PRODUCTION OF SOLANACEA FOR FRESH MARKET UNDER FIELD CONDITIONS: CURRENT PROBLEMS AND POTENTIAL SOLUTIONS

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Abstract

Many changes have occurred in the fresh market tomato, pepper, and other Solanacea crop industries over the past 25 years. Increasing demands placed on growers through urbanization, government regulation and changes in attitudes towards the environment will necessitate many more changes over the next few years. This will include, but is not limited to, more careful use of land, water, and pesticides, while maintaining a high-quality product for the consumer. To meet these demands, researchers have continued to broaden their efforts on these crops. Plant breeding and genetics have long been a priority as new hybrids have led to major increases in yield, but have they led to major increases in fruit quality? Recent advances in transplant technology have likewise increased productivity of these crops. Now we see threats to our transplant industry via diseases spread by whiteflies. Progress on control of silverleaf whitefly, thrips, and various plant viruses continue to be major factors affecting the industry. Teamwork by plant pathologists, entomologists, horticulturists, and plant breeders have made dramatic strides in solving these problems over the past couple of years. New irrigation and fertilization technology is in constant need as water quality and quantity become major issues with the public. What will happen to various segments of the industries when methyl bromide is taken off the market? How will production be affected as labor becomes more expensive and less available? Fruit quality, especially with regard to preharvest factors that influence postharvest fruit quality, continues to be an

issue and a better understanding of quality is needed between the producer and consumer.

Key words: Tomato, pepper, eggplant, whitefly, methyl bromide, irrigation, fertilization, thrips, geminivirus, bacterial wilt.

Introduction

Field production of Solanaceous species grown for fresh market world wide is extensive. Production practices and cultivars used are far from standardized. Unfortunately, production problems plaguing Solanaceous crop producers are more generalized. In recent years, plant productivity of tomato and pepper grown for fresh market has increased significantly due to new cultivars and improved production practices.

Numerous problems plague Solanaceous crop producers and vary in severity according to location and intensity of the production system. Several problems can be singled out as potential threats to these industries. Some problems appear to have great potential for solution in the near future. For others, the solutions may be off into the future, especially where improved germplasm and/or resistance appear to be the only cure. It is the purpose of this review to discuss several problems facing Solanacea produced for fresh market and the potential solutions for the problems. A model of current research being conducted at the University of Florida was utilized to highlight working solutions to problems.

Plant production, planting systems, and stand establishment

Tomatoes and peppers are established in the field by direct-seeding using the plug-mix seeding method, transplanting containerized seedlings grown in multicellular trays in greenhouses, or transplanting bare-rooted seedlings. Containerized tomato transplants have been shown to have higher plant survival, faster establishment, improved plant uniformity, and earlier maturity compared to plants from direct-seeding (Weston and Zandstra, 1989).

Containerized transplants may be subjected to water, fertilizer, light, mechanical, and air temperature stresses, which may cause morphological and/or physiological changes during early root and shoot development in the greenhouse and/or field. Transplant condition or quality at time of planting were influenced by root-container size (Knavel, 1965; Weston and Zandstra, 1986), transplant nutrition (Jaworski and Webb, 1966; Melton and Dufault, 1991; Widders, 1989), transplant age (Chipman, 1961; Leskovar et al., 1991; Vavrina and Orzolek, 1992), and transplant storage (Dufault and Melton, 1990; Leskovar and Cantliffe, 1991). Transplant quality at time of planting also affects stand establishment, fruit size, and fruit yield (Chipman, 1961; Leskovar et al., 1991; Nicklow and Minges, 1962; Weston and Zandstra, 1989).

