**Table 8. Results of physical barriers against whitefly-transmitted viruses in tomato rows protected 30 and/or 60 days without and with chemical protection.**

| Treatment 1 | Treatment 2 | Incidence 30 days | Incidence 60 days | Severity 60 days | Yield TM/Ha |
|---|---|---|---|---|---|
| Without insecticides | Uncovered | 100% | 100% | 5 | 0 C |
| | Covered 30 days | 0% | 100% | 3 | 12.8 B |
| | Covered 60 days | 3% | 6% | 2 | 60.0 A |
| With insecticides | Uncovered 30 days | 100% | 100% | 4 | 15.0 B |
| | Covered 30 days | 0% | 30% | 2 | 55.0 A |

Due to the promising results obtained, five demonstration plots were established in the irrigation district of Zapotitán **(Tables 8A-C.)**. Due to the high cost of establishing the plots, only one plot was established with each of five different farmers. Each plot was formed by three rows of tomato plants and other three rows of pepper plants sown in 1 m wide/20 m long beds, 1.20 m apart from their centre point. The distance between plants was 50 cm, for a final density of 16,600 plants per hectare. One row of both tomato and pepper plants was cover with a polypropilene net (Agryl), one with a more expensive but resistant net (tricot), and one row was left uncovered as control. The pepper variety was 'Nathalie' and the tomato variety chosen was 'Sheriff'. The seedlings were raised under screenhouse conditions to avoid early virus infection (first IPM measure). Soil preparation, fertilization and weed control was done according to farmers' practices. A month later, the test plants were transplanted in the fields with only one application of a systemic insecticide (imidacloprid), and the two protected rows were covered. The net was taken off a month later when the plants were already starting their reproductive stage. Viral symptoms were scored using a 0-4 scale (no symptoms-no production), 30 and 60 days after transplant. The fruits were harvested and weighed at the end of the test. Two of the plots were lost to fungal and bacterial diseases because they were planted late into the rainy season. The following are the results obtained in the three surviving plots.

**Table 8.A. Results of physical protection against whitefly-transmitted viruses in tomato and pepper plot established in farm no. 2, District of Zapotitán.**

| Crop | Treatment | 30 Days After Transplant | | 60 Days After Transplant | | Yield (MT/Ha) |
|---|---|---|---|---|---|---|
| | | Incidence | Severity | Incidence | Severity | |
| Tomato | Uncovered | 50% | 1 | 100% | 2 | 6.61 |
| | Agryl | 0 | 0 | 60% | 2 | 16.38 |
| Pepper | Tricot | 0 | 0 | 65% | 2 | 15.87 |
| | Uncovered | 30% | 1 | 75% | 2 | 7.51 |
| | Agryl | 0 | 0 | 50% | 2 | 17.63 |
| | Tricot | 0 | 0 | 50% | 2 | 19.73 |

**Table 8.B. Results of physical protection against whitefly-transmitted viruses in tomato and pepper plot established in farm No. 3, District of Zapotitán.**

| Crop | Treatment | 30 Days After Transplant | | 60 Days After Transplant | | Yield (MT/Ha) |
|---|---|---|---|---|---|---|
| | | Incidence | Severity | Incidence | Severity | |
| Tomato | Uncovered | 50% | 1 | 100% | 2 | 5.5 |
| | Agryl | 0% | 0 | 100% | 2 | 13.7 |
| | Tricot | 0% | 0 | 100% | 2 | 15.6 |
| Pepper | Uncovered | 30% | 1 | 100% | 2 | 4.6 |
| | Agryl | 0% | 0 | 20% | 2 | 13.48 |
| | Tricot | 0% | 0 | 40% | 2 | 14.4 |

