The whitefly *Trialeurodes vaporariorum* as a potential constraint to the development of sustainable cropping systems in the mesothermic valleys of the Bolivian highlands

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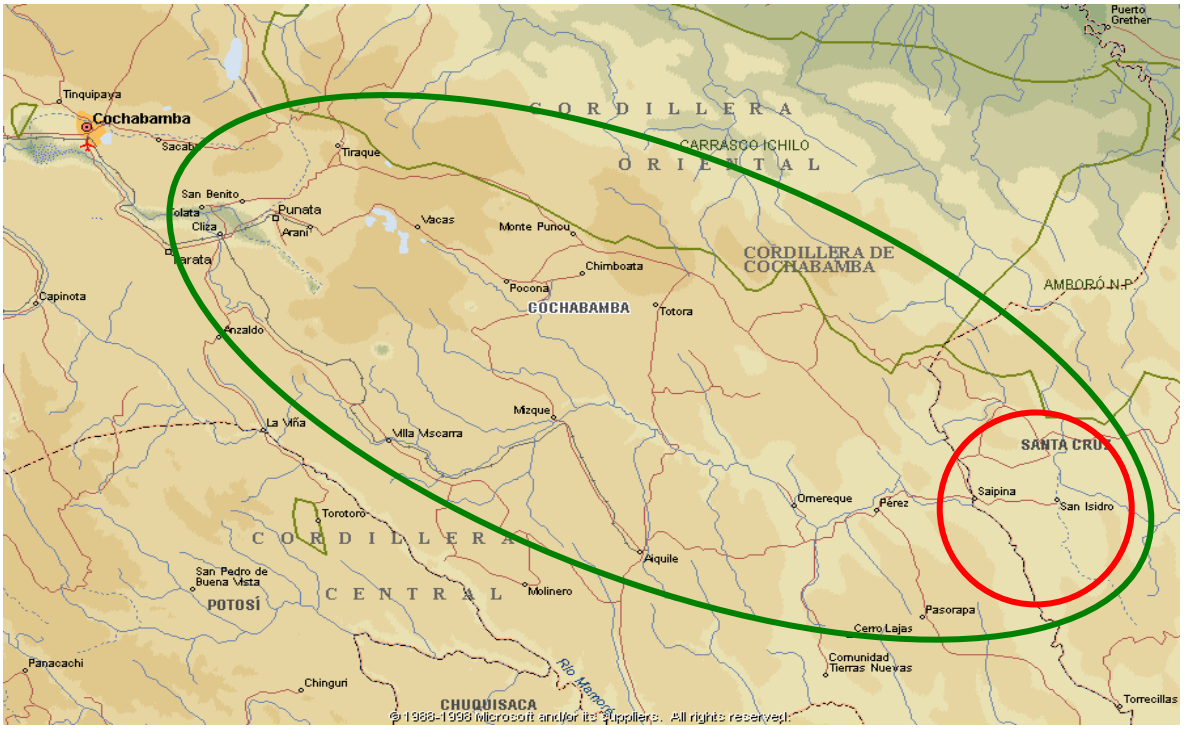
Trialeurodes vaporariorum (Westwood), is the main whitefly pest of several crops grown in the highland tropics at altitudes above 1000 meters above sea level. This whitefly species reproduces abundantly on many hosts and feeds on important food crops, such as potato, tomato and common bean, causing significant direct (sap extraction) and indirect damage (whiteflies excrete honeydew which promotes abundant fungal growth that reduces the photosynthetic capacity of affected plants). Yield losses due to the feeding of *T. vaporariorum* on susceptible hosts may be total. Consequently, farmers eventually become dependent on frequent insecticide applications to manage this problem. Due to the economic importance of this insect pest and environmental implications of pesticide abuse in whitefly-affected agricultural regions, the Tropical Whitefly IPM Project (TWFP) has been studying and managing the *T. vaporariorum* whitefly problem in pilot sites located in the highlands of Colombia and Ecuador since 1996. The Andean whitefly sub-project has concentrated its efforts on the education of farmers with a view to reducing pesticide applications and adopting sustainable IPM practices.

