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Vulnerability of Citrus Growers to Huanglongbing

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ABSTRACT

Objective: Analyze the vulnerability of citrus growers of San Rafael and Cotaxtla, Veracruz, Mexico, to the presence of HLB.

Methodology: Citrus growers were surveyed on their knowledge, proficiency, and perception of strategies implemented by the Campaign against HLB. Vulnerability was integrated into the Risk Index (IR), which included both the knowledge and perception of citrus growers toward the Campaign's strategies, the actions they perform, and those they are willing to perform. The IR between localities was compared and correlated to the grower's variables, the parcel, and the trust between social actors. Also, the organizational involvement of growers was compared.

Results: Growers of San Rafael and Cotaxtla are at a medium vulnerability level, with no significant difference between their IR (P=0.48). The grower IR increases as the degree of trust in social actors decreases (r=−0.30). Organizational involvement is equally low in both localities (P=0.15).

Study Limitations: The study does not apply to other localities.

Conclusions: Citrus growers may respond adequately and significantly to new vulnerability conditions imposed by HLB, which may endanger actions implemented based on their participation in the Campaign against HLB.

Keywords: social trust, knowledge, HLB, risk index, organization.

INTRODUCTION

Huanglongbing (HLB) is a devastating citrus disease caused by the bacteria *Candidatus Liberibacter* spp. and vectored by the insect *Diaphorina citri*. The disease was detected in 2009 in the State of Yucatan, Mexico (Hernández-Fuentes *et al*., 2012). Sampling, diagnosis, inspection, and monitoring are performed to detect HLB's introduction and dispersion to the national territory. The "National Campaign against HLB" (nowadays "Campaign of Regulated Pests of Citrus Plants") organizes control strategies operated by State Plant Health Committees (CESVVER in Veracruz) under the Federal Law of Plant Health (DOF, 2011).

On the other hand, the vulnerability of social groups to HLB has not been analyzed. The vulnerability has an outer side (the threat) and an inner side (the strategies and overcoming capacities of those affected). Studies have been focused

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on factors that determine the inner side of vulnerability (Coy, 2010). Measuring vulnerability allows to promote corrective measures and limit impacts upon supporting strategies to face and ease society's adaptation (Kelly & Adger, 2000). Vulnerability begins with the notion of risk, a concept not centered on an event's interest, but on how and what actions are generated, and how it influences human behavior (Coy, 2010). Vulnerability refers to the capacity of an individual or a group of people to anticipate, face, withstand, and recover before the effects of danger, either natural or caused by human activity (Sánchez-González & Egea-Jiménez, 2011). Decision-making indicators' are used to perform a qualitative vulnerability assessment. The vulnerability concept refers to "a community's incapacity to adapt to change by a phenomenon that constitutes a risk" (Wilches-Chaux, 1989). Risk refers to "when potential damages are the consequence of conscious decisions" (Luhmann, 1992). In this context, the study's objective was to analyze the vulnerability of citrus growers of San Rafael and Cotaxtla, Veracruz, to HLB's presence through a Risk Index (IR). The hypothesis was that IR would be different between localities and negatively correlate with the grower's trust.

MATERIALS AND METHODS

The study was performed in San Rafael (SR) and Cotaxtla (CO) municipalities, Veracruz, Mexico. At a State level, the municipality of SR represents 10.1% of the citrus-growing area and has an average citrus-growing yield of 69,240 t ha^{-1}. The climate is warm and humid with abundant rains in summer (1400 a 1600 mm, and mean annual temperatures ranging from 24 to 26 °C). CO represents 3.5% of the state citrus-growing area with 23,316 t ha^{-1} of average yield (SIAP, 2020), it has a subhumid warm climate with summer rains (1100 to 1300 mm, mean annual temperatures ranging from 24 to 26 °C). A beta survey test answered by 30 citrus growers estimated the proportion (p) of growers not knowing the disease. The sample size per municipality was estimated with the CESVVER citrus-growing registry (728 growers in SR and 314 in CO), through the formula:

$$n = NZ^2pq / \left(d^2[N-1] + Z^2pq\right)$$

where: n=sample size; N=grower registry per municipality; Z=trust level at 90%; p=70% of citrus growers without knowledge of HLB; q=30% of growers that have heard about HLB; d=random error margin: 10%.