Between 1985 and 1989, a flotation or sub-irrigation (commonly referred to as ebb and flow) system was constructed by Speedling, Inc.

in Florida and California (Thomas, 1992). This system, which was originally designed to grow tobacco plants to increase field survival and reduce transplant shock, is now being used to grow seedlings of many commercial vegetables. It utilizes recycled, stored, or collected water, saving water and reducing fertilizer and pesticide use compared with the traditional overhead irrigated systems. Trays are suspended on metal wires 0.20 m above concrete floors, and every 2 to 3 days, the irrigation water is raised to the level of the container, maintained for 15 to 45 min, and then decreased to its original level or returned to the main reservoir until the next irrigation.

During transplant production, tray cell moisture can be considered a major factor affecting transplant condition. Flotation systems are a viable, though more expensive, alternative to improve uniformity and quality of pepper transplants, as compared to standard transplant systems using overhead irrigation (Leskovar and Cantliffe, 1993).

Transplant age at shipping depends on the grower's preference. Growers in the northern United States prefer tomato transplants that are at least six weeks old and 12 to 15 cm in height. Growers in Florida prefer transplants that are 5 or 6 weeks old and 10 cm in height.

Studies on shipping containers, storage time and temperature, and plant age have been reported for bareroot and containerized tomato transplants (Nicklow and Minges, 1962; Risse and Moffit, 1984; Risse et al., 1985; Risse, et al., 1979; Weston and Zandstra, 1989). Storage at 10 to 13C for less than 10 days was recommended for tomato plants (Hardenburg, et al., 1986). Fruit yield was reduced when bareroot tomato transplants were packed at 1250 plants/crate compared to 1000 plants/crate (Risse, et al., 1985).

Plant performance after initial transplanting depends also on the physiological age of the transplants. Enhanced yield was reported using 3- to 5-week-old bareroot transplants as compared to 7- and 9-week-old transplants, respectively (Nicklow and Minges, 1962). Transplant size expressed as height, leaf area or shoot weight, when measured in the greenhouse, generally is larger for older than for younger transplants (Weston and Zandstra, 1989). In those studies (Nicklow and Minges, 1962; Weston and Zandstra, 1989), however, shoot and root growth changes that occur during transplant storage and subsequent to planting were not considered.

Leskovar and Cantliffe (1993) also conducted experiments in the spring and fall in Florida to evaluate tomato transplant age (2 to 6 weeks old). In the spring, growth was similar for 4-, 5- and 6-week-old transplants. Four- and five-week-old transplants produced the most early large fruit yield, but 4-week-old transplants produced greater total yield than 6-week-old transplants. In the fall, yields were similar among 2-to 5-week-old transplants.

Leskovar and Cantliffe (1990) evaluated growth changes in response to tomato transplant handling, storage, and age. Transplants, 45 days old, were stored in trays (not pulled) or packed in boxes (pulled) for 8 days at 5 and 15C. "Pulled" transplants had higher shoot growth than

"not pulled" transplants. Also, 35-day-old "not pulled" and "pulled" transplants were stored at 20/28C for 3 days. "Not pulled" transplants yielded more extra large fruit than "pulled" transplants.

In a study to determine the effects of the transplant production system on growth and yield of fresh-market tomatoes Leskovar et al. (1994) grew containerized transplants with the standard or conventional systems (SS) and with flotation system (FS). Standard system and FS transplants, and direct-seeding using coated seeds were evaluated in the field for root and shoot growth and yield during fall, winter, and spring plantings. Standard system transplants had greater leaf area, root volume, shoot dry weights, and shoot:root ratios than FS transplants. During early development, the FS transplants had more lateral root growth than SS transplants, but had similar total root growth and horizontal and vertical root distribution after transplanting in the field. Transplants and direct-seeded plants allocated 72% of the total root mass in the upper 0 to 10 cm of the soil. Both transplant types had similar fruit yields, but each yielded more than direct-seeded plants. Transplants grown with the flotation system were recommended for use provided that seedlings are grown and maintained with minimum hardening before establishment in the field.

