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Arthropod Vectors of Exotic Citrus Diseases: A Risk Assessment for the Texas Citrus Industry

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ABSTRACT

Citrus in Texas has not, thus far, been seriously affected by any arthropod-borne diseases. However, with the recent detection of the Asian Citrus Huanglongbing (HLB) in Florida and the presence of its psyllid vector (*Diaphorina citri*) in Texas, a study was undertaken to determine the risks faced by the state's citrus industry from such diseases, some of which are seriously impacting citrus production elsewhere. A panel of 11 citrus scientists evaluated the risk of 12 citrus diseases, which have or may have arthropod vectors, could pose to Texas citriculture in the following categories – economic impact, probabilities of introduction, establishment and rapid spread, and difficulty of detection and control. Using a score of 1 for low risk, 2 for moderate and 3 for high, Asian HLB and citrus tristeza were determined to carry the highest risks for their possible economic impact on citrus production and probability of invasion and establishment in Texas. These two diseases are also very difficult to control and both could compromise the profitability of citrus production in Texas. Using an overall combined assessment of the six risk criteria, Asian HLB currently appears to be a higher threat than tristeza. All the diseases evaluated in this study can affect at least some of the commercial varieties in Texas, but for the most important ones, there is thus far no simultaneous occurrence of the arthropod vector and the disease pathogen. In some cases such as with tristeza, only the pathogen and not the efficient vector is present, whereas with others (HLB, leprosis and citrus variegated chlorosis) only the vectors are present. However, the continuous detection of these diseases and/or their arthropod vectors in regions relatively near the citrus belt of Texas puts the state's citrus industry at more risk. Efforts need to be pursued to prevent the entry of these deadly diseases into Texas, to detect their presence early and initiate eradication measures. Moreover, the ongoing management strategies of their arthropod vectors have to be strengthened to ensure the sustainability of citrus production in Texas.

Additional Index Words: Huanglongbing, tristeza, leprosis

Citrus is affected by more than a dozen arthropod-borne diseases worldwide (Timmer et al., 2000), some of which are the most important limiting factors of citrus production, including tristeza and huanglongbing (HLB). Diseases such as witches' broom disease of lime, are economically significant but restricted to one geographic region and/or a few citrus species, while others are presently of limited economic importance. Reasons why some diseases are more serious in certain regions include, among others, climate, which can affect the survival and establishment of both the pathogen and vector, humans who can spread diseases in infected plant material, and alternative hosts for pathogens and vectors (Skaria, 2004).

The citrus industry of Texas has not suffered significant economic losses from any arthropod-borne pathogens thus far. This is mainly because, either susceptible varieties are not grown, or the pathogen and/or the vector is absent. However, the recent detection of HLB in Florida (Halbert, 2005), leprosis in Central America (Palmieri et al., 2005; Saavedra de Dominguez et al., 2001) and Mexico (Sánchez, 2005), and citrus variegated chlorosis in Costa Rica (Aguilar et al., 2005), has raised concerns in Texas that the citrus industry could be severely impacted by one or more of these diseases in the future. A brief overview of some of these pathogens and vectors in relation to Texas was recently published (French et al., 2005), and the following study is intended to be a more in-depth risk assessment of arthropod-borne citrus diseases for Texas.

In Florida, Garnsey & Browning (2003) developed a rationale for assessing the threat of various exotic citrus pathogens to that state's citrus industry. We used this rationale to assess the threat to Texas posed by those diseases which are known or suspected of having arthropod vectors.

METHODS

A review of the literature of arthropod-borne citrus diseases was carried out to determine the geographical distribution of each disease and vector, varietal susceptibilities, economic importance, and any other characteristic which may influence the risk. Garnsey & Browning's (2003) analysis was then applied. Based on the current knowledge on the presence or absence of 12 arthropod-borne citrus diseases and their vectors in Texas (Table 1), a panel

Table 1. Occurrence of major arthropod-borne diseases and their vectors of in the Lower Rio Grande Valley of Texas.

