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12.1 Factors associated with control of huanglongbing in Sao Paulo, Brazil: a case study

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Huanglongbing (HLB) was first identified in the central region of São Paulo State, Brazil, in March 2004. However, the first infections occurred probably 6 to 8 years before. As of November 2008, HLB is present in 201 of the 425 citrus growing municipalities of São Paulo State. In April 2008, the total number of symptomatic trees was estimated to be 1.15 million (0.58%) and at least 3 million trees have already been eradicated. The recommended practices for HLB management are based on inoculum reduction by frequent removal of symptomatic trees (at least four times per year) and control of psyllid vector populations by insecticide treatments (at least six sprays per year). After four years of HLB management, several São Paulo state farmers have shared their results on HLB control. Here, we present the data from twenty citrus farms where the recommended practices have been applied to varying degrees since 2004.

The most important factors associated with the success or failure of HLB control in a given farm, are indicated in Table 1. They are: i) HLB incidence (% of symptomatic trees) in the municipality where the farm is located, ii) distance (meters) from neighboring farms without HLB control, iii) total number of trees, iv) average age of the trees, v) time period (months) during which HLB inspection/eradication has been carried out, vi) average number of insecticide treatments per year, vii) average number of inspections/eradications per year, and viii) cumulative HLB incidence (% of all symptomatic trees removed) during the first year of control, ix) cumulative HLB incidence (% of all symptomatic trees removed) through June 2008, and x) number of eradicated trees per month. In most farms (except 2, 3, and 4), HLB eradication was initiated just after detection of the first symptomatic trees in 2004 or 2005. In almost every farm, the citrus growers applied at least six insecticide treatments per year for vector control and three inspections per year for identification and elimination of HLB-symptomatic trees. In Fig. 1, the cumulative eradicated trees per year have been presented for farms 1, 5, 8, and 11. In farm 1, this number decreased steadily from 2005 to a very low value in June 2008, demonstrating very effective HLB control. In this farm, the success of HLB control could be explained by the following favorable factors: location of the farm in a region of low HLB incidence, absence of neighboring farms without HLB control, trees older than 6 years, early start of the HLB control program. Because of these favorable factors, only four inspections and six insecticide treatments per year were enough to achieve good control. In farm 5, the number of eradicated trees decreased from 2004 to a low level in 2006, also showing effective control. The favorable factors in farm 5 were: absence of neighboring farms without HLB control, trees older than 6 years, and early start of the HLB control program. However, this farm is located in a region of high HLB incidence, and therefore a great number of inspections (15) and insecticide treatments (12) per year were necessary to

significantly reduce the number of symptomatic trees each year. In farms 8 and 11, the number of eradicated trees increased yearly, indicating a poor control because of the following unfavorable factors: location of the farms in a region of high HLB incidence, and presence of neighboring farms without HLB control. In addition, in farm 8 the trees were only one-year-old in 2004, and irrigated, which resulted in continuous production of leaf flushes, attractive to psyllids from the adjacent neighboring farms without HLB control. In this farm, in spite of as many as 26 insecticide treatments and 7 inspections per year, the number of eradicated trees continued to increase, particularly in 2007 and 2008. In farm 11, in spite of the relatively old trees (12 years of age) and 9 insecticide treatments per year, a low number of inspections per year (3) probably explains the poor HLB control. Farm 14 (Table 1), another example of poor HLB control, is located in a region of high HLB incidence, and has neighboring farms without HLB control. Even though control of HLB started as early as 2005 for relatively old trees (20 years of age), only two insecticide treatments and three inspections per year explain the very poor HLB control achieved.

A multiple regression analysis (Table 2) was performed with the 10 factors presented in Table 1. The number of eradicated trees per month (Table 1, factor 10) was considered the dependent variable. The other 9 factors were considered as independent variables, except the cumulative HLB incidence (Table 1, factor 9). The analysis was carried out using Statistica software (Statsoft, Tulsa, OK).). The eight factors (Table 1, factors 1 to 8) considered as independent variables explain 95% of the variation in the regression analysis, indicating that most of the factors considered to be associated with HLB control were valid. The most important factors (Table 2) for HLB control were: cumulative HLB incidence during the first year of control (initial HLB incidence) (Table 1, factor 8), average age of the trees (Table 1, factor 4), time period (months) during which HLB inspection/eradication was carried (Table 1, factor 5), and size of the farms (total number of trees) (Table 1, factor 3). These factors are those considered most important in almost all of the 20 farms analyzed. The regression analysis indicated (i) HLB incidence in the municipality, (ii) distance from neighboring farms without HLB control, (iii) number of insecticide treatments per year, and (iv) number of inspections per year, as non-significant at the 5% level because these factors were only involved with the HLB epidemic in some of the farms. Nevertheless, these factors should be considered important for HLB control in all farms.