The survey characterized the citrus grower by locality, age, education degree, growing experience, years of residence; also his knowledge on pests, actions by the Campaign against HLB fostered by CESVVER, actions that he performs on his parcel against the vector or the disease; and actions he is willing to perform for the control of *D. citri* and HLB. Citrus orchard (parcel) was characterized by area and plants ha^{-1}. Growers were asked about their knowledge of pests and actions by CESVVER. Citrus grower vulnerability to the presence of HLB was obtained through the Risk Index (IR), which integrated: a) the knowledge of pests and diseases in citrus, b) whether the grower knows the actions of CESVVER; c) what practices he performs to control the vector or disease; d) what he is willing to do; e) perception of CESVVER actions; f) perceptions on practices performed on his parcel, and g) perception of practices that he is willing to implement. IR was calculated by the formula:

$$IR = 70 - (a + b + c + d + e + f + g)$$

where 70 is the maximum classification of the sum of seven items deemed within a scale of 0 to 10.

The greater the individual classification of each item, the lower the risk. Vulnerability level was defined as low (IR<23), medium (from 23 to 47), or high (from 47 to 70); *i.e.*, the more knowledge that growers have on the vector, the more their adherence to CESVVER's indications and the lower their vulnerability. Growers were asked about their trust in several social figures (family, police, government, friends, physicians, "ejido" authorities) to build a social trust index (%). Mean and standard deviation (SD) of variables were calculated. The IR of localities was compared with analysis of variance and correlated to years of growing experience, years of residence in the locality, area, number of plants ha^{-1}, and social trust. The degree of involvement of growers in social organizations, The degree of involvement of growers in social participation is an index based on whether they participated in the association, whether they organized to solve a problem and whether they would participate in an organization. A χ^2 test compared localities in their degree of involvement in organizations.

RESULTS AND DISCUSSION

Citrus growers of San Rafael had an average age of 53 years (SD ± 14), higher than those from Cotaxtla (46 ± 12 years); all respondents in both localities were males. Seventy-four percent of SR citrus growers and 68% of

CO have an elementary education, and even 3% never started school. CONEVAL (2015) reports that the state of Veracruz occupies the 4th position at a national level in educational lag after the states of Chiapas, Michoacán, and Guerrero; being lower in San Rafael (28%), compared to Cotaxtla (40.1%). Pérez (2005) agrees that age and education level (along with gender, family situation, address, employment, and cultural level) allow identifying vulnerable groups. Most (89.7%) CO citrus growers have little experience (<10 years) in the production of citrus, while in SR, 68.2% have a long experience (Table 1).

Table 1. Citrus growers' social characteristics and their parcel attributes in San Rafael and Cotaxtla, Veracruz, Mexico.

Characteristics	San Rafael	Cotaxtla
	Mean ± SD, n = 53	Mean ± SD, n = 48
Education level (years)	6.4 ± 2.7	6.6 ± 3.9
Experience in citrus growing (years)	20.5 ± 14.2	6.8 ± 6.1
Time in locality (years)	47.5 ± 17.5	44.3 ± 18.5
Number of plants per parcel (plants ha^{-1})	347.2 ± 141.6	317 ± 66.7
Grown area (ha)	4.5 ± 3.8	3.4 ± 3.8