Disease	Pathogen		Arthropod vector(s)		Disease occurrence
	Species	Status	Species	Status	
Asian Huanglongbing	*Candidatus* Liberibacter asiaticum	-	Asian citrus psyllid, *Diaphorina citri* Kuwayama	+	No
African Huanglongbing	*Candidatus* Liberibacter africanus	-	*Trioza erytreae* (Del Guercio)	-	No
Citrus tristeza	*Citrus tristeza virus*	+	Brown citrus aphid, *Toxoptera citricida* Kirk.[a] Other aphid spp.	- +	No[b]
Citrus variegated chlorosis	*Xylella fastidiosa*[c]	-	Sharpshooters including *Homalodisca vitripennis*	+	No
Leprosis	Cytoplasmic rhabdovirus & nucleo-rhabdovirus	-	False spider mites, *Brevipalpus* spp.	+	No
Citrus yellow mosaic virus	Badnavirus	-	Citrus mealybug, *Planococcus citri*	+	No
Citrus chlorotic dwarf	virus?	-	Bayberry whitefly, *Parabemisia myricae*	-	No
Citrus stubborn	*Spiroplasma citri*	-	Leafhoppers	+?	No
Concentric ring blotch	Unknown agent	-	Citrus grey mite, *Calacarus citrifolii*	-	No
Witches' broom disease of lime	*Candidatus* Phytoplasma aurantifolia	-	Leafhopper, *Hishimonus phycitis*	-	No
Vein enation-woody gall	Citrus vein enation virus	-	Brown citrus aphid Other aphid spp.	- +	No
Australian citrus die-back	Phytoplasma?	-	Planthopper, *Siphanta acuta* ?	-	No

[a]Brown citrus aphid is the efficient vector
[b]CTV present in Texas, but native species do not seem to transmit it in the field and no disease symptoms reported
[c]*Xylella fastidiosa* is present in Texas but not the strain that causes citrus variegated chlorosis

of 11 scientists with expertise in citrus pathology and entomology, including the four authors, independently determined a risk level (High, Moderate or Low) for each disease/vector combination under the following headings: economic impact, probability of introduction, probability of establishment, probability of rapid spread, difficulty of detection, and difficulty of control. The risk levels were scored 3 (High), 2 (Moderate) and 1 (Low), and the scores of the different diseases were subjected to one-way analysis of variance within each risk criterion. Mean scores of the 12 diseases studied were separated using the Student Newman-Keuls' test (Zar, 1999). For each disease, an overall risk was determined as the proportion of each score category (Low, Moderate or High) obtained for this specific disease.

LITERATURE REVIEW

***Citrus tristeza virus* (CTV) and Aphids.** *Citrus tristeza virus* (CTV) is recognized as the most destructive pathogen of citrus, and is responsible for two diseases, quick decline of scions on sour orange rootstock, and stem-pitting. Over 100 million trees on sour orange are believed to have been killed by CTV worldwide (Román et al., 2004), and stem pitting has caused extensive crop losses in countries such as South Africa (Marais & Breytenbach, 1996). CTV is transmitted in a semi-persistent manner by four aphid species, *Toxoptera citricida* Kirkaldy, *T. aurantii* (Boyer de Fonscolombe), *Aphis gossypii* Glover and *A. spiraecola* Pagenstecher. The brown citrus aphid, *T. citricida* is the most efficient vector of CTV (Lee et al., 1994). Epidemiological studies have shown that CTV spread by this aphid can be extremely rapid, going from 5% to 95% infection in 2-4 years (Gottwald et al., 1996).

The virus has been present in Texas for many years (Olson & Sleeth, 1954), but a 10-year survey in the 1990s showed that in the main commercial citrus growing region of the Lower Rio Grande Valley the incidence was around 1% while in east Texas it was approximately 18% (Solís-Gracia et al., 2001). *T. citricida* has not been recorded in Texas, but the other species are present. Research conducted in Texas showed that *A. spiraecola* was able to transmit local strains of CTV (Smith & Farrald, 1988), while transmission studies with *A. gossypii* were unsuccessful (Dean & Olson, 1956; Smith & Farrald, 1988). The discovery of *T. citricida* in Florida in 1995 (Hardy, 1995) and Mexico in 2000 (Michaud & Alvarez, 2000) demonstrated that it will be just a matter of time until it arrives in Texas. The fact that severe strains of CTV have been identified in Texas (Herron et al., 2005) means that *T. citricida* if accidentally introduced, could spread such strains rapidly causing widespread tristeza decline of trees on sour orange, the rootstock which is still used almost exclusively in Texas citrus (da Graça & Sauls, 2000).