In 1999, whitefly populations began to increase above normal levels in the meso-thermic valleys of the departments of Cochabamba and Santa Cruz. The whitefly has since become a threat to crop production in these valleys, affecting crops such as potato, tomato, common bean and some cucurbits. As expected, farmers have been resorting to insecticides to control the problem, thus, increasing production costs and health risks for producers and consumers alike. Different Bolivian institutions have contacted the TWFP seeking assistance to manage this pest. Since 1999 the CPP has supported different projects in Bolivia. During the implementation of the MIP Valleys Project (R7462) whiteflies were identified as a major pest of potato and tomato in the mesothermic valleys. In July, 2003, the General Manager of PROIMPA (Promotion and Research of Andean Products), Dr. Antonio Gandarillas, with the technical support of M.Sc. Oscar Barea, Coordinator Integrated Crop Management, took the initiative to organize a visit of some of the most affected mesothermic valleys in the departments of Cochabamba and Santa Cruz . The region visited can be observed in the maps attached. Map 2 shows the actual area surveyed (green).

Results

There was a clear gradient in the incidence of whiteflies from Cochabamba to Santa Cruz, apparently associated with an altitude/temperature gradient from 2000 to 1500 meters above sea level. As the altitude decreased and the temperature increased, the whitefly populations increased significantly. However, according to the PROIMPA colleagues and farmers interviewed, whitefly populations are noticeably higher in August/September as the mean temperature increases and most crops in the region emerge.

Map 1. Area containing mesothermic valleys affected by whiteflies in Bolivia



Map 2. Area surveyed in the departments of Cochabamba and Santa Cruz, Bolivia

The main crops colonized by whiteflies were potato (Figure 1), common bean (Figure 2) and tomato (Figure 3). Pepper plantings were found in the area but this crop did not seem to be a good host for the whitefly species observed on the other crops mentioned above. Some sweet pepper plantings near the locality of Saipina, were severely affected by an apparent viral disease (Figure 4) and the plants were colonized by aphids. The most affected localities visited were San Rafael, Pulquina Abajo and San Isidro (red circle in Map 2). In these localities, whitefly populations were large enough to cause sooty mold problems in potato and common bean plantings. This problem is caused by the colonization of plants by sap sucking insects, such as whiteflies, which excrete abundant honeydew that promotes the growth of a fungus (mostly *Capnodium* sp.) that produces a dark mycelium which covers the leaves and other photosynthetic plant organs, eventually resulting in plant death (Figure 5). Whiteflies were also abundant on weeds (Figure 6) and other horticultural crops, such as sweet pea (Figure 7) and cucurbits.

Figure 1. Whitefly infestation on potato in the mesothermic valleys of Bolivia.

The crops colonized by whiteflies did not show symptoms of virus infection, except in few cases were plants had been infected from the seed (as in the case of potato), or by other insect vectors (some tomato plantings were affected by disorders probably caused by phytoplasmas). This observation, the morphological characteristics of the immature stages, and the altitude of the valleys, suggest that the predominant whitefly species observed in these mesothermic valleys is not *Bemisia tabaci* but rather *Trialeurodes vaporariorum*. To confirm this hypothesis, adult and immature individuals of the whitefly observed were processed using a RAPD technique (Figure 8). The results obtained confirmed the identity of the whitefly pest present in the survey area as *Trialeurodes vaporarriorum*. This whitefly species generally predominates at altitudes above 1,000 meters and it does not transmit the highly pathogenic viruses associated with the whitefly *Bemisia tabaci*, which predominates in the tropical lowlands and mid-altitude (up to 900 m) valleys of the world.

Figure 2. Bean leaf showing adult and immature whiteflies and resulting damage.

Figure 3. Tomato leaf showing adult and immature whiteflies.

Figure 4. Sweet pepper plants showing symptoms of viral infection

Figure 5. Bean plants severely affected by whiteflies and sooty mold.

Figure 6. Whiteflies on weed

Figure 7. Whiteflies on sweet pea plant

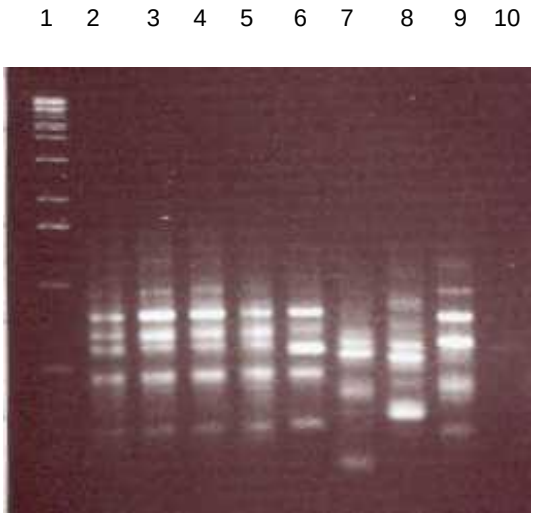


Figure 8. Agarose gel (1.5 %) showing amplification of bands with primer RAPD H9. 1- Marker: 1Kb; 2- 5: Bolivian whitefly samples; 6: control for *Trialeurodes vaporariorum;* 7: Control for *Trialeurodes variabilis;* 8: Control for *Bemisia tabaci* biotype A; 9: Control for *Bemisia tabaci* biotype B; and 10: Buffer control.