Fifty-eight percent of SR growers perceive *D. citri* as a pest of greater risk for citrus. They indicate that red spider [*Panonychus citri* (McGregor)] and other mites, several ant and aphid species [*Aphis spiraecola* Patch, *Toxoptera aurantii* Boyer de Fonscolombe, *Aphis* (*Toxoptera*) *citricidus* (Kirkaldy)], citrus rust mite [*Phyllocoptruta oleivora* (Ashmead)], citrus leafminer (*Phyllocnistis citrella* Stainton), citrus mealybug, [*Planococcus citri* (Risso)], citrus snow scale [*Unaspis citri* (Comstock)] and nematodes are major pests. Among diseases, gummosis (*Phytophthora* spp.) (67%) and HLB (45%) stand out. Also, canker (*Colletotrichum acutatum* J.H. Simmonds), Citrus Tristeza Virus (CTV), and greasy spot (*Mycosphaerella citri* Whiteside) were identified. Even when HLB and *D. citri* are of later introduction, Castillo *et al*. (2004) agreed with the main pests and diseases of citrus in the Central Region of Veracruz (citrus rust mite, citrus mealybug, and ants, as well as gummosis, CTV and anthracnose); although, they also included the Mexican fruit fly (*Anastrepha ludens* (Loew) as a pest of grapefruit. In CO, growers classify *D. citri* en in 4th place (29 %) after the red spider, aphids, and mites; other pests of lesser importance were citrus leafminer and rust mite. Diseases such as gummosis and CTV stood out; HLB appeared in 3rd place (20%), and this suggests that CO citrus growers do not perceive the potential risk of HLB. For Briones (2005), the risk idea is a social construct, as society itself defines what is risky and what is not, according to their history, territory, and institutions, where economic, political, symbolic, and cognitive factors intervene. The CTV case appears in the recent history of the region, which, in the decade of 2000, was deemed to be of high risk for citrus growing, which was not realized to be as damaging as expected. This background may contribute to decreasing the perception of HLB among growers.

Grower Knowledge about CESVVER's Actions

CESVVER establishes sentinel parcels to monitor the arrival of HLB and organizes Control Areas (ARCO), which is the disease control strategy at a broader scale. The campaign name awareness was similarly high in both localities (>80%; Figure 1), while awareness about ARCO and sentinel parcels was similarly low (<13%); these contrasts with the reports of other localities in Veracruz by IICA (2012), where 65% of the population knows about protection strategies. In SR, only 53% of respondents knew that their parcel had been inspected to collect *D. citri* and symptomatic plant tissues to determine HLB's presence, and only 29% were informed about the result of this activity (Figure 1). In CO, although

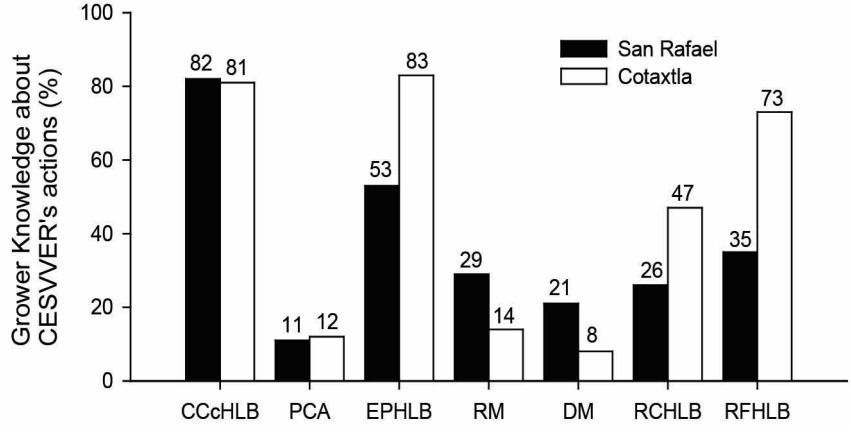

Figure 1. Grower Knowledge about CESVVER's actions: Knows about the Campaign *vs*. HLB (CCcHLB). Knows what a sentinel parcel and ARCO (PCA) are. CESVVER has looked in the grower's parcel for symptoms of HLB (EPHLB). Grower was shown results of *D. citri* or leaves sampled at his parcel (RM). He knows where to send samples to diagnosis by himself (DM). He received training to detect HLB symptoms (RCHLB). He received leaflets to identify symptoms of HLB and *D. citri* (RFHLB).

a greater proportion of growers knew about the actions of inspection and diagnosis (>80%), only 14% were told about the result (Figure 1). In both localities, the percentage of growers that know where to send samples for an official disease identification by technicians is low (21% in SR and 8% in CO; Figure 1). Although training directly influences this threat's perception, it has been the most neglected strategy; when in CO training accounted for almost 50% of respondent growers, it did so for 26% in SR only (Figure 1).

