c	Alternaria leaf spot, <i>Alternaria brassicae</i> White leaf spot, <i>Pseudocercospora capsellae</i>	East Asian	Cerkauskas et al. (1998)
Quinoa, <i>Chenopodium quinoa</i>	Ascochyta leaf spot, <i>Ascochyta</i> sp. Downy mildew, <i>Peronospora variabilis</i> Passalora leaf spot, <i>Passalora dubia</i>	Andean	Testen and Backman (2012); Testen et al. (2013a, 2013b)
Rapini (rappini), broccoli raab, <i>Brassica rapa</i> subsp. <i>rapa</i> , ruvo group ^c	White rust, <i>Albugo candida</i> Alternaria leaf spot, <i>Alternaria brassicae</i> A. <i>brassicola</i>	Southern European	Koike (1997); Koike et al. (2007)
Shiso, <i>Perilla frutescens</i>	Gray mold, <i>Botrytis cinerea</i> Leaf spot, <i>Cristulariella pyramidalis</i>	East Asian	Farr and Rossman (n.d.); Koike and Daugovish (2012)
Tah tsai, <i>Brassica campestris</i> subsp. <i>narinosa</i> ^c	White rust, <i>Albugo candida</i>	East Asian	Koike (1996)
Tomatillo, <i>Physalis ixocarpa</i>	Powdery mildew, <i>Sphaerotheca fusca</i> Early blight, <i>Phytophthora infestans</i>	Latino	Farr and Rossman (n.d.); Koike and Smith (1998)
St. John's wort, <i>Hypericum perforatum</i>	Leaf blight, stem dieback, <i>Diploceras hypericinum</i> Powdery mildew, cf. <i>Microsphaera hypericacearum</i> Rust, <i>Uromyces hyperici</i> Southern blight <i>Sclerotium rolfsii</i>	European	Farr and Rossman (n.d.); Glawe (2004); Keinath et al. (1999); Putnam (2000)

2006). Anecdotal instances of such illicit importation are pertinent and abundant: for example, “many seeds were smuggled in” (Coulter 2006) and “bulbs and seeds, sometimes smuggled across borders by friends and relatives” (Hondagneu-Sotelo 2014). Pathogens in commercially imported (and inspected) seed, including seed moved by plant germplasm centers, are of equal concern (McGee 1997) but more frequently pertain to familiar staple crops whose diseases are relatively

familiar to North American diagnosticians and other plant health professionals and for which screening methods are readily available. Given the relative lack of information on production of emerging crops, and given the problem of unauthorized importation of propagative material, a critical first step for plant health professionals is locating existing information on diseases of these less familiar, emerging crops.

DISEASE RECORDS IN LITERATURE

Plant pathologists report novel disease incidents on emerging crops in a variety of peer-reviewed venues, including this journal. For several English-language venues, reports concerning plant pathogenic fungi are incorporated into the searchable databases of the USDA-ARS Systematic Mycology and Microbiology Laboratory (Farr and Rossman n.d., henceforth SMML). This resource, addressing fungi on many plants (including ethnic food plants and plants used in traditional medicines), is useful and widely cited. However, fungi recorded in the SMML are not invariably pathogenic to the hosts listed, and the literature provided for each record should be consulted if pathogenicity is to be addressed. For example, SMML records for fenugreek (*Trigonella foenum-graecum*), now important in U.S. east coast ethnic markets (Govindasamy et al. 2010), comprise over 40 fungi. Some are obligate pathogens (powdery mildews, downy mildews, and rusts), but others are fungi better known for saprophytic habit (species in *Alternaria*, *Cladosporium*, *Epicoccum*, *Gliocladium*, etc.), and yet others can be seen to be pathogens by inspection of the literature provided, for example, Leppik (1960) for *Cercospora traversiana*. SMML conveniently lists the country and/or state for each record. Although indispensable for diagnosticians and others, readers should not assume SMML records are comprehensive, available for all locales, and contemporary. For example, records for fenugreek are mostly from foreign sources, and those for North America, although relevant, are decades old (Leppik 1960). SMML lists 22 names for fungi on tef (teff, *Eragrostis tef*), but none of the records are for North America, although tef is now grown in multiple locales in the United States as a specialty crop (Girma et al. 2012). For lablab bean (*Lablab purpureus*), there are 200 records in SMML, but only two (rusts from Puerto Rico) pertain to the United States, where the bean has been introduced (Imbruce 2007). Breadfruit (*Artocarpus altilis*) is grown in Hawaii, in large part to satisfy culinary preferences of immigrants from Samoa, Tonga, and the Marshall Islands (Ragone 1997). Ragone (1997) has a short section on diseases and pests, including a few fungal genera and one fungal species. SMML currently contains records of only four fungi from breadfruit in Hawaii, with the remaining 42 records from elsewhere, either a tribute to successful exclusion of fungi from breadfruit in Hawaii or just incomplete documentation. Although SMML is indispensable, its limitations must be addressed by exploiting other resources, of which we address important examples below.

