Cultural Control of the Whitefly/Geminiviruses Complex in Tomato

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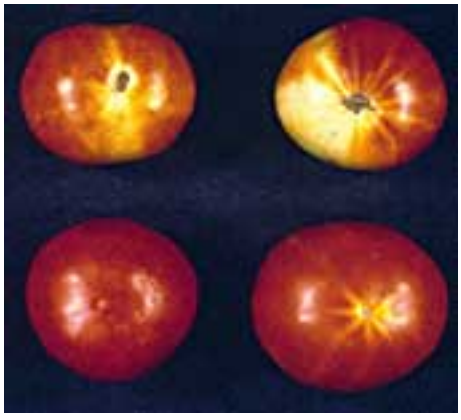
Damage caused by Bemisia

- **Sap depletion**
- **Accumulation of sooty mold**
- **Physiological Disorders:**
  Silver leaf
  Irregular ripening
- **Virus**
  clostorovirus
    TIC-V/TOC-V
  geminivirus
    TYLCV
    Others

Whitefly adults and nymphs feed by piercing the leaf surface and extracting phloem sap from sieve tubes with their sucking mouthparts. Sap contains mostly sugars produced in the leaves on its way to the roots and other structures. High whitefly populations may drain enough nutrients to deplete the plant. Additionally, whiteflies must consume so much sap to obtain scarce amino acids that great quantities of honey dew must be excreted, becoming a substrate for sooty mold that reduce the photosynthetic capacity of the foliage.



In addition to the direct damage mentioned above, salivary secretions of the silverleaf whitefly and perhaps other biotypes of Bemisia tabaci induce various physiological disorders in some plants. The silverleaf disorder seen in many squash and pumpkin varieties is caused by a shrinking of the palisade cells away from the upper epidermis leaving an airspace that gives the silver appearance. Blanching of various plant parts from whitefly feeding has been observed in stems of lettuce and various brassicas, bracts of poinsettias, and other plants. Irregular ripening of tomato is another whitefly induced disorder that can render fruit unmarketable. Moderate to low populations may be sufficient to cause these disorders, but at least they can be quantified.

By far the most damaging consequence of whitefly feeding can be transmission of plant viruses, particularly geminiviruses like tomato yellow leafcurl (TYLCV) and closteroviruses like lettuce infectious yellows. If the proportion of viruliferous whiteflies is high, the number necessary to spread the virus could be quite low. It impossible evaluate the potential damage represented by a certain whitefly populations in the field because one cannot estimate the number of viruliferous whiteflies, although some idea of their origin may provide a rough idea. Virus disease is most damaging when infection occurs early in the crop cycle.

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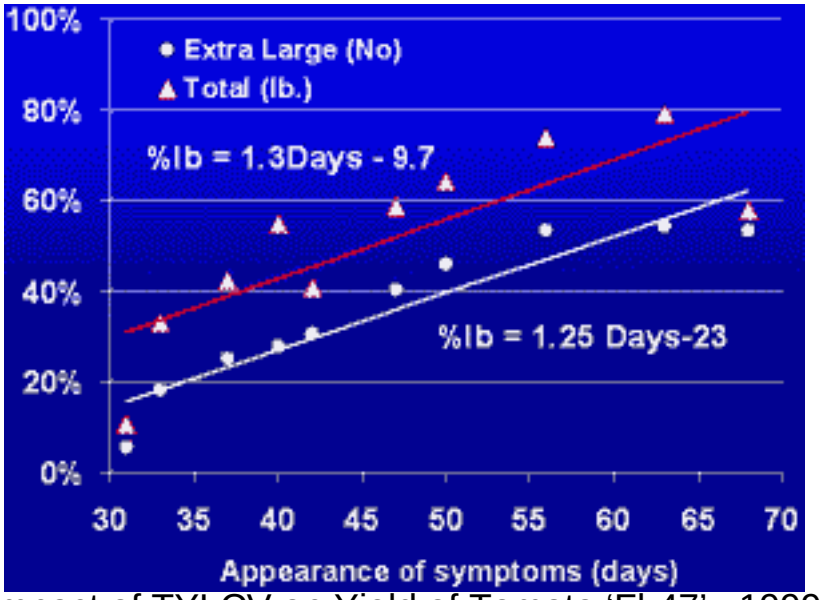
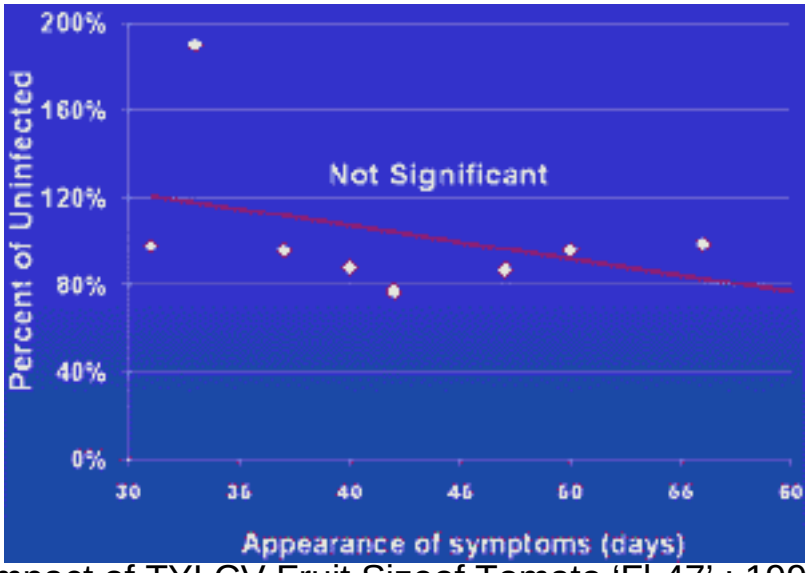
Here we see tomato plants infected with TYLCV that showed symptoms at 33, 44, 47 and 63 days after transplanting, compared to an uninfected plant on the left. The difference in plant size and number of fruit is obvious. The earlier the plant is infected, the greater the impact. The graph shows the mathematical relationship between time of first symptom appearance and reduction in total yield and number of extra large fruit compared to uninfected plants. Plants showing symptoms of TYLCV at 33 days after transplanting produced less than 10% as many fruit as

uninfected plants. At 70 days there was still a 60% loss. Predictive equations are given on the graph. No differences in fruit size could be seen between infected and uninfected plants. That is because TYLCV affects fruit production through flower abortion. Once the virus has set in, little fruit is set. Therefore, plants must be protected early to avoid serious losses from TYLCV.