The proportion of CO growers that received leaflets to identify symptoms of HLB and identify *D. citri* was also twice those of SR (Figure 1). Moreover, they were asked whether, after the training, they deemed to have sufficient information to identify *D. citri* on the field, to which 59% in SR and 61% in CO gave an affirmative answer; 53% of trained growers in SR and 54% in CO stated to be able to perform the sampling and recognize symptoms of HLB. Once growers recognize their capacity to perform and be part of the CESVVER strategies *vs*. HLB, it decreases the social group's individual and collective vulnerability. As a counterpart, the population fraction that is not adequately addressed and made aware might decrease the success of self-protection strategies to control HLB. FOESSA (2011) states that the greater vulnerability occurs when social integration is lesser, and segments that do not have adequate integration to campaigns remain disregarded for training. The perception of SR growers toward CESVVER's activities in the Campaign is good; nevertheless, not knowing its objectives and activities contributes to growers lacking risk perception, increasing their vulnerability, and decreasing their capacity to prepare and respond to a contingency. Briones (2005) considers that the perception of risk has consequences in the behavior and management of disasters in society, as persons make rational decisions that do not necessarily meet what authorities expect.

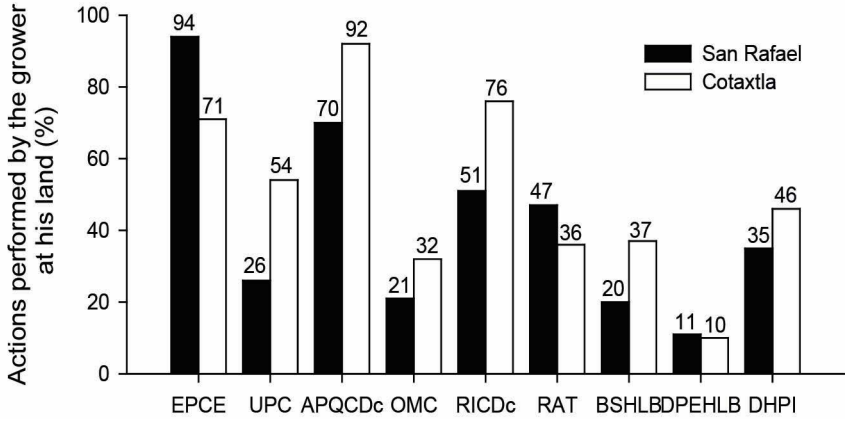

Figure 2. Actions performed by the grower at his parcel to control HLB. Grower removes sick citrus plants (EPCE). He uses certified plants (UPC). He applies chemical products for the control of *D. citri* (APQCDc); another control measure, different than (OMD); rotates pesticides upon controlling *D. citri* (RICDc). He receives technical advice (RAT). He seeks symptoms of HLB at his parcel (BSHLB). He performs an analysis to find sick plants (DPEHLB). He disinfects tools when possible or makes grafts (DHPI).

Citrus Grower Actions within his Parcel

More than 50% of growers in both localities performed plant removal, pesticide application, and pesticide rotation (Figure 2). Most actions are made in higher proportion by CO growers compared to those of SR, reflecting more training received by the former. SR growers performed only plant removal practices and received technical advice in a higher proportion than those from CO (Figure 2).

In CO, 54% of growers use certified plants, while 29% do this in SR. Cotaxtla citrus growers participate in programs supported by the Municipality Council, which offers certified plants at reasonable prices. Thus, they would be able to replace plants more frequently than in SR. On the other hand, 94% of SR growers remove sick plants, while 71% does this in CO. This may be related to a lesser experience of growers in this municipality (6.7 ± 3.1 years) compared to that of San Rafael (20.6 ± 14.2 years), and to the fact that, the lesser the cost of non-certified plants *vs*. certified ones, the easier the replacement decision is for the growers. Using certified plants and removing infected plants are baseline strategies in handling HLB, decreasing the potential dispersion of HLB at the parcel. For Pérez (2005), this type of decision-making determines vulnerability in a specific situation, including other relations among persons in different development media.