**Table 8.C. Results of physical protection against whitefly-transmitted viruses in tomato and pepper plot established in farm no. 3, District of Zapotitán.**

| Crop | Treatment | 30 Days After Transplant | | 60 Days After Transplant | | Yield (MT/Ha) |
|---|---|---|---|---|---|---|
| | | Incidence | Severity | Incidence | Severity | |
| Tomato | Uncovered | 5% | 1 | 50% | 2 | 10.2 |
| | Agryl | 0% | 1 | 40% | 1 | 25.0 |
| | Tricot | 0% | 1 | 40% | 1 | 19.0 |
| Pepper | Uncovered | 25% | 1 | 50% | 2 | 11.0 |
| | Agryl | 0% | 1 | 10% | 1 | 15.0 |
| | Tricot | 0% | 1 | 10% | 1 | 16.3 |

**Contributors:** Jose Maria Garcia, and Juana E. Pérez Mancía, CENTA.

**Breeding for resistance to whitefly-transmitted begomoviruses.**

In the case of **tomato** and **peppers**, there is practically no crop improvement in Latin America, despite the fact that this region is the centre of origin of these crops. Towards the end of Phase II, limited additional resources became available to the Tropical Whitefly Project, which allowed us to evaluate in Mesoamerica, some tomato genotypes selected by the Asian Vegetable Research Development Centre (AVRDC) of Taiwan, as sources of resistance to whitefly-transmitted viruses that occur in Asia. Dr. Peter Hanson, tomato breeder of AVRDC, and the Coordinator of the TWFP, personally evaluated the potential sources of resistance in the two pilot sites: Zapotitán, El Salvador and Yucatán, Mexico. The materials **(Table 9)** were evaluated between January and June 2003 in Zapotitan, according to a complete randomised block design, with three replications.

As mentioned above, these tomato genotypes had been selected in Taiwan (AVRDC) for their resistance to Old World tomato begomoviruses (whitefly-borne), such as *Tomato yellow leaf curl* *virus* (TYLCV) and *Tomato leaf curl virus*, which are completely different from the New World begomoviruses that attack tomato in the Americas, with the exception of TYLCV, which was introduced in the Caribbean Region in the 1990s. However, the lines bred in Florida (FLA), USA, were originally selected for their resistance to New World begomoviruses, before being shipped to Asia. The North American begomoviruses probably originated in South America, and then moved into the Caribbean region.

**Table 9. Tomato genotypes selected by AVRDC as potential sources of resistance to New World begomoviruses.**

| Genotype | Origin | Provider |
|---|---|---|
| TY 52 | LA 1969 (L. chilense)/Tyking | D. Zamir, Israel |
| FLA 456-4 | LA 2779 (L. chilense) | J. Scott, USA |
| FLA 505 | LA 1969 (L. chilense) | J. Scott, USA |
| FLA 478-6-3-0 | LA 1938 (L. chilense) | J. Scott, USA |
| FLA 653-3-1-0 | LA 2779 (L. chilense)/ Tyking | J. Scott, USA |
| H 24 | L. hirsutum f. sp. glabratum | G. Kalloo, India |
| TLB 111 | H 24 | AVRDC |
| TLCV 7 | H 24 | AVRDC |
| CLN 2026 D | Susceptible check | AVRDC |
| Trnity Pride | National cultivar | Seminis |
| Sheriff | Local cultivar | Harris Moran |

**Table 10** shows that there are two entries: FLA 456-4 and FLA 505 that behaved as resistant to the viruses present in the screening location chosen in the Valley of Zapotitan. Serological tests performed at CIAT, confirmed the presence of whitefly-transmitted viruses in susceptible materials, with the exception of the line FLA 478-6-3-0, which was infected by an aphid-borne virus. So, it is possible that this material has resistance to begomoviruses.

Whereas the purpose of this experiment was to detect possible sources of resistance and not to select commercial cultivars, the virus-resistant FLA 505 line possessed large, round fruits suitable for fresh (salad) consumption. These fruits were very sensitive to manipulation. FLA 456-4 had small, firm fruits but an orange colour, which is not suitable for the Central American market that prefers medium-sized, red tomatoes. These traits can be corrected in a breeding program. The remaining lines were readily infectected and suffered considerable yield losses, as seen in **Table 11**. It is possible that the affected FLA lines were susceptible to other viruses (probably aphid-borne), as suggested before according to preliminary serological tests.