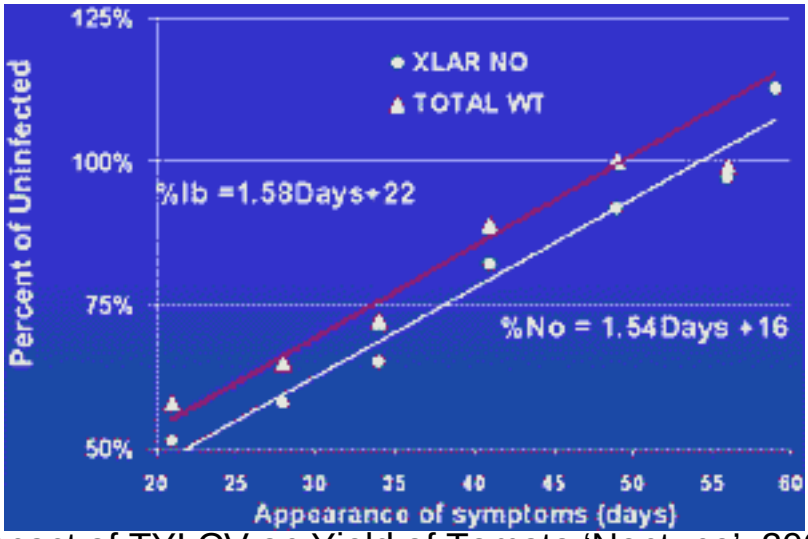
Impact of TYLCV on Yield of Tomato 'Fl-47' : 1999



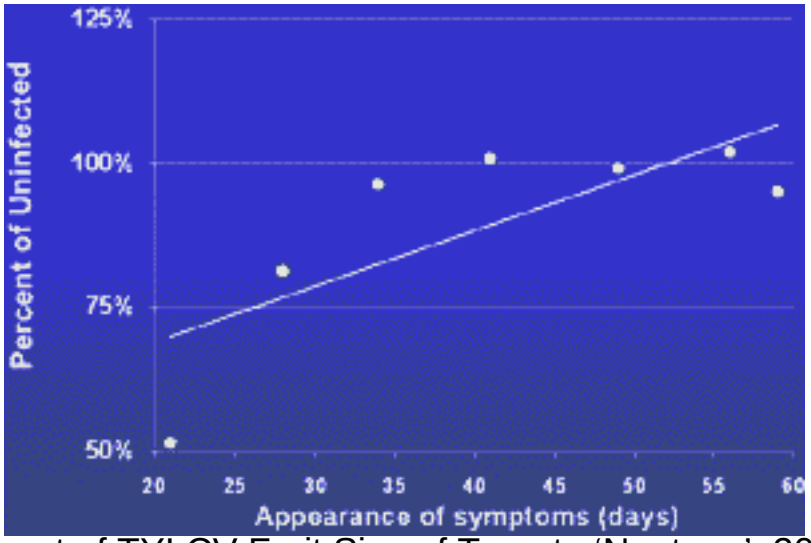
Impact of TYLCV Fruit Sizeof Tomato 'Fl-47' : 1999

Here we see that a linear relationship existed in this same 1999 experiment between the time of first symptom appearance and the number of extra-large fruit or the total fruit weight. The Y axis gives yield in % compared to the untreated control. The equations describe this relationship, and would provide a means of predicting yield loss from symptom appearance. At the same time there was no statistically

significant relationship between the average fruit weight and symptom appearance, indicating that fruit number not fruit size was the yield parameter most affected by the virus.



Impact of TYLCV on Yield of Tomato ‘Neptune’: 2000



Impact of TYLCV Fruit Size of Tomato ‘Neptune’: 2000

Here we see results from a similar experiment run in the spring of 2000. An open pollinated variety, Neptune, was used instead of the hybrid FL-47 used the previous year. Results are similar to the previous year in that the slope of the line is almost the same. However, the intercept is quite different, which means that the effect of early infection on yield was much less in 2000 compared to the uninfected controls than it was in 1999. This could mean that the uninfected controls yielded less in 2000 or that the impact of early infection was not as great as the previous year, due to different conditions such as the variety used. Nevertheless, the same overall principal holds: impact of TYLCV is greatest for early infection.

Impact of TYLCV on Tomato Yield: Conclusions

- Loss inversely proportional to age at time of infection

- Loss due primarily to poor fruit set (flower abortion)
- Loss also a function of varieties and environmental conditions

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Management of Bemisia/TYLCV

- **Chemical Control**
  Systemic, IGRs, Broad spectrum, Biorationals
- **Biological Control**
  Aphelinids (parasitoids), Coccinelids, Chrysopids
- **Genetic Control**
  Varieties resistant al TYLCV
- **Cultural Control**
  Everything else

What options does the grower have to control whiteflies and the viruses they vector? When faced with a pest problem, his first question is often, “what can I spray?” There are numerous options, although some of the most effective insecticides, the so called chloronicotinoids such as imidacloprid (Admire® or Comfidor®) are best applied to the root system. Some insect growth regulators (IGRs) are effective against immature whiteflies. Soaps and oils can also be effective and are available to organic growers.

Biological control pits predator, parasitic or pathogenic organisms against the pest. The presence of such organisms in the crop may be conserved by avoiding incompatible pesticides, encouraged by providing additional food and refuge, or augmented by releasing parasites and predators or spraying on beneficial fungi.

Thus, chemical and biological control are strategies which can be clearly defined. All other practices aimed at managing pest populations are placed in an all-encompassing category termed “cultural control”. These are largely crop management practices that influence pest populations.

Types of Cultural Controls

- **Escape in time**
  Rotations, Crop-free periods
- **Escape in space**
  Screen houses, Floating row covers,
  High plant densities
- **Behavioral Manipulation**
  Crop associations
  Trap crops, Companion crops
  Mulches, Living and Inert
- **Host suitability**
  Fertilization
- **Removal**
  Overhead irrigation, Roguing

Cultural controls include a hodgepodge of practices with little conceptual framework to tie them together. The scheme presented here is based primarily on mode of action. Perhaps the most potent tools for avoiding damage from whiteflies and associated viruses is escape in either time or space. If crops that serve as hosts are planted in a continual sequence, then there is no time for vector populations or virus inoculum to be reduced by natural processes. A crop-free period is necessary to separate susceptible crops. Escape in space refers to the use of barriers such as screen houses or floating row covers to protect crops from migrating whiteflies.