Only 20% of SR but 37% of CO growers look for HLB symptoms. In SR, 47% had received technical assistance, but only 36% in CO (Figure 2). In SR, technical assistance is provided by agrochemical salesmen (52%), CESVVER (32%), and the packing house they are associated with (16%). In CO, they receive technical assistance from CESVVER (41 %), agrochemical salesmen (35%), personnel from the Municipal Direction of Agricultural Promotion (12%), INIFAP (6%), and from other growers (6%). These numbers beat the 15% of grapefruit growers of Central Veracruz indicated

by Castillo *et al.* (2004), who received technical assistance from the private sector, mainly from agrochemical stores.

Actions that Growers Would Be Willing to Perform to Handle HLB

In both localities, the percentage of willingness to perform actions for handling HLB is high, and it is greater in CO than in SR in all items (Figure 3). Most growers in both localities would be willing to remove sick plants (94% in SR and 100% in CO; Figure 3).

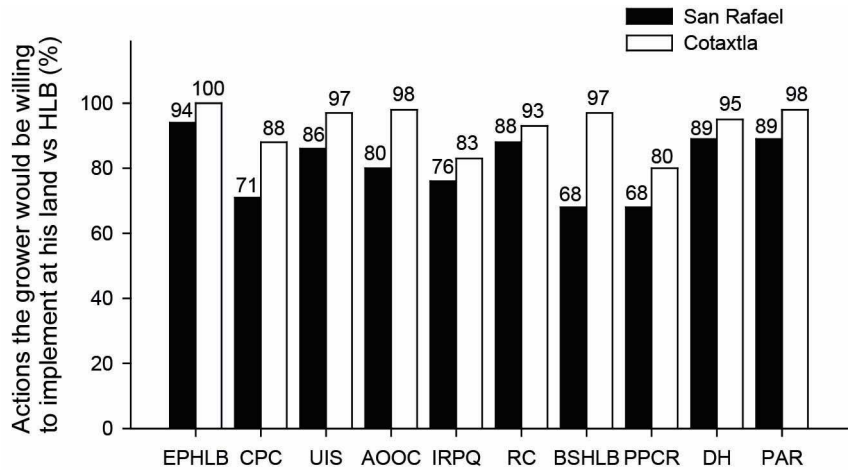

Figure 3. Actions the grower would be willing to implement at his parcel to control HLB (AProImp): Remove sick plants (EPHLB); purchase certified plants (CPC); employ selective pesticides *vs. D. citri* (UIS); adopt other options *vs. D. citri* (AOOC); implement pesticide training in the handling of (IRPQ); obtain training on how to handle HLB and *D. citri* (RC); seek for symptoms of HLB (BSHLB); pay for PCR analysis to find sick plants (PPCR); disinfect trimming and grafting tools to avoid HLB dissemination (DH); take part in regional applications *vs. D. citri* (PAR).

Practices that fewer growers are willing to incorporate are: pay for PCR analysis to find infected plants (68% in SR and 80% in CO), purchase certified plants (71% in SR and 88% in CO), and rotate pesticides (76% SR and 83% CO). The greater contrast between localities concerns the willingness to seek symptoms: only 68% in SR; meanwhile, 97% would do this in CO (Figure 3). Citrus growers' risk conception of the *D. citri* vector and the HLB may differ in the citrus-growing municipalities. Ríos and Murgida (2004) stated that risk perception in growers' groups grants sense to practices directed to face the risk. Also, for growers to adopt certain practices, they would implement these on few trees initially; after seeing results, they might decide whether to apply them to their parcel or not (Almaguer *et al.*, 2008). In SR, 89% and 98% in CO would take part in regional applications against *D. citri* (Figure 3), which would not be sufficient from an epidemiological viewpoint, as few untreated parcels would be a weak spot in the Campaign's effectiveness. Briones (2005) mentions that risk perception directly influences attitude and willingness to consider future adjustments in mitigation activities and efforts, the reason why some strategies may not be performed. Lack of inclusion and willingness to include some practices stated by CESVVER, such as using certified plants, visual diagnostics, and PCR, indicate that risk perception is lesser by SR growers than those from CO.

