Chapter 4.4

Conclusions and Recommendations

*César Cardona**, *Aristóbulo López-Avila*** and *Oswaldo Valarezo****

When the Systemwide Program on Integrated Pest Management (SP-IPM) launched its project for "Sustainable integrated management of whiteflies as pests and vectors of plant viruses in the tropics" (The Tropical Whitefly IPM Project, TWF-IPM), the nature of whitefly problems in the high Andes of Colombia and Ecuador was poorly understood. Anecdotal reports and fragmentary scientific studies, mostly published only in the "grey" literature, suggested that whitefly problems were severe and insecticide misuse widespread in this socially and economically important horticultural area (Chapter 4.1, this volume). The seriousness of the reported situation led partners in the project planning process to establish a sub-project specifically to look at "Whiteflies as pests of annual crops in the highlands of Latin America". However, at the outset of the project, the species of whiteflies responsible for the problems was uncertain and the role of insecticides and insecticide-resistance in aggravating whitefly-related problems was unclear. The first phase of this project provided, for the first time, an opportunity to survey systematically the main crop production areas of this ecologically complex region and characterize their whitefly problems, both from a biological point of view and in terms of farmers' perceptions of these problems.

Scientists and technicians of the participating national research organizations, the Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP) in Ecuador and the Corporación Colombiana de Investigación Agropecuaria (CORPOICA) in Colombia, conducted field surveys and farmer interviews between October 1997 and December 1998, in close collaboration with their counterparts from the project's coordinating organization, the Centro Internacional de Agricultura Tropical (CIAT) (Chapter 4.2, this volume). Researchers at CIAT continued until May 1999 to complete parallel studies of insecticide resistance in whiteflies from selected sites within the study area (Chapter 4.3, this volume).

The results of these studies (Chapters 4.2 and 4.3, this volume) provide a unique description of whitefly problems in Andean agriculture, which is not only of inherent scientific value but also will now serve as a sound foundation for action to address the very considerable agricultural production, human health and

* Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.
** Corporación Colombiana de Investigación Agropecuaria (CORPOICA), Bogotá, Colombia.
*** Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), Manabí, Ecuador.

environmental problems that the study revealed. Integrated pest management approaches are likely to play a key role in tackling these problems, both within the framework of future phases of the current project and beyond. Key lessons learned in this study and proposals for further action are discussed here and in the final chapter on Conclusions (this volume).

Conclusions

Whitefly identification and host crop importance

The greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) is the most important whitefly species in highland and mid-altitude areas of Colombia and Ecuador. Although it affects numerous horticultural crops and ornamentals, *T. vaporariorum* is most important as a pest of common bean (*Phaseolus vulgaris* L.) and tomato (*Lycopersicon esculentum* Mill.). This confirms previous work (Cardona, 1995; Corredor et al., 1999) on the increasing importance of *T. vaporariorum* as a major pest in the highlands of the Andes. However, it is now recognized that whitefly problems in the area are more widespread than initially thought.

Altitudinal distribution

The results of extensive surveys showed that *T. vaporariorum* occurs in mid-altitude and highland areas ranging from 700 to 2800 m above sea level and that *Bemisia tabaci* (Gennadius), the tobacco whitefly, ranges from sea level to 900 m above sea level. Thus, these two species overlap in many of the mid-altitude valleys. This is important because proper identification of whitefly species is a critical step in the formulation of research strategies. If, for example, *B. tabaci* is erroneously assumed to be the main pest species in mid-altitude valleys or highland areas, then IPM programs will be ill targeted and may not be effective.

Farmer perceptions

Whiteflies, in this case *T. vaporariorum*, were considered to be the key pest in common bean at 50% of the sites visited and the key pest in 45% of the tomato farms that were surveyed. A significant proportion of farmers think that whiteflies can reduce yields by 50% or more. This perception may well be justified. Previous studies (Cardona et al., 1993; Cardona, 1995) and work conducted in the first phase of the TWF-IPM Project showed that *T. vaporariorum* may cause losses ranging from 23% to 54% of the potential yield in snap bean (also *Phaseolus vulgaris* L.). There is no doubt that whiteflies have a high damage potential and that farmers are correct in believing that whitefly attacks have created numerous problems and have become a major constraint to agricultural production in the region.