Behavior manipulation refers to tactics aimed at interfering with the whitefly's ability to find crop plants. Included is companion or intercropping, where one of the crops is intended to serve as a trap, or to repel whiteflies from the area. Companion cropping might also be used to harbor beneficial insects, in which case it would be included as a biological control strategy. Another way of interfering with the whitefly's host seeking behavior is the use of mulches which may be inert or living. Inert mulches include reflective and colored plastics, straw and others. Living mulches may be planted or simply be weeds that are left in the field but managed to reduce competition with the crop.

Management of plant nutrients effects the suitability of a crop for whitefly feeding and reproduction. In general, succulent foliage produced by over fertilized plants stimulate whitefly reproduction. Finally, infected plants can be removed or diluted by roguing or high plant densities respectively. There is little information to document possible benefits of these latter practices.

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Escape in Time: Fallows, Rotations, Crop-Free Periods

Advantages:

- Brakes annual cycle of pests and diseases: reduces levels of inoculum
- History of success in controlling Bemisia and TYLCV in Florida, the Dominican Republic and Israel

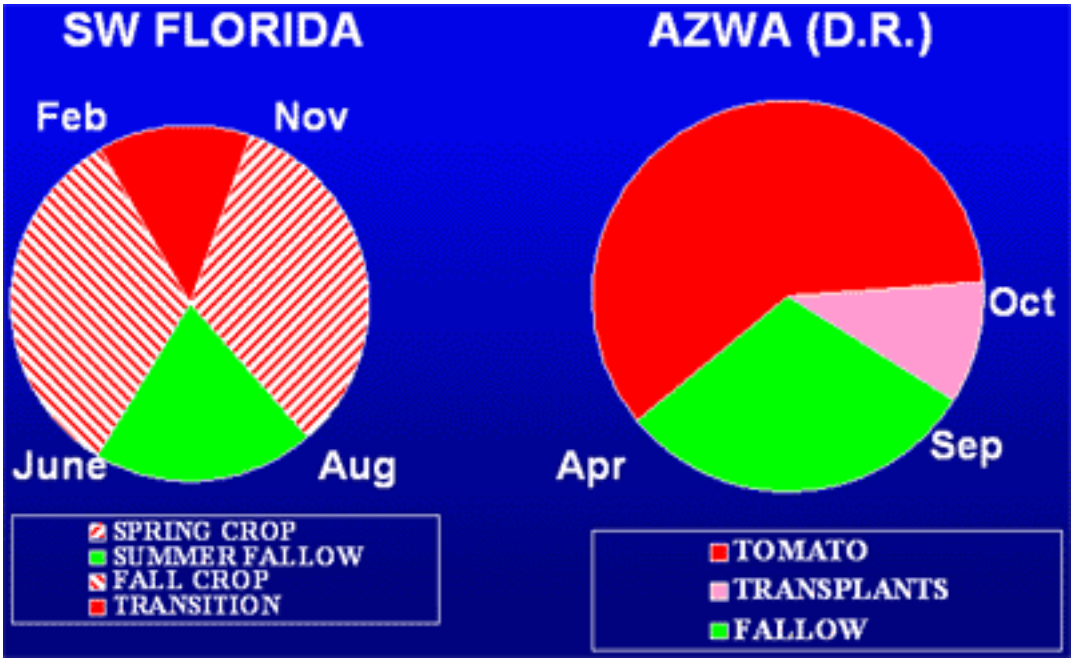
Disadvantages:

- Requires regional action for full effect

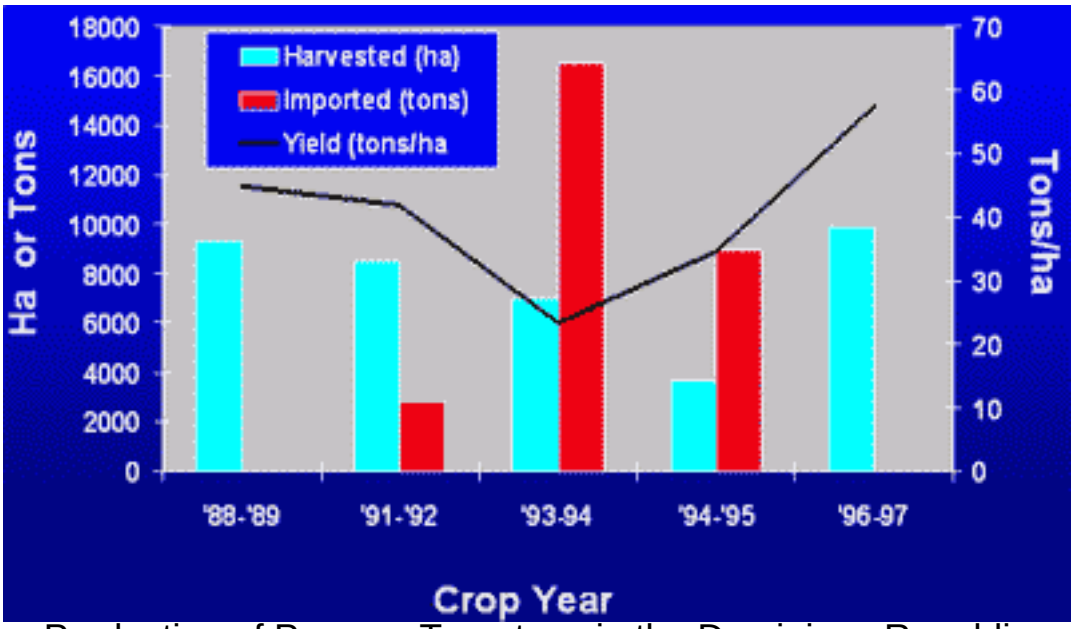
These practices remove the crop in time from sources of the vector and/or virus. This is possible, in part because TYLCV has a relatively limited host range, even though the whitefly has many. However, whiteflies generally do poorly on weeds and woody perennials in contrast monocultures of susceptible host crops, due to numerous factors: (1) natural biological control in the absence of insecticides, (2) poor host quality caused by drought, flooding and competition from other plant species, and scarcity of plant nutrients, and (3) scarcity of the most suitable host species that may be patchy and hidden among many poor hosts. Three or four generations under such suboptimal conditions are usually enough to cause populations to decline many orders of magnitude.

Crop free periods have been used successfully against whitefly-borne geminiviruses since the 1920s and 1930s in tobacco (southern Africa) and cotton (Sudan). More recently, they have been used to protect vegetable crops in Florida, the Dominican Republic, the Arava region of Israel and elsewhere.