A certified virus-free budwood program is now in operation in Texas (Kahlke et al., 2005), and for the major varieties it became mandatory in 2006 (da Graça & Watson, 2006). Research on alternative rootstocks has been conducted over the years (Wutscher & Shull, 1970), but none were considered to be superior to sour orange. The increased threat from CTV and *T. citricida* has now stimulated new studies which are showing that some new alternative tristeza-resistant rootstocks could be used in Texas (Louzada, et al. 2008).

Huanglongbing (HLB) and Psyllids. Huanglongbing (formerly greening disease) is caused by phloem-limited bacteria of the genus *Candidatus* Liberibacter, and is transmitted by two species of citrus psyllids. Aubert (1993) estimated that by the early 1990s, more than 60 million trees had been destroyed globally; many millions more will have been lost since then. The Asian form of the disease is caused by *Ca*. L. asiaticus and is transmitted by the Asian citrus psyllid, *Diaphorina citri* Kuwayama (da Graça & Korsten, 2004; Bové, 2006). It is considered the more serious form because young trees can die as a result of infection. The African form is caused by *Ca.* L. africanus, and is transmitted naturally by the African citrus psyllid, *Trioza erytreae* (Del Guercio); neither can survive for long periods at temperatures above 30^{o}C, in contrast to the Asian HLB and *D. citri* which are both heat tolerant. Consequently, Asian HLB and *D. citri* occur at lower elevations where temperatures can be higher, while the African form is found above 700 m. The newly discovered species in Brazil, *Ca.* L. americanus*,* appears to resemble the Asian species in terms of symptomology and vector relationships (Bové, 2006).

D. citri was detected in Florida in 1998 (Knapp et al., 1998), and by 2001 was found in Texas (French et al., 2001). It has also been reported in Costa Rica (Villalobos et al., 2005) and Mexico (López-Arroyo et al., 2005). Surveys for HLB began in Florida soon after the psyllid was found, but it was only in 2005 that the disease was found (Halbert, 2005). The type of Asian HLB that is now in Florida appears to cause severe symptoms on most citrus varieties, but grapefruit is one that is most seriously affected (T. Gottwald, pers. comm.). This is of great concern in Texas where grapefruit comprises 70% of commercial citrus production (da Graça & Sauls, 2000). This, combined with the apparent high suitability of the conditions in Texas for *D. citri*, means that the Texas industry could be seriously affected if HLB is introduced. A statewide survey to determine the extent of spread of the psyllid and whether any HLB is present was carried out in 2006, and while no HLB was found, the psyllid was recorded on citrus throughout south Texas (da Graça et al., 2007).

African HLB causes severe losses to sweet orange and mandarin, but is not as severe on grapefruit (Manicom & van Vuuren, 1990). The hot temperatures in the commercial citrus producing area of south Texas may not be suitable for *T. erytreae* to thrive. This psyllid species has not been recorded in the Americas.

Leprosis and False Spider Mites. Leprosis is a virus disease transmitted by at least three species of the false spider mite, *Brevipalpus phoenicis* (Geijskes), *B. californicus* (Banks) and *B. obovatus* Donnadieu (Childers et al., 2003a). There are two different, but structurally similar, viruses which can cause the disease. Most leprosis-affected trees appear to be infected with a cytoplasmic rhabdovirus, but a few are infected with a nucleo-rhabdovirus. The disease was present in Florida in the early years of the 20th century, but disappeared probably through efficient control of the mite vectors (Childers et al., 2003b). However, leprosis is a major problem in Brazil, where losses are estimated to be approximately $80 million annually, which represents 21% of production costs (Omoto, 1998). The disease has recently been reported in several other South American countries (Gómez et al. 2005; León et al. 2006), Central America (Palmieri et al., 2005; Saavedra de Dominguez et al., 2001) and Mexico (Sánchez, 2005). All three *Brevipalpus* species have been reported in Texas (Dean & Maxwell, 1967), and cause necrotic lesions on leaves, fruits and twigs (Childers et al., 2003b). Electron microscopy of affected tissue failed to detect any leprosis virus-like particles (Childers et al., 2003b).