The data indicate that is possible to achieve control of HLB under various conditions in areas endemic with the more aggressive *Ca.* Liberibacter asiaticus. A careful evaluation of the 10 factors involved in HLB control (Table 1) provides an explaination in every case for why in a given farm HLB control is successful or not. Strong efforts such as frequent inspections for symptomatic trees with well-trained inspectors as well as insecticide treatments must be started as quickly and as early as possible after detection of the first symptomatic trees in the farm. Moreover, it is essential for successful HLB control that these practices be adopted by all the citrus farms in the region. Isolated efforts result in only partial and often unsatisfactory control. Therefore, a global program of HLB management by inoculum reduction through removal of symptomatic trees and vector control by insecticide treatments is necessary. In the particular case of São Paulo State, since 2005 a mandatory federal regulation requires the immediate removal of all HLB-infected citrus or *Murraya paniculata* (orange jasmin) trees. The non-compliance with this federal law is one of the main reasons for the widespread occurrence of HLB-infected farms without HLB control. A new federal law was approved in October 2008. The affected citrus blocks with HLB incidences higher than 28% of symptomatic trees must be completely uprooted. For lower incidence blocks, only the symptomatic trees must be removed. The results of the present study substantiate that this new legislation is absolutely necessary for effective control of

HLB in São Paulo State and hopefully will be more efficiently applied and enforced than the previous law!