Insecticide use

Whiteflies in Colombia and Ecuador have become the target of intensive, in most cases excessive, use of insecticides. This in turn has resulted in the destruction of natural enemies and the creation of new secondary pest problems such as the leafminer *Liriomyza huidobrensis* (Blanchard) and pod borers such as *Epinotia aporema* (Walsingham) on common bean and the *Neoleucinodes elegantalis* (Gueneé) on tomato. As shown in the previous chapter, excessive insecticide use has resulted also in the development of high levels of resistance of whiteflies to conventional insecticides. Some farmers are now using costly novel insecticides that may become useless in a few years because of insecticide resistance. Knowledge on insecticide use patterns and insecticide resistance levels obtained in this first, diagnostic, phase of the TWF-IPM Project will be important in the formulation of insecticide resistance management strategies and in the development of IPM options aimed at reducing pesticide use.

Insecticide resistance

In highland and mid-altitude areas of Colombia and Ecuador, *T. vaporariorum* showed high resistance to methamidophos (an organophosphate), intermediate resistance to cypermethrin (a pyrethroid) and low resistance to methomyl (a carbamate), three test products chosen as exemplifying the major groups of conventional insecticides currently in use. In general, resistance levels seem to be related to intensity of insecticide use. Responses of *T. vaporariorum* to carbofuran and imidacloprid were determined, to provide a baseline for future monitoring of resistance against these products, both of which are in widespread use. The B biotype of *B. tabaci*, recently introduced into Colombia, showed high levels of resistance to methomyl and methamidophos and, in some places, moderate levels of resistance to cypermethrin.

Development of resistance to representative conventional insecticides was higher than those reported in a previous study (Buitrago et al., 1994). The diagnostic survey showed that insecticide resistance is widespread, affecting common bean and tomato growers alike. These are important findings that help explain why conventional insecticides are no longer effective and why farmers are now using excessive numbers of applications of conventional pesticides and new generation pesticides that are costly. In the long-term, the need to use more expensive insecticides may threaten the economic viability of common bean and tomato production in mid-altitude and highland areas where small-scale, usually poor, farmers predominate.

Recommendations

There is an urgent need to develop and implement IPM systems that will help re-establish the ecological equilibrium. Experience in the Sumapaz region of Colombia has shown that this is feasible: implementation of a relatively simple IPM package based on cultural control and sanitation practices, timely application of effective insecticides and reliance on natural control in certain areas resulted in a 66% reduction in insecticide use (Cardona, 1995). Although the system was economically and technically viable, adoption rates varied with geographical area within the region and were not as high as researchers expected. A main obstacle encountered was the high level of risk aversion (as defined by Tisdell, 1986) among small-scale farmers. However, overall adoption rates of 30%-35% were regarded as high by social scientists linked to the project (Nohra Ruiz de Londoño [CIAT Impact Unit], personal communication, 1996) and suggest that careful planning, active participation of farmers in decision making, and participatory research approaches may help overcome barriers to adoption.

Several promising IPM tactics have been identified (Cardona, 1995; CIAT, 2000). These include the replacement of broad-spectrum insecticides with more selective ones, and the timing of applications according to pre-established action thresholds. In addition, cultural control measures such as the incorporation of crop residues, leaf roguing and manipulation of planting dates may be effective in some circumstances. Advances have been made also in the evaluation of the parasitoid *Amitus fuscipennis* MacGown and Nebeker (Manzano et al., 2000) and the entomopathogen *Verticillium lecanii* (Zimm.) (González and López-Avila, 1997) but more work needs to be done in order to measure the effectiveness of these and other natural enemies. These preliminary efforts to develop and test IPM strategies locally, coupled with findings from the diagnostic phase of the TWF-IPM Project, can be used as a basis for developing more widely applicable IPM strategies. The overall results of these efforts should be the development of systems that will: (1) reduce levels of pesticide used by common bean farmers; (2) reduce health risks to farmers and consumers; and (3) re-establish the ecological equilibrium in areas that have been disturbed by excessive pesticide use.