Annual Crop Cycles



In southwest Florida there are two vegetable crops each year, one in fall, and the other in spring. Transplants are set out beginning in mid-August through September and tomatoes are harvested from Mid November through December. Planting begins again in mid-January through February and harvesting from mid April through May. Separation between the two seasons is based on fear of freezes that are most common in January. However, as memories of the last killing frost fade with time, market incentives can predominate, causing an extension of the fall season over the winter or early spring planting. Fortunately, the practices of prompt cleanup after spring harvest and maintenance of volunteer-free fields in summer are almost universally followed. However, in other parts of Florida with more farms and more divers agriculture, and/or a shorter crop-free period, there is likely to be more carryover in summer.



Production of Process Tomatoes in the Dominican Republic

In the Dominican Republic a 90 day crop-free period is mandated for the summer months when only non-hosts such as sorghum are allowed. This system was mandated in response to devastating epidemics of TYLCV in the early 1990s. Compliance with the ordinances, along with deployment of tolerant hybrids and judicious insecticide use, was credited with allowing local industry to overcome the crisis.

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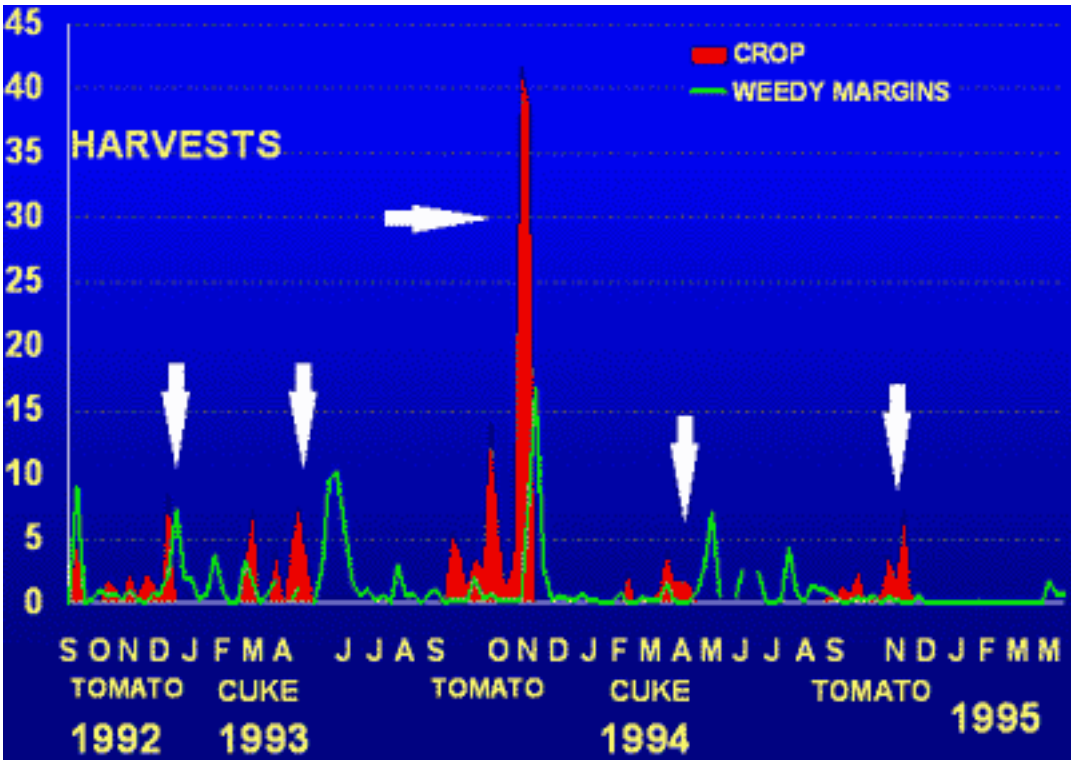
Whiteflies on Sticky Traps



In Florida, silverleaf whitefly was detected first in 1986 on poinsettia, but soon became a major pest of vegetables in south and central parts of the state. Tomato was most impacted, first from irregular ripening induced by nymphal feeding, then through transmission of tomato mottle geminivirus (ToMoV). Yield losses and control costs in Florida tomato were estimated at $141 million for the 1990-91 season. Epidemiological studies at the field level showed that most spread of ToMoV was primary, that is originated from outside the field. Areawide sampling showed whiteflies building up on crops and migrating from crop to crop, with weeds serving only as intermediate hosts, ultimately supporting only few whiteflies over fallow periods. These results supported earlier recommendations emphasizing the importance of a crop-free period during summer requiring removal of all crop residues, and separation of fall and spring crops in time and space to reduce carryover of whitefly populations and ToMoV to consecutive plantings. Summer cleanup was quickly adopted, especially in the southwest growing region where fall whitefly populations

were never high after the first year as a consequence. A campaign to separate the fall and spring crops by not planting for two months in the winter met more limited success due to market pressures, but still reduced losses after the disastrous spring of 1991.

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Escape in Space:
Screen Houses

Advantages:

- Effective
- History of success in Israel

Disadvantages:

- High Cost
- Restricted air flow

Field and greenhouse grown crops can be protected from whitefly damage using a variety of physical exclusion methods. In some cases, the entire crop is grown inside a greenhouse or under an insect proof structure. In Israel, almost all tomatoes are grown inside enclosed structures constructed of solid plastic and/or fine screening to escape the pressure of whitefly-transmitted viruses. Greenhouses in Spain and elsewhere in the Mediterranean are also adapting this technology. Insect screening is available in a variety of mesh sizes to allow selection of materials that optimize insect exclusion requirements while allowing adequate air flow through the screening

Clean transplants can be the first line of defense against developing damaging populations of whiteflies in field and greenhouse grown crops. Likewise, field sown or transplanted seedlings can be protected early with light spun-bonded polyester “floating” row covers, that lay over the tops of plants. Without a supporting structure. The material remains in place until it is necessary to remove it for cultural practices or bee pollination.