Leprosis causes severe symptoms on sweet orange, but the susceptibility of grapefruit remains to be determined. The presence of the mite vectors in Texas, and the spread of the virus towards the state raises serious concerns. Sweet orange comprises 30% of Texas citrus production (da Graça & Sauls, 2000), so even if grapefruit is not severely affected, there could still be an economic impact. Control of the mites is the only way of preventing losses from leprosis, and this is achieved in Brazil at considerable costs.

Citrus Variegated Chlorosis (CVC) and Sharpshooters. CVC was first reported in Brazil in 1987 (Rossetti et al., 1990). It is caused by the xylem-limited bacterium *Xylella fastidiosa* which is transmitted by several species of sharpshooters. It has become a serious disease there, and has been reported elsewhere in South America (Brlansky et al., 1991), and in Costa Rica (Aguilar et al., 2005). The potential for further spread of CVC could be considered to be high. Sweet orange varieties are highly susceptible, but grapefruit appears to be either tolerant or resistant, depending on the variety (Li et al., 1996).

The citrus strain of *X. fastidiosa* has not been found in the USA so far, although other closely related strains do occur, such as the one which causes Pierce's Disease of grapes (Hopkins, 1989). This is vectored by, amongst others, the glassy-winged sharpshooter, *Homalodisca vitripennis* (Germar), formerly *H. coagulata* Say, which is native to the south western areas of the USA, including Texas (de León et al., 2004). *H. vitripennis* has been shown to be able to transmit CVC (Damsteegt et al., 2006)

***Citrus yellow mosaic virus* (CYMV) and Citrus Mealybug.** CYMV is a badnavirus transmitted by the citrus mealybug, *Planococcus citri* (Risso) (Ahlawat et al., 1996). Thus far, it has only been reported to occur in India, but it affects all types of citrus causing serious yield losses and quality reduction. *P. citri* is present in Texas, and was reported in 1971 to have the potential of becoming a serious economic pest (Dean et al., 1971).

Citrus Chlorotic Dwarf (CCD) and Bayberry Whitefly. CCD has only been reported from Turkey where it has been especially severe on lemon, grapefruit and some mandarins (Korkmaz et al., 1995). The causal agent has not been identified, but is believed to be a virus (Korkmaz & Garnsey, 2000). It is transmitted by the bayberry whitefly, *Parabemisia myricae* (Kuwana). This insect is known to occur in California (Rose et al., 1981) and Florida (Hamon et al., 2000).

Citrus Stubborn and Leafhoppers. Citrus stubborn, caused by *Spiroplasma citri*, is especially serious on young orange, mandarin and grapefruit trees and is a problem mainly in hot, arid regions (Bové & Garnier, 2000). The disease is vectored by several species of leafhoppers including *Circulifer tenellus* (Baker) and *Scaphytopius nitridus* (DeLong) in the southwest of the USA, and *C. haematoceps* (Mulsant & Rey) and *C. tenellus* in Mediterranean countries. These insects have wide host ranges, and feed on many weed species, many of which are also hosts of *S. citri*. California and Mediterranean countries have wet winters, and hot, dry summers, and during the latter, weeds die and leafhoppers move on to citrus.

C. tenellus has been recorded in west Texas (Romney, 1939, cited by Creamer et al., 2003), but no records could be found of it occurring in the Lower Rio Grande Valley (LRGV) of Texas.

Concentric Ring Blotch and Citrus Grey Mite. Concentric ring blotch is a minor problem in parts of South Africa, occasionally found in some nurseries and orchards (Doidge & van der Plank, 1930). Most citrus varieties, except some lemons, are affected. The causal agent is unknown, although spiroplasma-like organisms have been observed in affected tissue (Kotzé et al., 1987). The disease appears to be transmitted by the citrus grey mite (*Calacarus citrifolii* Keifer) (Dippenaar, 1958; Rossouw & Smith, 1963). Six citrus mite species have been identified in Texas (French, 2002), but *C. citrifolii* is not one of them.