Recently, Vavrina and co-workers (Vavrina et al., 1994) evaluated the impact of transplanting on tomato and pepper growth and yield. Vavrina et al. (1994) reported that pepper transplant growth in Florida benefited from deeper planting during stand establishment in spring and fall. After 30 days in the field, peppers planted to the first true leaf or cotyledon leaves had more leaves, a larger leaf area, earlier bloom, reduced lodging, and more shoot dry matter accumulation than plants set at rootball depth. By 60 DAT (days after transplanting), increased dry matter accumulation trends with deeper plantings were still evident. Seasonal effects on pepper morphology were also evident. Peppers planted in the fall had more leaves, larger leaf area, and higher shoot dry weight (30 DAT) than peppers planted in the spring.

The advantage of deeper planting was extended to not only plant structure, but also to harvest. First harvest yield was 26% and >17% total yield higher with pepper transplanted to cotyledons rather than the rootball depth. Individual fruit weight was unaffected by planting depth.

Despite various cultural regimes, cultivars, and soil types, deeper planting of pepper transplants grown with subsurface irrigation and polyethylene mulch in the subtropics led to increased yields and fruit size, providing a competitive marketing edge for the grower. Similar results were obtained by increased planting depths for tomato (Vavrina, 1995).

Fertilization and irrigation practices

Recommendations for fertilizing Solanaceous crops should be based upon data obtained through replicated field trials and documented in writing. Over the years, fertilization rates used by tomato and pepper growers were excessive, often more than twice the recommended rate.

On the sandy soils of Florida, fresh market tomatoes can be successfully grown on even less nitrogen (125 vs 200 kg/ha) than recommended (Hochmuth, et al., 1987; Hochmuth, et al., 1989). In some cases, N higher than 200 kg/ha appears to depress yield (Clark, et al., 1991; Hochmuth, et al., 1987; Hochmuth, et al., 1989). This would indicate that growers' current N rates are depressing their yields.

With regard to K fertilization, research has shown responses to around 200 kg K/ha, even on a very sandy soil with very low residual K (Hochmuth, et al., 1991). In some cases, there is very little response to K above 100 kg K/ha (Locascio, et al., 1994). Tomato response to K is maximized at 150 to 200 kg K/ha which is slightly less than the recommended rate. Very little effect of N or K has been found on fruit quality (Hochmuth, et al., 1991; Locascio, et al., 1994).

Many times pepper growers also use twice the recommended rate of fertilizer. Under Florida conditions, there is little response in pepper yield to K applied above 35 kg/ha, even though current recommendations go as high as 160 kg K/ha (Hochmuth, et al., 1988b). N fertilization for pepper grown in Florida is slightly lower than that recommended for tomatoes (Hochmuth, et al., 1987). The difference between species is that high fertilization rates have been found to decrease pepper fruit quality (Hochmuth, et al., 1995).

Optimized fertility management is tied to water management particularly with drip and seep irrigation (Clark, et al., 1991; Hochmuth, 1992b). N and K leach in sandy soils. Leaching of N into the groundwater could lead to a health hazard. Leaching of both N and K represent lost profits.

Growers need to know the water requirements of their crop (Locascio and Smajstrla, 1989; Clark, 1992) and how these water requirements change with season and planting date. For example, in Florida, Solanaceous crops are planted over a wide window with variable climatic conditions including rainfall, temperature, and day length. Growers should fertilize the crop and not the soil. Also, they must fertilize for crop needs and take into account the nutrients in the soil. With drip irrigation, growers have the opportunity to manage water and fertilizer throughout the season. Fertigation principles for optimum nutrient and water management with drip irrigation have been developed (Hochmuth, 1992a; Hochmuth, 1994b)

With the use of drip irrigation on sandy soils, the time of fertilizer application is critical for maximum yield (Locascio, et al., 1989). Application of all N preplant or all by drip irrigation generally resulted in reduced yield over application of some N preplant with the remainder applied with the drip irrigation system. With all N applied by drip irrigation, early crop growth is reduced, while with all N applied preplant, the late season crop needs are not meet adequately and yields are reduced. Concern for timing of fertilizer application is minimized when tomatoes are grown on soils heavier than coarse sands. With an N requirement of about 200 kg/ha, 20 to 40% of N should be applied preplant with the remainder applied in weekly fertigations during the season. The injected N can be split among 6 to 12 equal injections or injected proportional to growth of the crop

(Hochmuth, et al., 1995). Tissue testing can help monitor plant nutritional status during the season (Hochmuth, 1994a; Hochmuth, et al., 1988a).