The immediate objective of any future IPM initiative should be to reduce pesticide use. Farmers currently depend so heavily on chemical pesticides, and environmental disruption is of such magnitude, that for the foreseeable future it is most unlikely that any IPM system could be effective without a chemical component. In the longer term, as more farmers adopt IPM approaches and environmental equilibrium is re-established, more ambitious, pesticide-free, strategies might become feasible; however, for the moment at least, monitoring of resistance should continue and sound strategies to manage insecticide resistance will have to be developed. Testing of new chemicals that are effective but less detrimental to the environment will also be important.

Based on the diagnostic phase survey work, IPM pilot studies should be continued in the following hot spots: Sumapaz, Oriente Antioqueño, Tenerife, Pradera and Nariño in Colombia, and in the Chota valley in northern Ecuador. However, problems associated with *T. vaporariorum* extend far beyond the Colombian and Ecuadorian highlands and common bean. This whitefly also has been reported as a significant field pest affecting melon (*Cucumis melo* L.) and tomato in Mexico (Flores et al., 1995), tomato in Costa Rica (Alpizar, 1993), tomato and common bean in the Dominican Republic (FUNDESA, 1996), as well as tomato, common bean and snap bean in Venezuela (Arnal et al., 1993), Ecuador (Mendoza, 1996), Colombia (Cardona, 1995), Bolivia (CIAT, unpublished records), Brazil (Gerk et al., 1995), Peru (Núñez 1995) and Argentina (L'Argentier et al., 1996; Giganti et al., 1997). *T. vaporariorum* is also a major pest in greenhouses in Colombia (Corredor et al., 1999) and Argentina (Viscarret and Botto, 1996; Salas et al., 1999). The benefit of developing effective IPM approaches for *T. vaporariorum* is therefore likely to be felt beyond the highlands of Colombia and Ecuador.

In order to overcome existing barriers to adoption (Cardona, 1995), IPM components should be tested with local communities using participatory research methods (Ashby, 1990). A possible approach that already has shown promise in Latin America (Brown and Hocdé, 2000) is to involve Comités de Investigación Agrícola Local (CIALs) in the testing (and, in some cases, validation) of individual IPM components and of promising IPM strategies. If major changes in existing practices are found to be necessary such as the general adoption of particular cropping dates or crop rotations, then the implementation of IPM will have to be discussed with local communities and government. The success of IPM approaches will depend ultimately on establishing consensus among IPM stakeholders. Given farmers' attitudes to chemical pesticides and their current reliance on these products as the sole method of addressing whitefly problems, farmer education (Whitaker, 1993) will be most important; however, if a major shift towards IPM approaches is to be achieved, advocacy efforts directed at consumers and the various stakeholders involved in agricultural production and processing is likely to be necessary as well.

Whitefly problems in the Andean highlands are evidently serious, extensive and deep-rooted, so immediate success cannot be anticipated. However, a phased approach, as conceived within the framework of the TWF-IPM Project, promises tremendous benefits to producers, consumers and the environment. The necessary investment in research, education and policy change should therefore be undertaken without delay.

References

Alpizar, M. D. 1993. Aspectos básicos sobre las moscas blancas con énfasis en *Bemisia tabaci* y *Trialeurodes vaporariorum*. Bol. Divulgativo no. 112, Ministerio de Agricultura y Ganadería, San José, CR. 22 p.

Arnal, E.; Russell, L. M.; Debrot, E.; Ramos, F.; Cermeli, M.; Marcano, R.; Montagne A. 1993. Lista de moscas blancas (Homoptera: Aleyrodidae) y sus plantas hospederas en Venezuela. Fla. Entomol. 76(2):365-381.

Ashby, J. A. 1990. Evaluating technology with farmers. A handbook. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 95 p.

Brown, A. R.; Hocdé, H. 2000. Farmer participatory research in Latin America: Four cases. *In*: Working with farmers: The key to adoption of forage technologies. Procs. International Workshop, 12-15 October 1999, Cagayan de Oro City, Mindanao, PH. Australian Centre for International Agricultural Research (ACIAR), Canberra, AU. p. 32-53.

Buitrago, N. A.; Cardona, C.; Acosta, A. 1994. Niveles de resistencia a insecticidas en *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae), plaga del fríjol común. Rev. Colomb. Entomol. 20(2):109-114.