Witches' Broom Disease of Lime (WBDL) and Leafhopper. WBDL was first found in Oman in 1986 (Bové, 1986), and later in the United Arab Emirates (Bové et al., 1993) and Iran (Bové et al., 2000). It is caused by a wall-less procaryote, *Candidatus* Phytoplasma aurantifolia, and infects lime, citron and sweet lime, but not apparently sweet orange and mandarin. Grapefruit is not grown commercially in these countries, and has not been reported as a host. The leafhopper, *Hishimonus phycitis* Distant, has been suspected as the vector because DNA probes showed the presence of the phytoplasma although transmission experiments were unsuccessful (Bové et al., 1993).

However, recently WBDL was transmitted to Bakraee, a mandarin hybrid, by field collected *H. phycitis* in Iran (Salehi et al., 2007). A witches' broom disease of lime also occurs in India, as does *H. phycitis*, but it has not been established that this WBDL is the same as that found elsewhere (Ghosh et al., 1999). Bové et al. (2000) are of the opinion that this disease is not the same as WBDL because the symptoms are somewhat different, and it does not appear to be as destructive as the disease in Oman. There is no lime industry in Texas and *H. phycitis* has not been recorded.

Vein Enation - Woody Gall and Aphids. Citrus vein enation virus (CVEV) is a tentative luteovirus (da Graça & Maharaj, 1991) transmitted in a persistent manner by *T. citricida* (Maharaj & da Graça, 1989), *A. gossypii* and *Myzus persicae* (Sulzer)(Hermoso de Mendoza et al., 1993). It causes woody galls on rough lemon rootstocks, and vein enations on rough lemon, Mexican lime and sour orange. It is not considered to be economically important, except for a few cases in South America of severe galling on rough lemon rootstocks of young trees causing some stunting (Bazan de Segura & Ferrand, 1969). The disease appears to be suppressed at high temperatures and is rarely found in the hotter areas of California (C. Roistacher, pers. comm.), and symptomatic young trees moved from a greenhouse to a field in California developed few new galls, and original galls ceased enlarging or receded (Wallace, 1981). The hot temperatures of south Texas may suppress CVEV as well.

Australian Citrus Dieback and Planthopper (?). This disease may be caused by a phytoplasma (Broadbent et al., 1976; Broadbent, 2002). It appears to spread naturally in the field, but no vector has been identified, although the green planthopper, *Siphanta acuta* (Walker), is a candidate (P. Broadbent, pers. comm.); it is not known to occur in Texas. The disease, which is most severe in grapefruit, has not been reported outside Australia, and even there its occurrence is sporadic.

Citrus Sudden Death (CSD) and Unknown Vector(s). CSD is a new citrus disease in Brazil. It was first found in 1999, and affects trees on Rangpur lime (Müller et al., 2002) and Volkamer lemon (Bové, 2005), rootstocks not used in Texas. The causal agent has not been identified, nor has a vector. The disease resembles the decline of trees on sour orange caused by CTV (Román et al., 2004) and is spreading in a pattern identical to that of CTV and *T. citricida* (Bassanezi et al., 2003). In addition to CTV, a marafivirus was found in infected trees (Bové, 2005; Maccheroni et al., 2005), but its role in CSD, if any, remains unknown.

Other Diseases. In addition to the above diseases, there are others which appear to be associated with arthropod vectors, but which are very minor diseases in the areas they have been reported, and consequently little research has been conducted on them.

Leathery leaf has been reported in India affecting mandarins, and there is some evidence of aphid transmission (Ahlawat et al., 1972). No other details appear to have been published. In addition to the witches' broom of lime in India described above (Ghosh et al., 1999), two other graft transmissible diseases have been reported in that country which may be caused by phytoplasmas, rubbery wood in lemon and lime (Ahlawat & Chenulu, 1985) and blastomania in Rangpur lime (Mali et al., 1975). In southern Africa, a similar disease called multiple sprouting of sweet orange has been reported (Schwarz, 1970). If phytoplasmas are involved, there are likely to be insect vectors.