THE EXAMPLE OF “ETHNIC” VEGETABLES

Occasionally, comprehensive surveys are published for a given crop or category of crops. For “oriental vegetables” grown in Ontario, Cerkauskas et al. (1998) reported pathogens on Chinese and Napa cabbage, bok choy, Chinese leaf mustard, pak choy, Chinese broccoli, and Chinese radish (Table 1). Some of these vegetable specialty crops were also addressed in Koike et al. (2007), along with vegetables more frequently used in mainstream North American diets. These crops, such as flowering Chinese cabbage (*Brassica campestris* ssp. *chinensis*), are also grown in the United States (Govindasamy et al. 2010; Zhang et al. 2013), and experimental pest and disease management tools have been assessed (Zhang et al. 2013). However, as seen below, management tools are often suboptimal to lacking. This situation contrasts with the introduction of chickpea addressed above, for which management options are now well developed. Moreover, chickpea is a single species, although there are desi and kabuli varieties (Chen et al. 2011). “Oriental vegetables” are primarily cabbage family (Brassicaceae), but ethnic vegetables occur in other plant families, have numerous plant taxa (including cultivars), were often recently introduced, and have diseases that are correspondingly diverse,

as are pathways for elicit seed importation (Wang and Cerkauskas 1999). Acreage for individual plantings of vegetables is seldom as large as for pulses, and this will have impacts on management options.

The situation can be illustrated via some extension publications focusing on commercial production of such crops: for example, Tubene and Myers (2008) for amaranth, cilantro (*Coriandrum sativum*), and tomatillo (*Physalis philadelphica*, *P. ixocarpa*). But pest and disease management of these crops is not addressed with specifics in Tubene and Myers (2008), although “leaf spot” and “white rust” of amaranth are mentioned. An alternative reference from the same institution (University of Maryland Extension 2013) does not address diseases of amaranth, cilantro, or tomatillo, but the reference provides recommendations for fungicidal seed treatment of Chinese cabbage, okra (*Abelmoschus esculentus*), and peppers and for control of “downy mildew” (not further specified) in “mustard greens” (usually indicating *Brassica juncea*). Fungicide recommendations (including seed treatment) are provided for Chinese cabbage, mustard greens, okra, and peppers by Wyenandt et al. (2017). For additional sources on Chinese cabbage, mustard greens, tomatillo, and amaranth, see Table 1.

Adekunle et al. (2011) noted for Ontario, “much research is needed to determine ... how pests of ECV [ethnocultural vegetables] can be controlled ... there are still no registered pest control products available for ECVs, which means they have to be grown organically.” Pests are one of the main constraints in production of the ethnocultural vegetable crop bitter melon (*Momordica charantia*), a medicinal and food plant, in Ontario (Nawaratne 2012). In the absence of recommendations for ethnic crops, some growers have used pesticides that are recommended for related major crops, and consequently experimental studies document the comparative persistence of fungicides and other chemicals on such ethnic crops (Ripley et al. 2003). It is difficult to ascertain the degree to which pesticides are actually used in ethnic crops in North America, although a history of pesticide registrations for minor crops via the IR-4 program is available online (<https://portal.nifa.usda.gov/web/crisprojectpages/0028044-enabling-pesticide-registrations-for-specialty-crops-and-minor-uses.html>). In a cooperative study by the USDA and UNESCO, Hightower and Brennen (2013) explicitly indicated pest, disease, and weed management as the leading priority of immigrant farmer training programs, but they did not provide specifics, although some of their citations indicated relevant crops and markets (e.g., lablab beans, water spinach, amaranth, and bok choy in an ethnic market in San Diego) (Brown 2011).