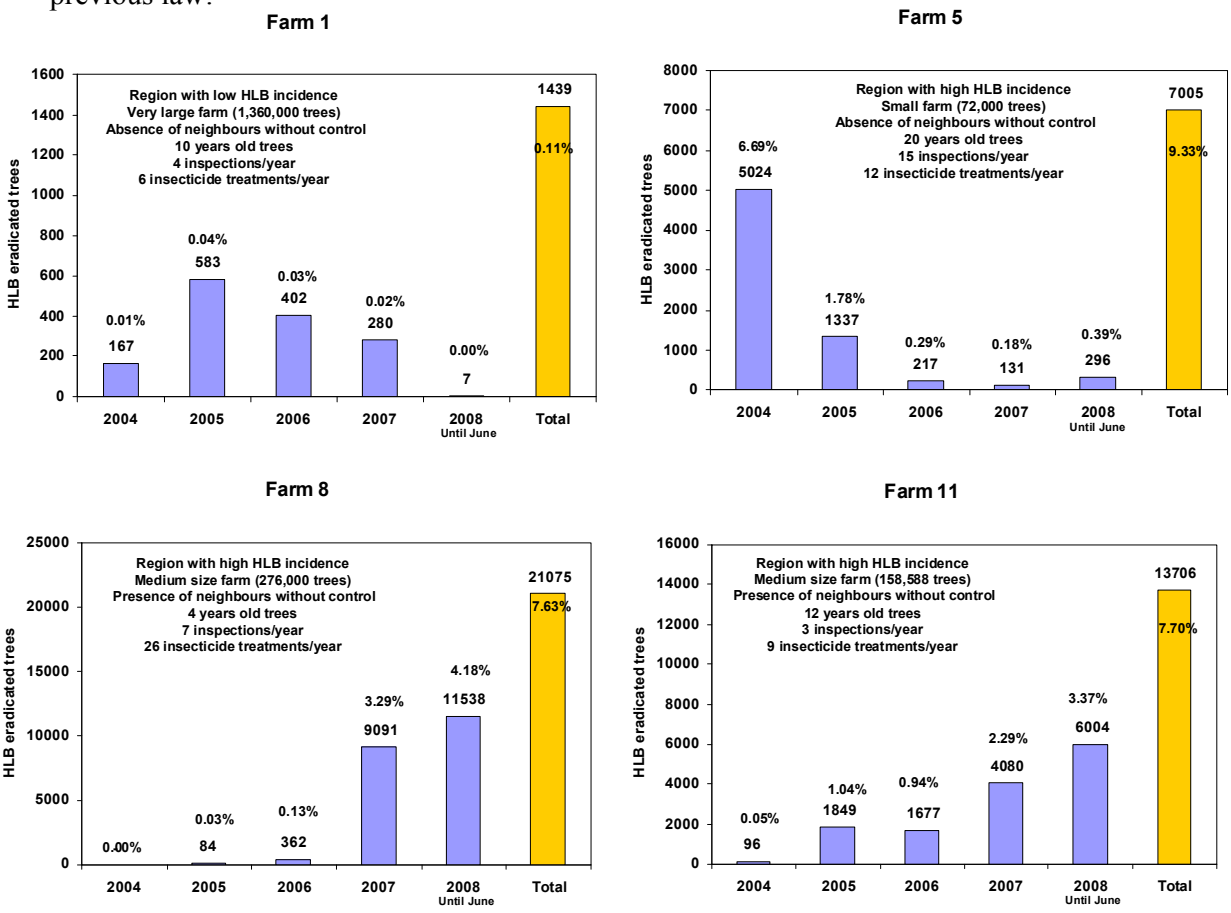

Fig. 1. Progress of HLB-eradicated trees in four of the farms studied.

Table 1. Factors associated with the HLB control in twenty citrus farms in São Paulo, Brazil.

Farm	Factors*									
	1	2	3	4	5	6	7	8	9	10
1	0.02	5,000	1,349,000	10	48	6	4	0.01	0.11	28.1
2	3.25	0	276,905	15	14	27	13	4.50	12.00	1483.4
3	3.16	0	265,391	14	14	27	12	17.60	37.30	3734.4
4	3.16	0	119,876	6	14	25	13	10.50	43.10	2791.4
5	1.29	2,000	72,000	20	50	12	15	6,69	9.33	38.0
6	0.04	2,000	231,000	15	50	8	9	0.00	0.40	18.5
7	0.02	5,000	360,000	4	50	18	6	0.00	0.03	2.2
8	3.16	0	276,000	4	50	26	7	0.00	7.63	421.2
9	4.18	4,000	260,255	6	50	13	4	0.03	2.90	149.4
10	5.11	0	233,255	12	48	9	3	0.02	2.47	119.5
11	5.11	0	158,588	12	49	9	3	0.05	7.70	247.6
12	5.11	0	241,232	12	48	9	3	0.04	5.79	289.1
13	2.03	2,000	522,612	12	47	9	2	0.04	0.35	35.1
14	5.11	0	162,532	20	41	2	3	6.69	24.59	709.6
15	5.05	0	165,069	5	48	9	25	0.10	6.81	230.8
16	4.18	2,000	284,784	7	50	7	24	0.68	4.20	200.4
17	2.84	0	3,008,000	10	50	17	3	0.15	1.60	872.3
18	4.18	2,000	670,000	14	20	32	19	2.11	3.86	586.3
19	3.47	2,000	481,000	15	50	8	26	0.13	3.53	326.6
20	0.40	1,000	74,000	8	48	5	21	0.03	2.43	37.0

* 1) HLB incidence (% of symptomatic trees) in the municipality where the farm is located, 2) distance (meters) from neighboring farms without HLB control, 3) total number of trees, 4) average age of the trees, 5) time period (months) during which HLB inspection/eradication has been carried out, 6) average number of insecticide treatments per year, 7) average number of inspections/eradications per year, 8) cumulative HLB incidence (% of all symptomatic trees removed) during the first year of control, 9) cumulative HLB incidence (% of all symptomatic trees removed) through June 2008, and 10) the calculated number of eradicated trees per month [(cumulative number of HLB eradicated trees through June 2008 – cumulative number of eradicated trees in the first year of control)/time period during which HLB inspection/eradication has been carried out]

Table 2. Multiple regression analysis considering the calculated number of HLB trees eradicated/month as dependent variable and the other factors presented in Table 1 as independent variables.

Independent variables	Estimated parameter	*P**
Cumulative HLB incidence in first year	0.719536	0.00002
Average tree age	–0.259314	0.00547
Time period of eradication adoption	–0.362555	0.02230
Total number of trees	0.173138	0.03180
Distance from neighboring farms without HLB control	–0.150839	0.10546
Number of insecticide treatments/year	–0.051635	0.64594
Number of inspections/year	–0.026020	0.70930
HLB incidence in the municipality	0.011162	0.89455

Calculated F value=28.8 and R^2=0.95

* probability level