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Crop Associations: Pros & Cons

Advantages:

- Attractive
- Compatible with organic production
- Promotes crop diversification

Disadvantages:

- Difficult to demonstrate benefits
- Difficult to manage

Companion Crops: Types and Requirements

Trap Crops

- Need to be more attractive and/or tolerant to pest than main crop
- Must be more long-lived than main crop

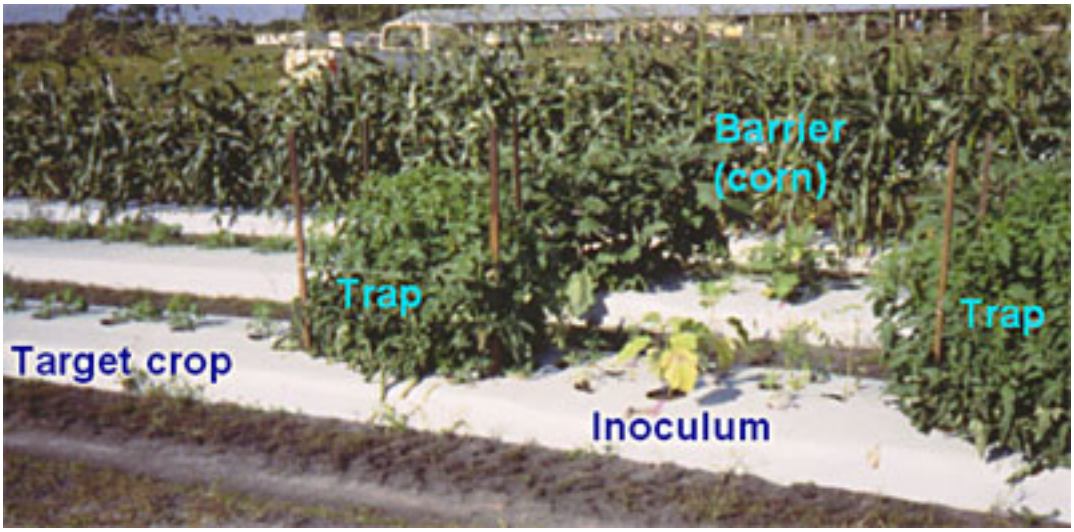
Refuge Crops

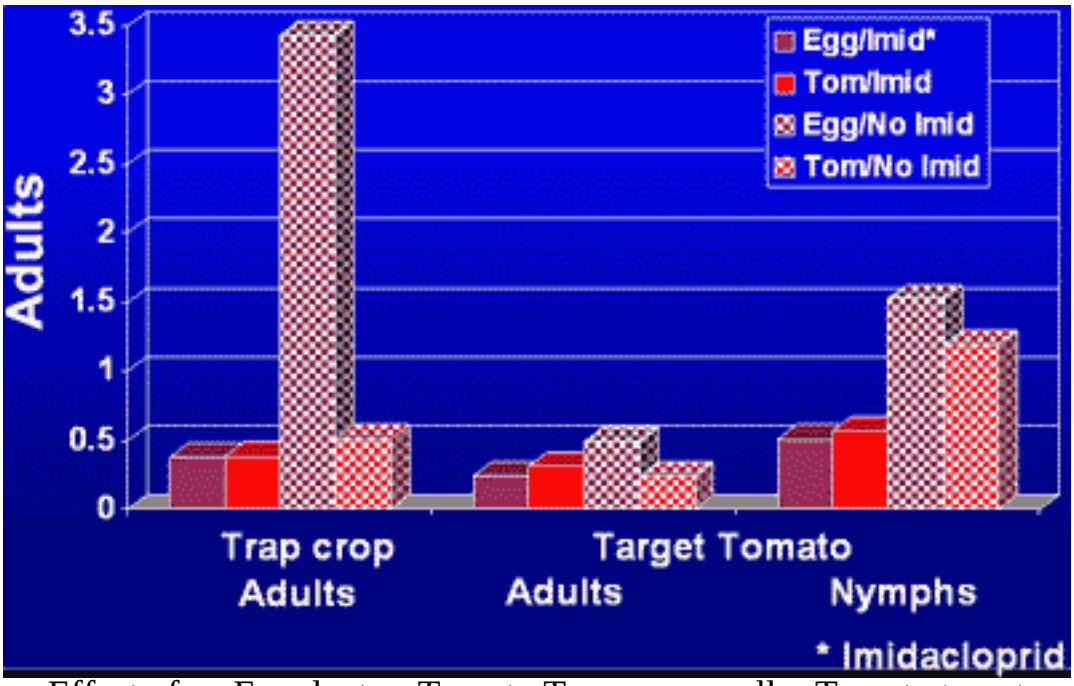
- Must be attractive by providing: Nectar, prey, or favorable chemical and/or physical properties

Crop associations may be used either to create a refuge for natural enemies or manipulate the host seeking behavior of the pest to protect the principal or most susceptible crop. However, there has been little experimental data to document benefits of these practices. In Florida, tomato planted next to eggplant treated with imidacloprid had fewer whiteflies than tomato planted next to tomato, although tomato next to untreated eggplant had more. Thus, the trap crop proved capable of acting as a source as well as a sink. The practice is not recommended because the insecticide was deemed more efficiently used on the crop rather than the trap crop.

Inconsistent data could be an artifact of experimental design, but is more likely due to the fact that it is difficult for a trap crop to remain attractive through the entire crop cycle. Attractiveness is eventually lost due to maturity, senescence, or a high pest population. The trap crop becomes a liability and must be sprayed to prevent whitefly migration to the main crop. Even if it could be made to work, the logistics of managing 2 crops is difficult at best. Trap crops have not proved to be a reliable approach to deal with whiteflies and resources might better be allocated toward a single crop.

Experimental design for evaluating effects on Bemisia of trap crops placed between an inoculum source and a target crop:





Effect of an Eggplant or Tomato Trap on a smaller Tomato target

Trap Crops: Conclusions

- Limited Potential to reduce pest populations in main crop
- Considerable Potential to increase pest populations unless controlled chemically.
- Insecticides better used in main crop.
- Trap crops don’t work!