**Table 10. Field screening of tomato genotypes selected by AVRDC as potential sources of resistance to begomoviruses in Zapotitan, El Salvador.**

| Genotype | Incidence | Mosaic | Curling | Stunting | Malform |
|---|---|---|---|---|---|
| TY 52 | 100% | 2 | 2 | 4 | 3 |
| **FLA 456-4** | 0% | 1 | 1 | 1 | 1 |
| **FLA 505** | 0% | 1 | 1 | 1 | 1 |
| FLA 478-6-3-0 | 20% | 2 | 2 | 1 | 2 |
| FLA 653-3-1-0 | 100% | 1 | 1 | 1 | 1 |
| H 24 | 100% | 2 | 3 | 4 | 3 |
| TLB 111 | 100% | 2 | 4 | 4 | 3 |
| TLCV 7 | 100% | 2 | 4 | 4 | 3 |
| CLN 2026 D | 100% | 2 | 3 | 3 | 2 |
| Trinity Pride | 100% | 2 | 3 | 3 | 2 |
| Sheriff | 100% | 2 | 4 | 3 | 3 |

Scale: 1 = no symptoms; 5 = maximum symptom expression.

**Table 11. Evaluation (yield) of tomato genotypes selected by AVRDC as potential sources of resistance to begomoviruses in Zapotitan, El Salvador.**

| Genotype | Yield (MT/Ha) |
|---|---|
| TY 52 | 0.4 C |
| FLA 456-4 | 28.0 A |
| FLA 505 | 11.0 B |
| FLA 478-6-3-0 | 3.7 B |
| FLA 653-3-1-0 | 1.4 C |
| H 24 | 0.5 C |
| TLB 111 | 0.3 C |
| TLCV 7 | 0.1 C |
| CLN 2026 D | 0.5 C |
| Trinity Pride | 0.7 C |
| Sheriff | 0.3 C |

**Contributors:** Juana E. Pérez Mancía (CENTA), Peter Hanson (AVRDC).

**Loroco:** *'Whitefly and virus control in a horticultural crop usually managed by women in their backyards, with high income potential'.*

Loroco (*Fernaldia pandurata* ) is a local vegetable (flower buds are harvested) that has reached unexpectedly high prices due to external demand from Salvadoran and Guatemalan migrants working in the US as well as from local restaurants and U.S. fast-food chains operating in Central America. This crop is tended mostly by women in their backyards **(Figure 8)**, and provides a significant amount of income for resource-poor households. A hectare of loroco has the potential to produce a net profit of US $ 15,000 in its third year of cultivation. Unfortunately, this native crop usually lasts about a year due to whitefly and virus attacks **(Figures 9 and 10)**.

**Figure 8. Loroco plot under shade in the Valley of Zapotitán.**

The TWFP decided to conduct some preliminary tests with this crop considering its potential contribution to poverty alleviation. To this end, three plots were located in the Valley of Zapotitán, each experimental plot occupying and area of 1,000 square meters, divided in two treatments, the traditional planting system (500 sq/m) , and the improved system (500 sq/m) under shade (covered with palm leaves), as shown in **Figure 11a, b**.

**Figure 9. Whitefly attack on loroco.**

**Figure 10. Whitefly and virus damage to loroco (see damaged buds).**

Supports were spaced in a 4X4m pattern and plants were transplanted at 2X2 m distances. After the first year, the buds were harvested once a week. As part of an IPM package, the planting material for both treatments was produced under insect-proof conditions. The distance between the support stakes was 4 meters, and the distance between plants was 2 meters. The variables studied were: plant vigour, disease incidence, and yield. It must be taken into account, that loroco is a perennial crop, which develops its maximum yielding capacity after the second year of planting. The 2003 plots were transplanted in May, and first evaluated in February 2004. None of the experimental plots were allowed to be colonised by whiteflies, using a mild detergent whenever these insects were observed to colonise the test plants. No insecticides were used in these experiments.