Information on disease management of ethnic vegetables is sometimes available online, but it is not necessarily open access nor directed toward North American audiences. The Australian sites AusVeg (<https://ausveg.com.au/>) and Asian Vegetables (<https://www.daf.qld.gov.au/plants/fruit-and-vegetables/vegetables/asian-vegetables>) provide common names for pests and diseases. The extent to which agricultural chemicals are registered for control varies by country, so readers should not assume that registered uses in Australia or elsewhere have their equivalents in North America.

THE EXAMPLE OF FABA BEAN AT WRPIS

As stated for chickpea above, it has been the historical mission of plant introduction stations to research possibilities for improving U.S. agriculture via the introduction of suitable plant germplasm (Hodge and Erlanson 1956; Hyland 1977). One such current program at WRPIS focuses on faba bean (*Vicia faba*). In North America, specialty grocery stores stock imported canned or dry faba beans or faba bean snacks (Fig. 1), but local fresh faba beans are becoming increasingly available (Fig. 2) as faba bean is grown by small and medium-scale farmers, primarily for immigrant and ethnic consumers (Miles and Hu 2014). Faba bean is an old crop, perhaps one of the

FIGURE 1

Imported canned (left) and dry (right) faba beans from a retail “international market” in Pullman, Washington.

foundation crops of the Neolithic, although no wild progenitors have been found (Muehlbauer et al. 1994). It was for millennia cultivated in the Middle East, Europe, and Asia (Ladizinsky and Abbo 2015).

Enhancing germplasm of faba bean appropriate for cultivation in the inland PNW makes up a significant portion of research at WRPIS (Landry et al. 2015a, 2016). Cold hardiness is important for the inland PNW, but faba bean has been grown for local markets for some time in the more moderate climate of coastal Oregon and Washington. Advances in cold hardiness have been achieved (Landry et al. 2015b), but plant health problems have also arisen.

In particular, plantings in both western and eastern Washington bore symptoms typical of *Ascochyta* blight (caused by *Ascochyta fabae*), previously reported in North America from Canada (SMML). This is not unanticipated and is analogous to the experience with chickpea in the PNW, described earlier. Representative isolate Vfaba#1:2013 from Whitman County matched the description of *A. fabae* in Punithalingam and Holliday (1975), and following methods in Berbee et al. (1999) the glyceraldehyde-3-phosphate dehydrogenase gene sequence had 100% identity with *A. fabae* (GenBank accession no. DQ383959) (Peever et al. 2007). When faba bean seedlings were inoculated with suspensions of conidia of Vfaba#1:2013, lesions typical of *Ascochyta* blight of faba bean (Richardson 2008) were produced on inoculated plants (but not on mock-inoculated controls) in each of two trials, and the fungus was recovered into pure culture in each trial. Plantings from Washington State also bore symptoms of chocolate spot (caused by *Botrytis fabae* and *B. cinerea*), previously reported from Alaska, California, Georgia,

North Carolina, and New York (SMML), and we have recovered *Botrytis* sp. isolates (not yet further identified) from symptomatic tissue. We are aware of the proliferation of new *Botrytis* species, including one reported from faba bean (Zhang et al. 2010). In addition to *A. fabae* and *Botrytis* sp., long recognized as pathogenic to *V. faba* (e.g., Davidson et al. 2004; Kaiser et al. 1997), we are currently conducting pathogenicity tests on faba bean using isolates of other fungi obtained from faba bean in Washington State. The North Dakota Department of Agriculture, partnering with North Dakota State University, is concurrently investigating diseases of faba bean in that region (USDA Specialty Crop Block Grant Program 2016). We hope that further development of cold-tolerant cultivars, site-appropriate cultural practices, and enhanced information on diseases and pests will address needs of growers who want to adopt faba bean production.