In addition to leprosis, *Brevipalpus* mites have been associated with another disease in Brazil, zonate chlorosis, which is not as severe as leprosis and is restricted to coastal areas (Chagas, 2000).

None of these diseases has ever been associated with serious economic losses, and in addition, little is known about their causal agents and possible vectors. Consequently, they were not rated by the panel.

RESULTS AND DISCUSSION

Except for CTV, none of the economically important diseases affecting citrus in the world currently occurs in Texas mainly because their pathogens are not present (Table 1). In contrast, the arthropod vectors of these deadly diseases have been accidently introduced and thrive well in the subtropical climate of the LRGV of Texas. For CTV, the most serious citrus pathogen reported so far in Texas, its efficient vector the brown citrus aphid, *T. citricida* has not been detected.

The results of the risk assessment carried out by the 11-member panel of scientists are summarized in Table 2. Overall, Asian HLB and tristeza were ranked as the diseases of highest risk to the Texas citrus industry. Leprosis and CVC were ranked third and fourth respectively. Fig. 1 shows a summary of the overall risk associated with each arthropod-borne citrus disease. These rankings are not surprising, and confirm that Texas has good reason to be concerned.

Chung (2006) reported that a risk assessment was conducted in Florida on several exotic citrus diseases caused by all types of pathogens using Garnsey & Browning's (2003) method. HLB was ranked as the most important, followed by the fungal disease, citrus black spot, and then tristeza (stem pitting). No

Table 2: Risk assessment of arthropod-transmitted diseases that pose major threats to citrus production in the Lower Rio Grande Valley of Texas.

Threat[a]	Economic Impact	Introduction Probability	Establishment Probability	Rapid Spread Probability	Detection Difficulty	Control Difficulty
HLB/ Asian citrus psyllid	3.0 ±0a[b]	3.0 ±0a	3.0±0a	2.8 ±0.1a	2.4 ±0.2ab	3.0 ±0a
Leprosis/False spider mites	2.5 ±0.2ab	2.4 ±0.2b	2.6 ±0.2a	2.3 ±0.2ab	2.3 ±0.2ab	2.2 ±0.2b
CTV /Aphids	3.0 ±0a	2.9 ±0.1a	2.9 ±0.1a	2.9 ±0.1a	1.5 ±0.2ab	2.4 ±0.2a
CVC/ Sharpshooters	2.4 ±0.2ab	1.8 ± 0.1c	2.5 ±0.2a	2.3 ±0.2ab	2.1 ±0.2ab	2.4 ±0.2c
CYMV/ Citrus Mealybug	2.2 ±0.2bc	1.3 ±0.1d	1.8 ±0.2b	2.2 ±0.2abc	1.7 ±0.2ab	2.1 ±0.3d
CCD /Bayberry Whitefly	1.9 ±0.2 bcd	1.2 ±0.1d	1.5 ±0.2b	1.6 ±0.3bc	2.0 ±0.3ab	2.3 ±0.2d
Citrus stubborn/ Leafhoppers	1.8 ±0.2 bcd	1.4 ±0.2d	1.5 ±0.2b	1.5 ±0.2bc	1.5 ±0.2b	1.7 ±0.2d
CRB/Citrus grey mite	1.5 ±0.2cd	1.0 ±0d	1.4 ±0.2b	1.4 ±0.2bc	2.6 ±0.2a	1.9 ±0.3d
WBDL/ Leafhopper	1.2 ±0.1d	1.0 ±0d	1.2 ±0.2b	1.3 ±0.2c	1.8 ±0.2ab	1.8 ±0.2d
CVEV/ Aphids	1.4 ±0.2cd	1.2 ±0.1d	1.5 ±0.2b	1.7 ±0.2bc	1.5 ±0.2ab	1.7 ±0.2d
ACD/ Planthopper	2.0 ±0.3 bcd	1.0 ±0d	1.5 ±0.2b	1.4 ±0.2bc	2.2 ±0.2ab	1.9 ±0.3d
CSD/unknown Vector	1.6 ±0.2 bcd	1.2 ±0.1d	1.3 ±0.2b	1.6 ±0.2bc	1.6 ±0.2ab	1.9 ±0.3d
HB/ African citrus psyllid	2.0±0.3bcd	1.1 ±0.1d	1.4 ±0.2b	1.5 ±0.2bc	2.3 ±0.2ab	2.6 ±0.2d