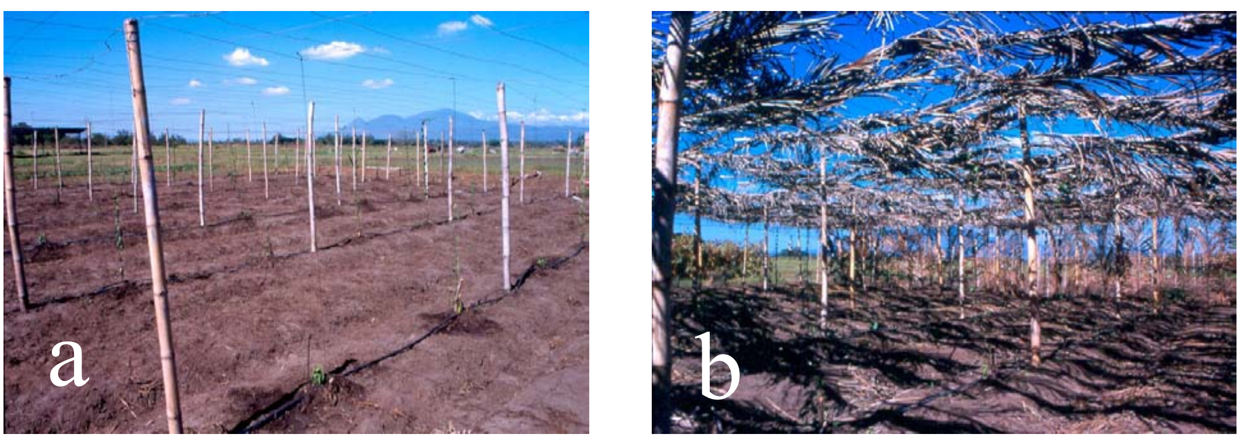



**Figure 11. Traditional (a) and covered (b) loroco plots evaluated for virus incidence and yield.**

In the traditional loroco planting system (uncovered), viral disease incidences > 50% were observed in the three plots two months after planting, whereas the loroco plants under shade had average disease incidences < 10% in all three experimental plots **(Table 12)**.

Nine-month loroco plants grown under the traditional open system, showed an average viral disease incidence of 70%, whereas the loroco plants grown under shade had an average viral disease incidence of 12% **(Table 12)**. Plant vigour under the uncovered and covered systems was 7 and 2, using a 1-9 scale, where 1 meant normal plant vigour and absence of symptoms **(Figure 12)**, and 9 was a systemically infected plant, showing malformation **(Figure 13)**.

**Table 12. Preliminary results of loroco trials in the valley of Zapotitan.**

| Plot | Treatment | Virus Incidence | | Yield (Lbs) |
|---|---|---|---|---|
| | | 3 Months | 9 Months | 12 Months |
| | Uncovered | 68% | 85% | 70 |
| 1 | Covered | 10% | 20% | 120 |
| | Uncovered | 60% | 75% | 80 |
| 2 | Covered | 9% | 12% | 140 |
| | Uncovered | 30% | 50% | 110 |
| 3 | Covered | 7% | 5% | 200 |

**Figure 12. Loroco leaves under shade showing no virus symptoms.**

Harvesting of loroco buds for both treatments was initiated in June 2003, and 8 months later, yields for the protected plots were 43.5% higher than those for the traditional planting system **(Table 12)**. This difference may have been larger, should we have used unprotected planting material, as was the case in the past. Moreover, the yield of the unprotected loroco plants will probably start declining after the first year as a result of the high incidence of viral disease. These are preliminary but encouraging results for this ethnic crop. Loroco has also shown to be a non-traditional export crop. In 2000-2001, El Salvador exported over 23 metric tons of this crop. A pound of loroco sells for US $ 10.oo in the U.S. market, primarily to Salvadoran and Guatemalan ex-patriates.