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Types de Mulch

Polyethylene Film

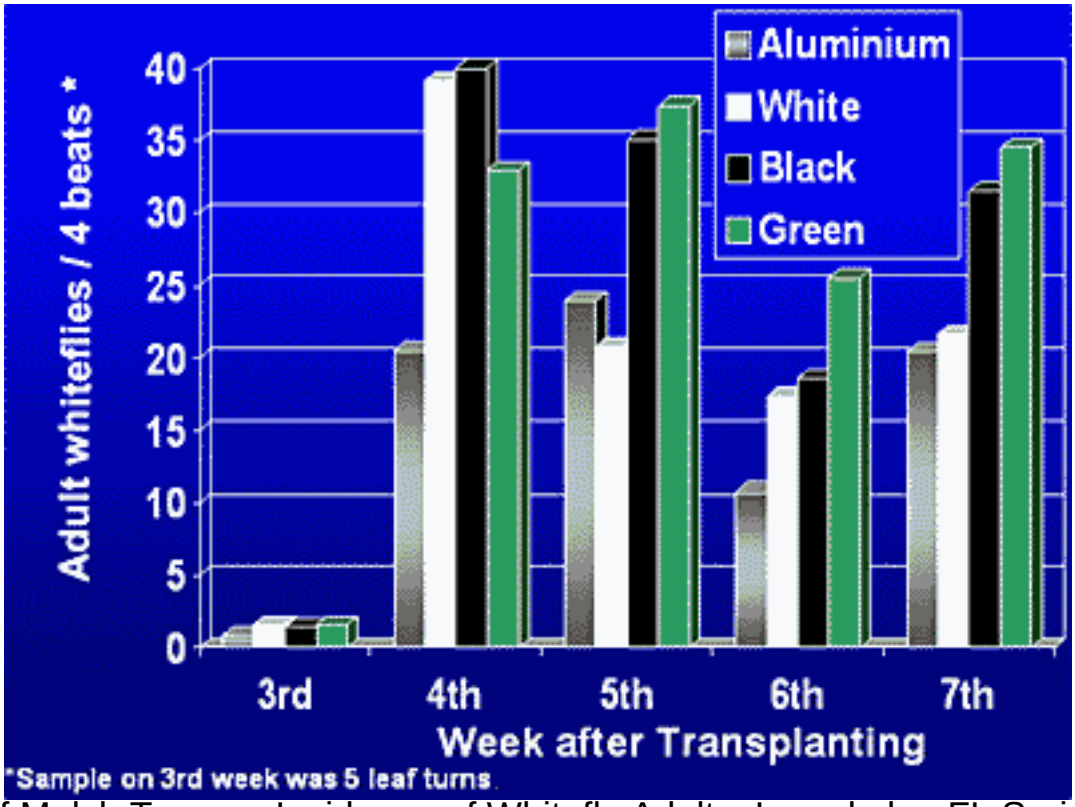
- Colored
- Reflective
- Transparent

Vegetative

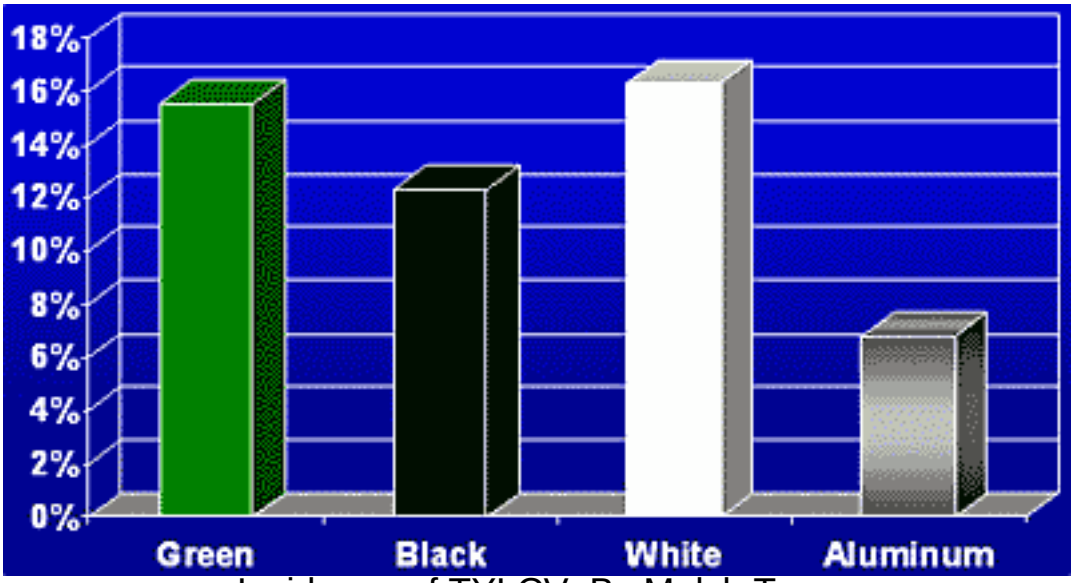
- Live
- Dead
- Residues

Mulches are used to interfere with the whitefly's ability to find the crop plants. All function only in the early part of the crop cycle. Silver mulch reflects ultraviolet radiation erasing the plants signature and has proved the most effective inert type. By discouraging adult whiteflies from alighting on the plants, movement of virus into the crop during the critical early period can be reduced. We have seen positive results in trials in Immokalee as have other researchers in other regions of the state. Aluminized reflective mulch is most effective during the early part of the crop cycle before it is covered by the plant canopy. Spray residues can also reduce amount of light reflected. Soil under aluminized mulch is cooler than under the black mulch, so is most appropriate for the fall season planting prior to 15 Oct. Also, heat reflected by aluminized mulch may cause leaf burn and reflected light may be bothersome to workers.

Living mulch masks or conceals the crop. It is thought that whiteflies are attracted to the general location by color (yellowish green) but are more likely to land on a mulch plant. After hopping around without finding a satisfactory host they fly off and are taken away by the wind.



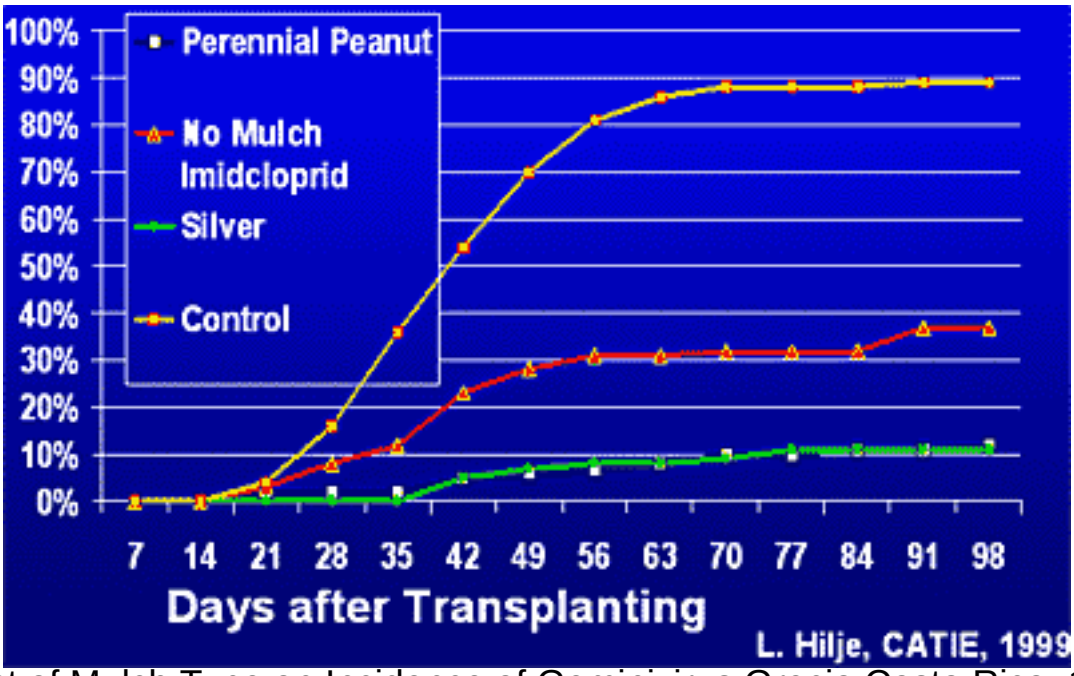
Effect of Mulch Type on Incidence of Whitefly Adults, Immokalee FL Spring 1998