Dimensions that Integrate the Risk Index

The SR and CO municipalities did not show statistical differences in Risk Index (IR for SR = 27.92, CO = 26.92, P = 0.483) (Table 2); vulnerability showed a medium level, similar in both municipalities.

They might pass from a medium vulnerability level to a high one if both neglect activities performed so far. On the contrary, they may decrease their vulnerability by increasing their response to those training actions and activities they would be willing to perform to control HLB. Cutter *et al.* (2003) explain that the information of factors, such as technology and access to resources, may modify persons' vulnerability.

Table 2. Risk Index (IR) for HLB in San Rafael and Cotaxtla, Veracruz, Mexico.

Dimensions	Indexes, Mean ± SD	
	San Rafael n = 53	Cotaxtla n = 48
Grower knowledge about D. citri and HLB	5.1 ± 3.5	2.4 ± 3.4
Grower knowledge about CESVVER's actions	3.5 ± 2.4	4.6 ± 2.1
Actions that the grower performs inside his parcel	6.7 ± 0.6	7.4± 0.7
Actions that he would be willing to implement at his parcel	4.2 ± 1.8	4.9 ± 2.1
Perception of CESVVER by growers	7.0 ± 0.6	7.2 ± 0.7
Perception of actions performed at his parcel	8.2 ± 2.4	9.3 ± 1.1
Perception of actions that would be implemented at his parcel	7.4 ± 0.7	7.4± 0.6
IR =	27.9 ± 8.5	26.9 ± 6.4

Social Trust of Growers, Tool for Decreasing HLB Vulnerability

Most SR (97%) and CO growers

(92%) do not trust their leaders. Therefore, the Campaign decision-makers' actions should be oriented to the social groups' integration, social recognition, and growers' capacity to decrease their vulnerability to this disease. Leaders must be part of the solution. According to Díaz & Díaz (2002), when a leader can disclose risk, conflicts between general and local interests may be solved while generating a trust-generating atmosphere. For Cid *et al*. (2012), the degree of trust is related to an attitude and a state of personal world knowledge, more than an objective vision of the world. In SR and CO, IR, and therefore vulnerability, has an inverse correlation to trust in social actors ($r=-0.302$); *i.e*., if the trust is lost, grower vulnerability increases. Assessing growers' willingness to trust might foster their participation and organization (Yáñez *et al*., 2006). Therefore, generating trust and fostering collective and individual capacities through training and assessment is very needed. Agricultural institutions should conceptualize prevention with equity that allows leveling opportunities for different actors to decrease vulnerability.

Citrus Grower Involvement in Organizations and their Vulnerability to HLB

The degree of involvement in grower organizations was not different between localities ($P=0.154$). In SR, few respondents (15%) take part in grower associations, although 69% are willing to participate in an organization that allows them to set themselves free of the middleman, specifically to obtain pesticides at a better price, training, and advice for marketing. In CO, 52% of growers would be willing to participate in an organization, although 24% do not have any interest and the rest (24%) are already part of some grower association not exclusive for citrus growers. These traits show weakness in the organization of growers. Growers do not perceive HLB as a threat so significant that it compensates problems derived from organizations, as Gonnet (2011) stated about volunteer organizations. In any case, the lack of organizational involvement might prevent an appropriated individual and group response and increase their vulnerability condition to the HLB threat.

CONCLUSIONS

The Risk Index defined a medium vulnerability in San Rafael and Cotaxtla, Veracruz, Mexico, based on the knowledge and perception of the threat, the prevalence of protection actions, and capacities to overcome the issue by growers. Grower vulnerability increases when the degree of trust of social actors' decreases. The low involvement in grower organizations in both municipalities decreases their capacity to respond adequately to the HLB's presence. Their performance might be deficient upon implementing Campaign strategies against HLB and its vector, mainly in actions that demand their participation.

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