[a] HLB=Huanglongbing, CTV=*Citrus tristeza virus*, CVC=citrus variegated chlorosis, CYMV=*Citrus yellow mosaic virus*, CCD=citrus chlorotic dwarf, CRB=citrus ring blotch, WBDL=witches' broom disease of lime, CVEV=citrus vein enation virus, ACD=Australian citrus dieback, CSD=citrus sudden death

[b] Scores : 3=high risk; 2=moderate risk; 1-low risk. Means followed by the same letter within each column are not significantly different (P > 0.05, Student-Newman Keuls' test)

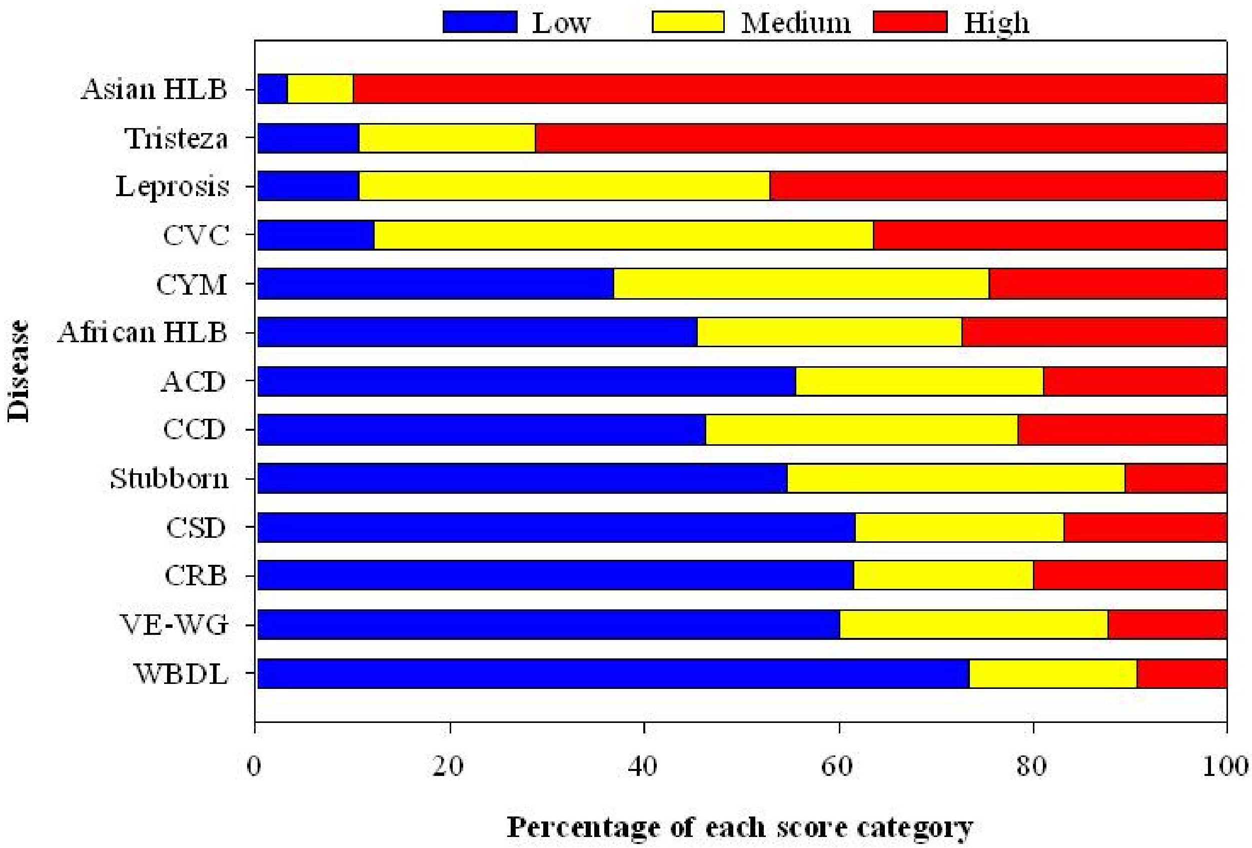

Fig. 1. Summarized overall risk associated with each arthropod-borne citrus disease in Texas (Asian HLB = Asian Huanglongbing, CVC = citrus variegated chlorosis, CYM = citrus yellow mosaic, African HLB = African Huanglongbing, ACD = Australian citrus dieback, CCD = citrus chlorotic dwarf, CSD = citrus sudden death, CRB = concentric ring blotch, VE-WG = vein enation woody gall, WBDL = witches' broom disease of lime)

distinction was made between Asian and African HLB, and tristeza-induced sour orange decline was not considered, presumably because Florida has largely ceased the use of sour orange as a rootstock (Saunt, 2000). The Florida and Texas panels thus both consider these two diseases to be very serious threats. In Florida, HLB has been described as the most severe threat ever to its citrus industry, and the only one which could eliminate the industry (Timmer et al., 2007).

The next graft and arthropod-borne diseases in the Florida ranking were, in order, CVC, CCD and leprosis, while the Texas panel ranked leprosis above the other two. It is possible that the Florida panel was of the opinion that a higher level of human traffic between the state and Brazil exposes the Florida citrus industry to CVC, but it is not apparent why leprosis, another serious disease in Brazil, was ranked lower than CCD which occurs only in Turkey, although the vector is present in Florida (Hamon et al., 2000).

Amongst the factors contributing to the high ranking of Asian HLB and CTV by the Texas panel is the economic impact that is already being experienced in Florida. Conditions in both states are ideal for these two diseases and their vectors. Leprosis and CVC could also have serious effects in both states, as the vectors for both are present, and leprosis has previously been a problem in Florida (Childers et al., 2003b). African greening received a low rating for Texas, probably because of the knowledge that the pathogen and the vector could not tolerate high temperatures in the LRGV.