**Figure 13. Virus-infected loroco leaves in the traditional system.**

**Contributor:** Estela Escamilla (CENTA).

**Research activities and results: Yucatán, Mexico**

The second pilot site was the State of Yucatán, Mexico, characterized by its traditional agricultural practices since pre-Columbian times and, more recently, by a continuous struggle on the part of small-scale farmers to diversify their agriculture with high-value horticultural crops, in hopes of improving their livelihoods.

The first set of activities initiated in 2001-2002, was designed to characterise ***the ex ante*** **socio-economic situation** of these target regions. In Yucatan, Mexico, a study was already in progress when the project started, and the CPP-TWFP partially supported this study in order to use the data for the *ex ante* analysis. In Yucatán, there has been a clear trend from traditional 'milpa' (shifting maize-bean-squash cultivation) to horticultural production among small-scale farmers of Mayan origin. This trend pursues the same basic objective of maximising profits from limited land resources. An *ex-ante* study was conducted in Yucatan among resource-poor farmers, based on different models of integrated agricultural production systems, considered by different authors as the most sustainable for the American humid tropics. Production systems included: traditional food staples, fruit crops, vegetables, animal husbandry and forestry. In the case of traditional crops, such as maize, the strategy was to increase their productivity through the use of improved varieties and better agronomic practices (e.g. drip irrigation, fertilisers). Backyard animals, such as pigs and sheep were added to these production systems successfully. Fruit crops, such as citrus, papaya and banana, and tree species were also included, although their perennial nature did not significantly contributed to the preliminary evaluation of the economic benefits of these integrated production systems.

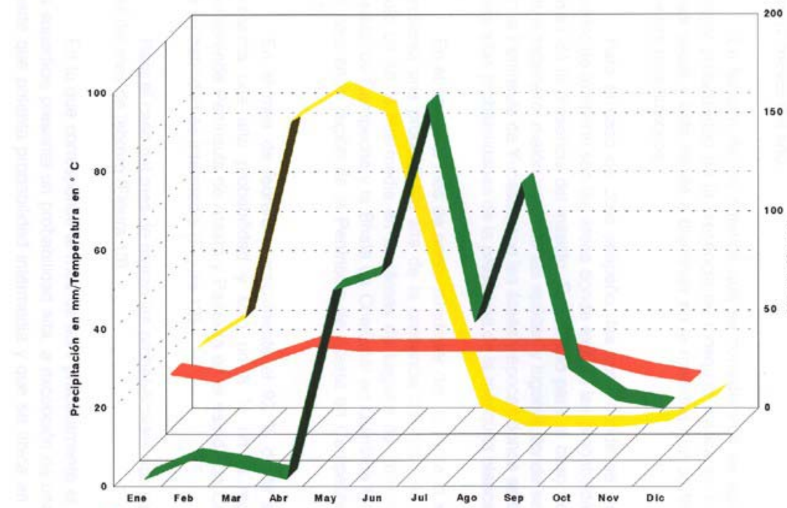
The document (in press) entitled "Integrated Production Modules for Low-Income Producers in the Yucatan Peninsula", addresses the need to change their traditional monoculture systems (e.g.