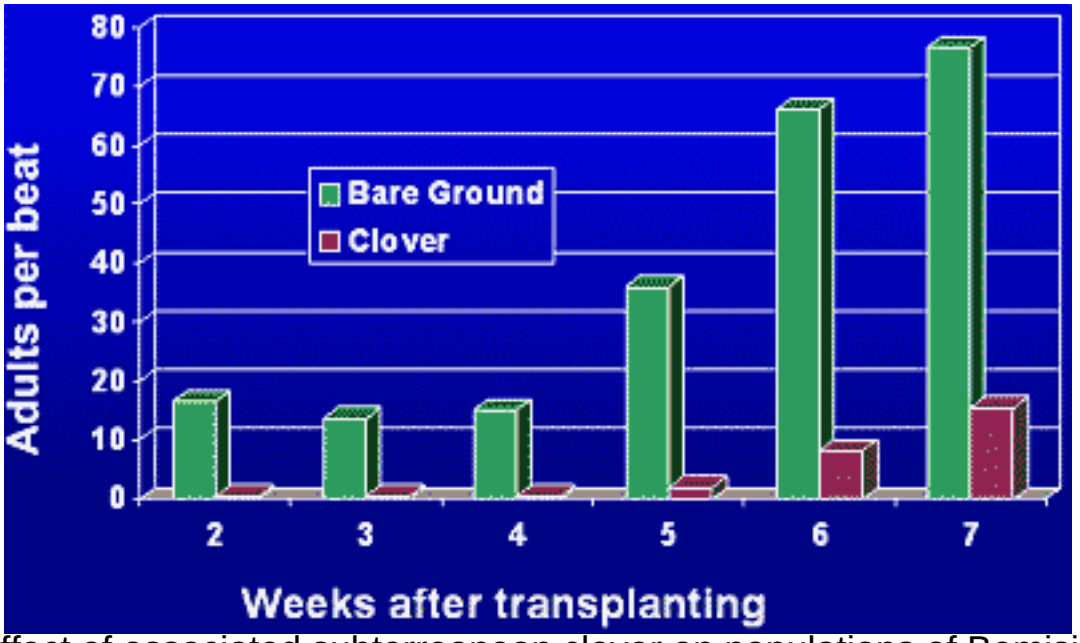
Incidence of TYLCV By Mulch Type

Plot Layout in Costa Rica

Living mulches represent a potentially low cost alternative to reflective aluminized plastic mulch without environmental liability. They are particularly suited for small, especially organic farms, as they are locally available, may return extra organic matter and even nutrients to the soil, and could provide additional income through sale of seed, forage or other products. Some have been evaluated for tomato production in Costa Rica, including perennial peanuts, a weed, "cinquillo" and coriander. Basically, any low-growing plant can be used. Coriander gave the best economic results in Costa Rica because it could be harvested and sold at about 30 days, removing potential competition and providing extra income to the growers.



Effect of Mulch Type on Incidence of Geminivirus Grecia Costa Rica, 1998

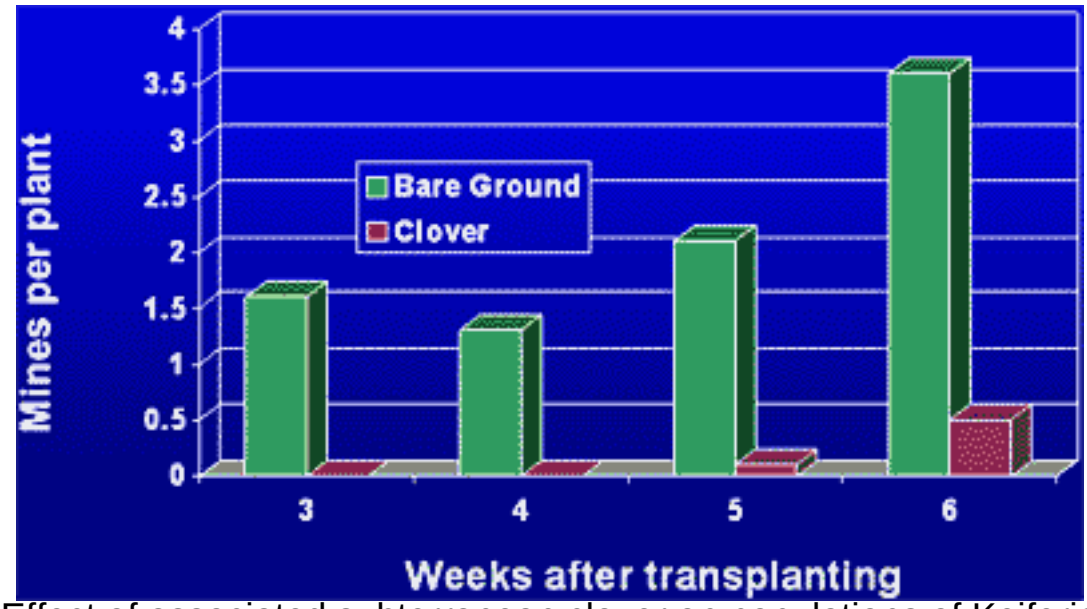


Effect of associated subterreanean clover on populations of Bemisia

Subterranean clover was successfully tested during a spring crop in Florida. Not only were whiteflies greatly reduced in mulched plots compared to bare ground, but tomato pinworm and southern armyworm infestation also declined. Thus, the protection afforded to the young crop plant by living mulch is not exclusive to only one or a few pest species.

We have not yet tested the effect of living mulch in row middles between plastic-mulched beds, but it is likely that the effect weakens with distance from the plant. The most effective use of this technique would likely be creation of permanent beds planted to a low-growing cover crop into which transplants would be set in relatively narrow herbicide band (no till) or tilled band (low-till). Undoubtedly, the main challenge in such system would be management of the cover crop so as to minimize competition

with the vegetable crop.