The remaining diseases were ranked as much lower risks in both states, although the order was slightly different. All have some feature which suggests that they would not be serious diseases in Texas, such as unfavorable weather for the vectors (stubborn), non-use of susceptible rootstocks (CSD) or scions (WBDL), absence of vectors (CRB) and no reports of serious economic losses in other countries (CVEV). Despite these low rankings, one must be aware of these and other diseases, because under Texas conditions it is possible that they may be more serious than where they currently exist. Australian citrus decline is most serious on grapefruit in Australia, but it is sporadic and not of great economic importance. However, under Texas conditions, it may become a serious disease in grapefruit.

Clearly, Texas needs to be prepared for the potential losses which the high risk diseases could cause. On-going surveillance is essential, as are the steps to ensure the budwood sources remain disease-free. The Texas Department of Agriculture should have the resources needed to enforce regulations, and soon it may become necessary for citrus nurseries in Texas to produce trees under insect resistant screens as is now the case in Florida (Crawford, 2007). Area wide control of vectors is also essential to reduce the rate of spread of any diseases which may be introduced. With good preparations and vigilance, Texas citriculture should have excellent prospects for the future.

In addition, Texas needs to be aware of other exotic diseases which are not arthropod borne, such as canker, black spot, postbloom fruit drop, mal secco and *Phaeoramularia* spot (Timmer et al., 2000), which may also threaten the industry in the future. The Florida citrus industry had experienced severe economic loss in the past three years as a result of several hurricanes and tropical storms (Pash et al., 2006). In addition, hurricanes and tropical storms disseminated the bacterium *Xanthomonas axonopodis* pv. *citri*, the causal agent of Asiatic citrus canker (Gottwald and Irey, 2007). Such information is currently not available for the effects of major weather events on the distribution of Asian Huanglongbing and its vector. The Gulf Coast of Texas is also vulnerable to hurricanes and tropical storms which could increase the spread of disease carrying arthropods.

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