Cardona, C. 1995. Manejo de *Trialeurodes vaporariorum* (Westwood) en frijol en la zona Andina: Aspectos técnicos, actitudes del agricultor y transferencia de tecnología. Memoria IV Taller Latinoamericano sobre moscas blancas y geminivirus, 16-18 octubre 1995, Zamorano, HN. CEIBA 36(1):53-64.

Cardona, C.; Rodríguez, A.; Prada, P. C. 1993. Umbral de acción para el control de la mosca blanca de los invernaderos, *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae), en habichuela. Rev. Colomb. Entomol. 19(1):27-33.

CIAT (Centro Internacional de Agricultura Tropical). 2000. Annual report, Project IP-1. Bean Improvement for Sustainable Productivity, Input Use Efficiency, and Poverty Alleviation. Cali, CO. p. 143-147.

Corredor, D.; Fischer, G.; Angarita, A. 1999. Integrated pest management in cut flower crops grown in plastic houses at the Bogotá Plateau. Procs. Int. Symp. on cut flowers in the tropics, 14-17 October 1997, Bogotá, CO. Acta Horticulturae 482:241-246.

Flores, A.; González, M. C.; Alarcón, A.; Ferrera R. 1995. Bioproducción de melón en campo. Rev. Chapingo Serie Hortic. 1(4):83-88.

FUNDESA (Fundación para el Desarrollo Agropecuario, Santo Domingo). 1996. Proyecto de evaluación de variedades e híbridos de tomate por tolerancia a geminivirosis transmitida por moscas blancas. Boletín FDA no. 9:2, 8. Santo Domingo, DO.

Gerk, A. O.; Vilela, E. F.; Pires, C. S.; Eiras, A. E. 1995. Biometría e ciclo de vida da mosca branca, *Trialeurodes vaporariorum* (Westwood) e aspectos da orientacao de seu parasitoide Encarsia formosa Gahan. An. Soc. Entomol. Bras. 24(1):167-171.

Giganti, H.; Dapoto, G.; González, J. R.; Junyent, R. 1997. Insectos y ácaros asociados a los principales cultivos hortícolas del Alto Valle del Río Negro y Neuquén, Argentina. Hortic. Argentina 16:40-41.

González, J. G.; López-Avila, A. 1997. Evaluación de cepas nativas de *Verticillium lecanii* (Zimm.) en el control de la mosca blanca de los invernaderos *Trialeurodes vaporariorum* (Westwood). Rev. Colomb. Entomol. 23(1-2):25-30.

L'Argentier, S. M.; de Manero, E. A.; Liacono A. 1996. Especies de Aleyrodidae (Homoptera) presentes en poroto (*Phaseolus vulgaris* L.) y en las malezas asociadas al cultivo en las provincias de Jujuy y Salta, República Argentina. Rev. Investig. Centro de Investigaciones para la Regulación de Poblaciones de Organismos Vivos 10:1-4.

Manzano, M. R.; van Lenteren, J. C.; Cardona, C.; Drost, Y. C. 2000. Developmental time, sex ratio, and longevity of *Amitus fuscipennis* MacGown and Nebeker (Hymenoptera: Platygasteridae) on the greenhouse whitefly. Biol. Control 18(2):94-100.

Mendoza, J. 1996. Qué está pasando con la mosca blanca en el Ecuador? Rev. INIAP 8: 8-10.

Núñez, E. Y. 1995. Reporte de Perú. Memoria IV Taller Latinoamericano sobre moscas blancas y geminivirus, 16-18 octubre 1995, Zamorano, HN. CEIBA 36(1): 157-162.

Salas, H.; Fernández, M.; Willink, E. 1999. La mosca blanca de los invernáculos en cultivos hortícolas de Tucumán. Avance Agroind. (Argentina) 19:39-41.

Tisdell, C. 1986. Levels of pest control and uncertainty of benefits. Aust. J. Agric. Econ. 30:157-161.

Viscarret, M. M.; Botto, E. N. 1996. Descripción e identificación de *Trialeurodes vaporariorum* (Westwood) y *Bemisia tabaci* (Gennadius) (Hemiptera, Homoptera: Aleyrodidae). Rev. Chil. Ent. 23:51-58.

Whitaker, M .J. 1993. The challenge of pesticide education and training for tropical smallholders. Int. J. Pest Manag. 39(2):117-125.