Solanacea and methyl bromide

These crops are intensely grown and economic production requires the use of broad-spectrum fumigants, polyethylene mulch, adequate rates of fertilizer, irrigation, and use of pesticides to control foliar insects and diseases. Many Solanaceous growers use a raised bed, plastic mulch production system for tomato, pepper, and eggplant to improve yields (Locascio and Myers, 1974; Locascio, 1987). In addition to warming the soil, reducing leaching of fertilizer salts, and reducing water loss from the bed, the use of polyethylene mulch provides a barrier for preplant fumigation for pest control.

Plant-parasitic nematodes, fungi, bacteria, and weeds are all pests which significantly impact most vegetable crops grown in the southeastern United States and in particular in Florida. Lack of control results in a reduction in yield and quality of the crop. Over the past 25 years, methyl bromide and methyl bromide-chloropicrin combinations have become the overwhelming fumigants of choice with the use of polyethylene mulch due to their excellent effectiveness against a broad spectrum of pests. Application methods are reliable and economical against most pathogen/pests that exist in typical production soils.

Preplant fumigation with methyl bromide or methyl bromide-chloropicrin is highly effective against plant-parasitic nematodes, including the root-knot [*Meloidogyne incognita* (Kofoid & White) Chitwood] nematode, pathogenic fungi such as, *Rhizoctonia solani* Kuhn, *Macrophomina phaseolina* Tassi (Goidanich), and *Fusarium* spp., weeds such as, purple and yellow nutsedge (*Cyperus rotundus* L. And *Cyperus esculentus* L.). Many of these pests are found on most sites where vegetables are grown commercially and control of all is necessary for economic production.

In 1991, methyl bromide was identified as an ozone-depleting substance and was implicated in the depletion of the stratospheric ozone layer. The U. S. Environmental Protection Agency (EPA) mandated a phaseout of all use of methyl bromide by the year 2000. The proposed ban of methyl bromide was later extended to 2001. Although methyl bromide's contribution to ozone depletion has not been scientifically established, this proposed phase-out of methyl bromide is a very serious threat to vegetable production as conducted today. Some chemicals or combinations of chemicals have been identified as possible alternatives, including dazomet, metham sodium, 1,3-dichloropropene (1,3-D), chloropicrin (pic), and pebulate. However, no presently available chemical offers the high level of broad-spectrum control and ease of application of methyl-bromide.

In 1993, studies were initiated by several scientists at several Florida locations to evaluate chemical alternatives to methyl-bromide for polyethylene mulched tomato. In a study at Gainesville where

nutsedge and root-knot nematode were major pests, tomato fruit yields were closely related to the degree of nutsedge and nematode control provided by the various treatments. With no treatment 5 weeks after transplanting tomato, emerged nutsedge plants were 252/m^2 on the bed top. Nutsedge counts were lower per m^2 (number in parenthesis) with methyl bromide 98%-pic 2% (21), methyl bromide 67-33 (32), pic + pebulate (42), and with 1,3-D+17% pic (1,3-D+C-17) + pebulate (53). Counts were higher with pic (95) and 1,3-D+C-17 (126) alone, and with dazomet (232), and metham sodium (188).