maize, rice, henequen) for mixed cropping systems that includes basic grains, vegetables, fruit crops, animals and forestry. The study focused on the development of the Farmers' Family Production Units (UPFC), which group 80% of the small-cale farmers in the region. The TWFP was particularly interested in the module: 'Production of Vegetables, Fruit Crops, and Basic Grains'. This study was conducted by Arnulfo Gómez, Luis Miranda, and José Tun Dzul of INIFAP-Mocochá. The last investigator is part of the TWFP-INIFAP group of collaborators. The study unit had four hectares, planted to tomato, chillies, watermelon, cucumber and 'calabacita' (small squash). The labour force consisted of the farmer, four sons, and three labourers. The *ex ante* income of this farm was approximately US $ 5,000. The innovations introduced in this module to maximise profits were: 1) drip irrigation (which is being promoted by the TWFP in conjunction with the microtunnel technology), 2) production of basic grains for food security, particularly during the rainy period when vegetables suffer from phytosanitary problems related to the high humidity characteristic of the rainy season. And 3) production of crops with short (vegetables), medium (bananas, papaya), and long (citrus, trees) production cycles.

The results of this study over three years, showed that the drip irrigation system is a good investment because it reduced the cost of labour in 70% for that task. The initial investment can be recovered in the five years of life that the irrigation system is supposed to last. The maize and cowpea planted for consumption, ended up being sold in the market in the green stage (immature) because the production of vegetables failed due to whitefly-related problems. This problem affected the entire Peninsula of Yucatán. The fruit crops, particularly papaya, produced over 18 MT/Ha. The forestry component was at an early stage to contribute to the total farm income at the time of the first analysis. Ultimately, the system was not profitable due to the whitefly problem (Cost/Benefit < 1.0 = 0.4) and collapse of the horticultural component. The authors concluded that "the project was severely affected by the emergence of viruses transmitted by whiteflies, which caused severe yield losses in the horticultural crops selected, mainly in tomato and chilli, the primary crops of this module. Should the whitefly problem been managed, this production module could have produced a net return on the capital invested of > 32%.

**Biological characterisation of pilot site.**

A thorough analysis of the ecology of the whitefly *Bemisia tabaci* in the Yucatán Peninsula was conducted in 2001-2002. This study describes the horticultural areas of the state, where the TWFP works; maps the distribution of *B. tabaci* in Yucatán; and describes the dynamics of whitefly populations according to environmental factors (rainfall and temperature) that favour whitefly/virus outbreaks **(Figure 14)**. This information has been used to produce 'whitefly risk maps' for every month of the year and horticultural area in the region **(Figure 15)**, which has greatly aided the TWFP in the selection of 'hot spots' and implementation of IPM measures. As in most regions of Central America, the increase in whitefly populations occurs between the months of December and May.




| | Ene | Feb | Mar | Abr | May | Jun | Jul | Ago | Sep | Oct | Nov | Dic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitación | 0 | 5 | 3 | 0 | 48 | 52 | 95 | 40 | 75 | 28 | 20 | 18 |
| Temperatura | 20 | 18 | 23 | 27 | 26 | 26 | 26 | 26 | 26 | 23 | 20 | 18 |
| No. Moscas | 40 | 55 | 155 | 170 | 160 | 80 | 10 | 0 | 0 | 0 | 3 | 16 |

**Figure 14. Whitefly population dynamics and related environmental factors in the Yucatan Peninsula, Mexico.**

The main crops chosen in Yucatan were tomato and chilli, primarily the 'Habanero' chilli grown for its high quality in this region and exported to the rest of the country. Given the high rate of transmission of the begomoviruses detected, such as *Pepper golden mosaic virus, Pepper huasteco yellow vein virus, Tomato mottle virus* and *Tomato yellow leaf curl virus*, it was assumed that the main whitefly vector was *B. tabaci*. However, it was not known whether the B biotype had already emerged in Yucatan until samples were analysed at CIAT last year **(Figure 16)**.

These tests confirmed the presence of the original biotype (A) of *B. tabaci*, and some unidentified biotypes. Only one tomato sample yielded a possible individual with characteristics of biotype B of *B. tabaci*. It is thus evident that the B biotype is present in Yucatan, albeit in low frequency.