Table 1 shows the results of the samples collected from different sites and plant species following serological tests using monoclonal antibodies that detect geminiviruses transmitted by the whitefly *Bemisia tabaci* or potyviruses transmitted by aphids. As mentioned earlier, none of the samples reacted with the geminivirus-specific monoclonal antibody, as expected in the absence of *B. tabaci*. The potyviruses detected in pepper and in one tomato plant are transmitted by aphids, and are very common in Latin America, where most commercial pepper varieties do not possess resistance to these viruses.

Conclusions

Even though this survey was undertaken during the winter period of the year, when whitefly populations are not at their peak, and most of the agricultural land was being prepared for the next planting, the whitefly problem was quite evident. The survey allowed us to determine that the main whitefly pest in the mesothermic valleys visited was *Trialeurodes vaporariorum*. This observation agrees with previous findings made throughout the Andean region for agricultural regions above 1000 meter above sea level, including some exploratory work carried out in Bolivia in past years by the TWFP and PROPIMPA. *T. vaporariorum* can cause major yield and quality losses in different food and industrial crops. Common bean and potatoes were the two most affected crops observed at this early stage of the planting season. Tomatoes were also significantly colonized, but we did not observe sooty mold or any other whitefly-related problems on this crop, as it was the case for both common bean and potato in some of the fields visited. Peppers (*Capsicum* spp.) do not seem to be affected by whiteflies in these valleys, but aphids and aphid-borne viruses were shown to be a threat to pepper production. Tomato varieties in the valleys visited, seem to be severely affected by a phytoplasma-like pathogen most likely transmitted by a sap-sucking insect (Homoptera).

Work is in progress to characterize the causal agents of the 'purple leaf' syndrome observed in tomato, as well as the potyviruses detected in pepper and one tomato plant.

All farmers interviewed clearly identify the whitefly as a major pest, and, consequently, try to control it by means of frequent pesticide applications. We encountered pesticide applicators wherever we went (Figure 9). Thus, pesticide abuse is widespread in these valleys.

Table 1. Serological results of samples collected in Bolivia

Mtra.	Crop	Locality	Resultados de Laboratorio			
			ELISA			
			Geminivirus		Potyvirus	
			Atc. m. 4C1-3F7		Agdia	
			Absorbencia*	Reacción	Absorbencia*	Reacción
1	Tomato	Pulquina Abajo - Pta. Morada (A)	0.0105	(-)	0.0410	(-)
2	Tomato	Pulquina Abajo - Pta. Morada (B)	0.0120	(-)	0.0190	(-)
3	Tomato	Aiquile Ilicuni - Pta. Morada	0.0060	(-)	0.0380	(-)
4	Tomato	Aiquile Ilicuni - Pta. Morada 2>QT	0.0065	(-)	0.0295	(-)
5	Tomato	Aiquile Ilicuni - Pta. Morada	0.0100	(-)	0.0260	(-)
6	Bean	San Isidro - 1	0.0035	(-)	0.0325	(-)
7	Bean	San Isidro - 2	0.0060	(-)	0.0210	(-)
8	Bean	San Isidro - 3	0.0055	(-)	0.0300	(-)
9	Pepper	San Isidro	0.0050	(-)	**1.8615**	**(+)**
10	Pepper	San Rafael - 1 Poty?	0.0055	(-)	**2.6810**	**(+)**
11	Pepper	San Rafael - 2 Poty?	0.0065	(-)	**2.8620**	**(+)**
12	Pepper	San Rafael Poty? - Distorsión	0.0035	(-)	**2.6455**	**(+)**
13	Tomato	Saipina - San Rafael	0.0070	(-)	**1.3280**	**(+)**
Control Negativo			0.0050	(-)	0.0150	(-)
Control Positivo			0.9485	(+)	0.7740	(+)

* Promedio de dos lecturas de Absorbencia a 405 nm después de 60 minutos de reacción.