Effect of associated subterranean clover on populations of Keiferia

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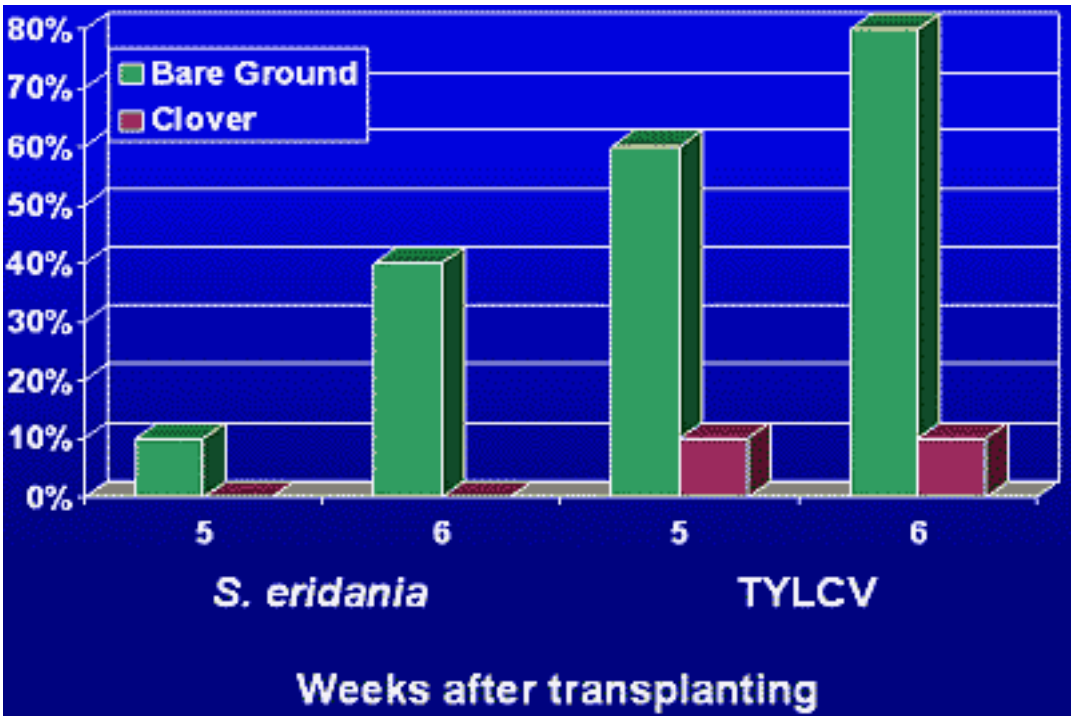
Plants Damaged by S. eridania or Infected by TYLCV



Host plant resistance is not really a cultural control but is included here because it is appropriate to organic production. Varieties resistant to TYLCV are presently utilize genes from wild species of Lycopersicon although transgenic varieties may be available in the future. Seed is still limited and the types of varieties available may not have horticultural characteristics that would please everyone. Nevertheless, the level of

resistance is quite high, such that perfectly normal looking plants grow in spite of heavy pressure, as can be seen in the following photos. However, we do not know yet how long this resistance would up over time. It may be significant that screen houses are still used in Israel spite of the availability of resistant varieties.

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Resistance to TYLCV

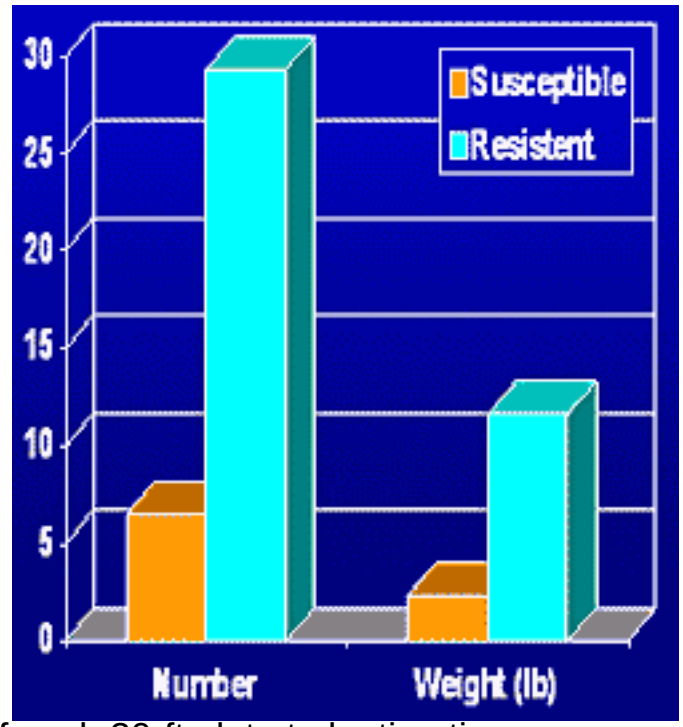
Advantages:

- Avoids worst consequences of whitefly
- Avoids use of insecticides and other inputs to control whitefly

Disadvantages

- Availability and cost of seeds
- Undesirable horticultural characteristics

Resistance to TYLCV



Tomato varieties have been developed through conventional selection techniques which show high levels of resistance to TYLCV. Seed is available in limited quantities for some of these varieties, notable from Hazara and to a lesser extent, from Peto. Some of these varieties were tested at multiple sites in Florida during the 1999-2000 season and demonstrated good agronomic characteristics. Furthermore, for the test carried out during the spring season in Immokalee, the trials inoculated with TYLCV by setting an infected transplant in the middle of each 30-ft plot at planting time. Whitefly populations were considerable and the virus moved rapidly through the plots. Symptoms were extremely uniform within each plot, showing a great deal of variatal consistency. All the susceptible material (Leila, Sanibel and Fl-47), was infected early, showed sever symptoms including dwarfing and low fruit set. In contrast, only one of the resistant varieties showed any symptoms, and they were relatively mild. Yield from

resistant plants was 6 times greater than from susceptible plants. Clearly, resistant varieties represent a viable alternative for managing TYLCV.

Control Cultural de Bemisia y Geminivirus: Conclusions

Avoidance:

- Always necessary

Habitat Manipulation:

- Companion crops doubtful Live and Reflective Mulches work early in the plant cycle.

An absolute requirement for dealing with the whitefly/geminivirus complex successfully is the presence of a physical or temporal barrier separating new crops from older, infected and infested crops. This can be accomplished through one or more crop-free periods, and/or exclusion methods such as insect-proof screening or sufficient distance from other susceptible crops. Avoidance is especially important for organic growers who have no recourse to insecticides, but is necessary for all growers because even insecticides cannot reduce populations low enough where levels of inoculum are high. Once these conditions are met, whiteflies and geminivirus can be successfully managed by a combination of tactics that include biological control, virus resistance, and inert or living mulches.