CONTRASTS AND COMMONALITIES

This brief review has addressed Asian, African, Oceanian, and Latin American crop plants, but readers are reminded that European immigrants also brought their own traditions (and plants), including plant-based medicines. However, not all introduced crops are equally problematic for plant health professionals. For example, medicinal plants from Asian traditions can be problematic. Information is either directed toward growing conditions and practices specific to Asian countries or is not consistently available in English. Extensive literature, in English, on diseases and pests of medicinal plants exists for South Asia, including recommendations for organic control (e.g., Chavan and Korekar 2011; Gahukar 2012; Gupta et al. 2010). There

FIGURE 2

Fresh, local faba beans at an organic food store near Corvallis, Oregon.

are significant contributions, in English, from East Asia as well (e.g., Ni et al. 2010; Sano et al. 2009), but the majority of such literature is in Asian languages (e.g., Chen et al. 2006). In the absence of analogous literature for North America, and better documentation of the pathogens and pests involved, there will be slow progress on formulating management recommendations for these crops in North American environments. By contrast with such crops, plants used by European immigrants tended to be familiar to established European populations here (even if some medicinal uses were novel), and they seldom constituted emerging crops. For example, plants used by Norwegian immigrants to North America for medicinal applications include beets (*Beta vulgaris*), hops (*Humulus lupulus*), mustards (*Brassica* spp.), onions (*Allium cepa*), potatoes (*Solanum tuberosum*), and flax (*Linum usitatissimum*) (Stokker 2007). Ukrainian immigrants treated maladies with wormwood (*Artemisia* spp.), flax, lowbush cranberry (lingonberry, *Vaccinium vitis-idaea*), poppy (*Papaver* spp.), and garlic (*Allium sativum*) (Mucz 2012). What these latter plants have in common is that they are in the European crop tradition, or if medicinal (e.g., yarrow, *Achillea millefolium*; chamomile, *Matricaria* spp.), were often familiar to North Americans of European descent. They are often endemic (rather than native) to North America, and are frequently harvested from the wild. These patterns are repeated for Slavic immigrants; for example, beets, onions, and garlic are regarded as medicinal as well as culinary, and other medicinal plants (dandelion, *Taraxacum* spp.; St. John's wort, *Hypericum perforatum*; *Calendula* spp., marigolds) are gathered from the wild or home gardens (Van Son 2007). Because they were either already well known or most often gathered from the wild, these plants pose fewer challenges to the plant health professional than do plants from Africa, Asia, Latin America, or Oceania.

Some food and medicinal plants of the Native Americans, utilized for centuries to millennia prior to arrival of Europeans and others, are also underinvestigated for microbial associates.

WRPIS is currently collaborating with Washington State University on cataloguing fungal associates, including pathogens, of camas (*Camassia quamash*), long a major food for Native Americans but largely ignored by immigrants (Freed 2016). It is ironic that this plant, utilized in the PNW for many centuries, suffers the same status with respect to disease management as do plants originally imported from Africa, Asia, Oceania, or Latin America and utilized by immigrants from those regions. Other specialty crops from the Native American tradition are better documented in SMML (e.g., Jerusalem artichoke, *Helianthus tuberosus*) and have corresponding literature on disease management (e.g., Dugan and Miles 2016). Also cultivated by Native Americans was the pawpaw (*Asimina triloba*), now regarded as an emerging fruit crop (Hummer et al. 2012, with comments on some fruit diseases), and for which there is an abundance of records in SMML from North America. If a plant becomes grown commercially, documentation on pests and diseases considerably improves; see, for example, Ortiz-Hernández and Carrillo-Salazar (2012) on fungal pathogens of pitahaya (dragonfruit, American cacti, *Hylocereus* spp.), long grown in Mayan and Mestizo family gardens in Mexico and Central America for food and medicine (De Clerck and Negreros-Castillo 2000; Neulinger et al. 2013). Of course, several food plants of the Americas, such as maize, potato, and many others, long ago became mainstream crops, and documentation on pests and diseases is abundant.

CONCLUSION

Whether of Asian, African, Latin American, Oceanian, or Native American origins, many emerging crops pose challenges because of their unfamiliarity to North American plant health professionals. Their inclusion in works of greater compass (e.g., Koike et al. 2007), or targeted synopses such as this one (Table 1), should be an asset to plant health professionals. Proactive awareness of emerging crops and vigilance by extension agents, diagnosticians, and others will be essential for integrating these crops and their growers into conventional

and organic agriculture. The latter may be especially important, given the obstacles to registration of pesticides for crops of limited acreage. A forthcoming publication from the American Phytopathological Society, the *Compendium of Herb Diseases and Pests*, will address some emerging herb crops as well as the more familiar herbs (Robert Harveson, *personal communication*). Progress in documenting pathogens of these emerging crops, and devising corresponding disease management strategies, will simultaneously enable food security and enjoyment of a rich, global culinary diversity.

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