However, it was apparent that the insecticides were only killing some of the active adults, particularly those found on the top surface of the leaves (Figure 10), but not those feeding on the underside of leaves, their immature forms or eggs, as observed directly on plants recently sprayed. Farmers were very much aware of the inefficiency of all the insecticides used to date, and all of them wished they could find a better product. Interestingly, whereas the new generation of insecticides (neonicotinoids) available to control whiteflies is already used by both large- and small-scale farmers in Central America, they are not popular in this region of Bolivia.

Figure 9. Pesticide applicators in potato (top) and tomato (bottom) fields

The neonicotinoids include chemistries such as Imidacloprid (Gaucho and Confidor are the commercial names for seed and foliage treatment, respectively) and Thiamethoxam (Cruiser and Actara are the commercial names for seed and foliage treatment, respectively), and they have proved very effective in IPM programs. The only drawback is their higher cost.

Figure 10. Whitefly adults killed by insecticides on the surface of potato leaves.

Recommendations

As mentioned before, most farmers visited were aware of the futility of applying the various insecticides available to them so far. I assured them that they were wasting their money using these products, and that they could achieve the same level of adult whitefly control using mild soaps diluted in water. It is necessary to demonstrate the use of soaps to control whiteflies in this region. Preferably, soaps should be biodegradable and devoid of phytotoxicity at the dosages recommended. A reduction in the use and abuse in pesticides in these agricultural valleys, should contribute to a gradual reduction in whitefly populations. At this time, it is necessary to determine the levels of insecticide resistance in the *T. vaporariorum* population, to exclude those insecticides that are no longer effective, even if they are being used against other insect pests. In areas where the whitefly populations are out of control, tests with the neonicotinoids should be initiated to demonstrate their effectiveness with usually only one or two applications and much better safety properties. A seed treatment or early application of a neonicotinoid and subsequent application of diluted soaps should maintain whitefly populations below the economic damage threshold for the time being. These treatments should lead to a recovery of the local biocontrol agents in the short term.

It is apparent that the whitefly problem in the mesothermic valleys visited is one of a pest that reaches high population densities due to several possible factors, such as a favorable environment with periods of low precipitation and tolerable/suitable temperatures; diversification of crops (more suitable hosts); and pesticide abuse (elimination of biocontrol agents, mainly predators). Fortunately, no whitefly-borne viruses were detected during this visit. These findings indicate that the IPM measures developed and implemented by the Andean subproject of the Tropical Whitefly Project should be effective for the mesothermic valleys of Bolivia. It is urgent to take immediate action against the whitefly problem in this region of Bolivia to avoid the collapse of the current efforts to diversify the cropping systems in these valleys with a view to maximizing the profitability of the traditional small-holdings of thousands of resource-poor farmers. To this end, it is also necessary to disseminate the information available for the integrated control of whitefly pests, particularly *Trialeurodes vaporariorum*, in different ways, such as radio broadcasts and graphic material, both in Quechua and Spanish. A Farmer Participatory approach would be appropriate for this task, with the proper technical assistance from knowledgeable plant protection professionals working together with sociologists of any other FPR specialists. I understand that Farmer Field Schools have already been implemented in some of these valleys in the past.

The whitefly problem was more evident as we descended onto the lower mesothermic valleys below 1500 m, already in the department of Santa Cruz. It is possible that further down, towards the lowlands of Santa Cruz, the whitefly species *Bemisia tabaci*, the main whitefly pest and vector of numerous plant viruses, begins to predominate. The TWFP already has evidence that this whitefly species exists at altitudes up to 1200 m in the department of Santa Cruz, and that it transmits viruses such as *Bean golden mosaic virus* in common bean plantings located in these mid- to low-altitude regions. Fortunately, the TWFP has virus-resistant common bean lines suitable for these conditions, and this whitefly species is not expected to become a problem in the mesothermic valleys surveyed on this trip.

In conclusion, the whitefly problem in the mesothermic valleys of the departments of Cochabamba and Santa Cruz is indeed a serious one in need of prompt attention. In fact, the magnitude of the problem is similar if not worse than the *Trialeurodes* outbreaks in the Colombian and Ecuadorian highlands. However, the management of this pest is simpler than in the case of *Bemisia*, and has a high return for any modest funds invested, in a relatively short period of time. Finally, the TWFP already has developed a suitable IPM package to manage this pest, and PROIMPA has highly motivated and qualified staff to implement this methodology in Bolivia.

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Technical report presented by

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