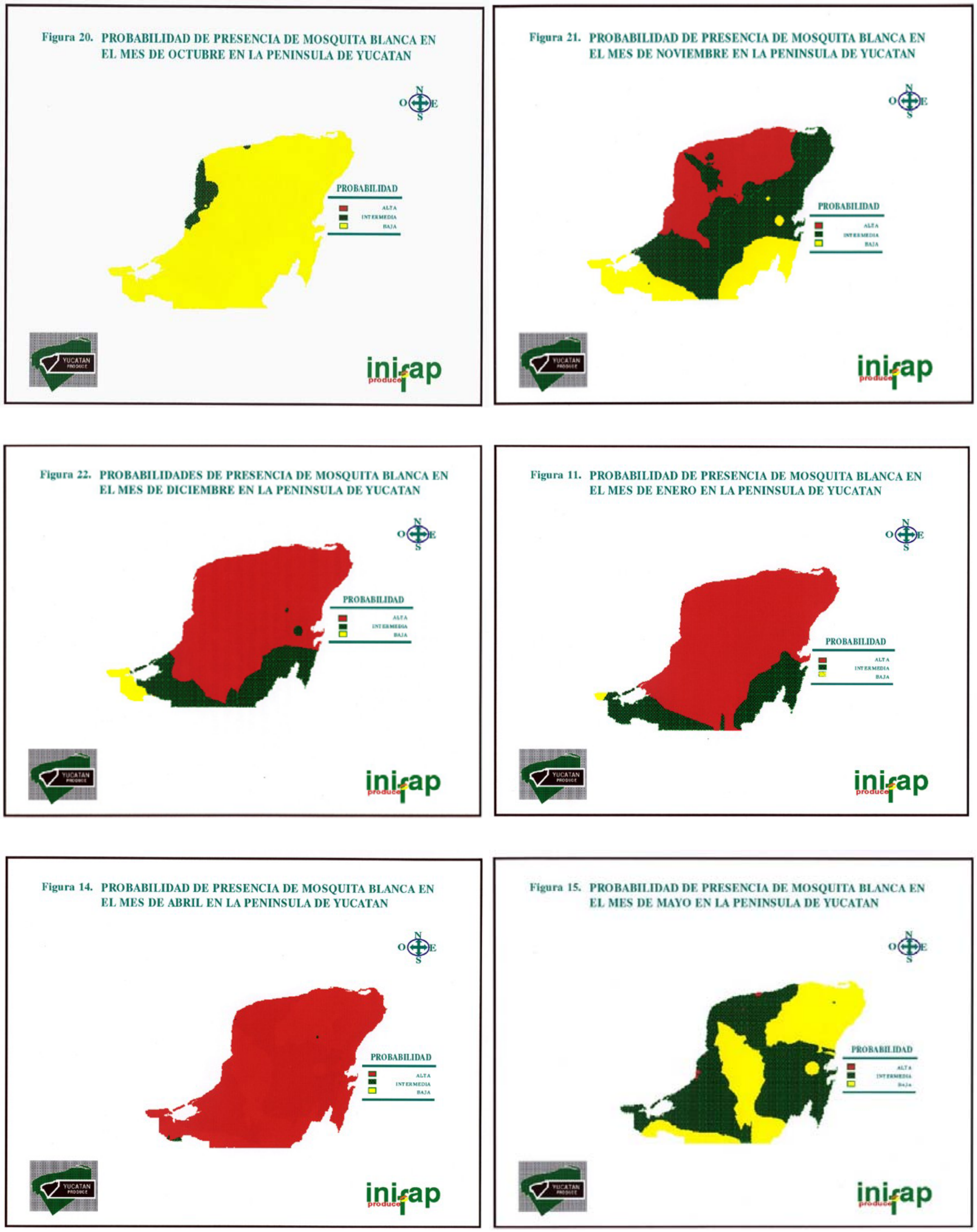



**Figure 15.** **Whitefly/geminivirus risk probability in selected months of the year according to climatic parameters in the Yucatán Peninsula, Mexico.**

**Continued** ➡