Root-knot galling indices were lower on tomato roots in plots treated with methyl bromide and 1,3-D + C-17 than in plots treated with pic, metham sodium, dazomet, and the untreated control. Marketable fruit yield was negatively correlated (P=0.01) with the root-knot galling index. Relative fruit yields were 100% with the two methyl-bromide treatments, 86% with the two pebulate containing treatments, 60 to 70% with pic, 1,3-D + C17, dazomet, and metham sodium, and 40% with no treatment.

In a similar study at Gainesville on a site where root-knot (*Meloidogyne arenaria* race 1) and *Sclerotium rolfsii* were present, relative marketable tomato fruit yields were 100% with the two methyl-bromide treatments (98-2 and 66-33), 77% with 1,3-D + C-17 + pebulate, 74% with pic, 72% with 1,3-D + C-17, 60 to 65% with pic + pebulate and with metham sodium, and 50 to 56% with dazomet and the untreated control.

Studies indicate that no pesticide tested provided the broad-spectrum control provided by methyl bromide. Where nutsedge was present, pebulate with 1,3-D and pic provided partial control of this weed and apparently allowed sufficient plant growth to obtain a 86% relative yield. Where root-knot nematode and soil diseases were more severe, pebulate combined with pic alone and with 1,3-D + pic provided a 74 to 77% relative yield to that provided with methyl bromide. This 14 to 26% yield reduction with alternative fumigants is probably not adequate for long-term economic production of tomato. Thus, the search for a methyl bromide replacement must continue.

Current major pests

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows & Perring, so named for the silvering of infested squash leaves (Perring et al., 1993; Bellows et al., 1994), has become a key pest of vegetables, broadleaf row crops, and ornamentals in much of the tropics and subtropics of the world including Florida. Life stages include the adult, egg, and four nymphal instars, the last of which is often called the pupal stage. High populations can debilitate plants through sap removal and the sun-screening effects of sooty mold accumulation on secretions of honeydew. Moderate populations can induce plant disorders through nymphal feeding (Costa et al., 1993), and even low populations can threaten crops through the transmission of plant viruses, such as tomato yellow leaf curl virus which recently decimated 20,000 acres of processing tomatoes in the Dominican Republic. First detected in Florida in 1986 on poinsettia, the pest quickly spread to vegetable

crops including tomato, cucurbits, and eggplant (Schuster et al., 1989). Heavy infestations on tomato in 1987 and 1988 caused irregular ripening of the fruit, a plant disorder which at first caught growers unaware until after shipment so that losses included harvest and transport costs (Maynard and Cantliffe, 1989).

Tomato mottle geminivirus (TMoV) swept through most production areas of Florida in the fall of 1989 causing widespread damage to tomato crops (Simone et al. 1990). Even more destructive was the Christmas freeze in Florida of 1989 which destroyed the vegetable crop taking the SLWF and TMoV with it. Although massive replanting in January proved financially disastrous due to low prices, the crop was relatively free of SLWF and TMoV, providing a valuable lesson on the importance of a crop-free period to breaking the SLWF and TMoV cycle. After research had shown that weeds were not functioning as significant inoculum sources of TMoV (Polston et al., 1993), growers were urged to destroy all crop residues after the spring harvest and during the summer to maintain fields free of volunteers that could provide inoculum sources for the fall crops. Response to these recommendations was good and incidence of whitefly and TMoV was greatly reduced during fall 1990. The role of beneficial insects in decimating whitefly populations during the summer fallow period was verified by observations of high rates of predation and parasitism in weed hosts (Schuster et al., 1992). Unfortunately, the SLWF and TMoV built up sufficiently during fall harvest to carry over into the spring crop, accounting for much of the estimated $125 million of losses and control costs that crop year. Winter crops such as cabbage provided a bridge to cary SLWF populations from fall into spring cropping seasons (Schuster et al.,1992). Crop rotation and spatial separation were recommended to separate overlapping fall and spring crops, and pressure the following spring was considerably reduced. UV-reflective aluminum mulches were shown to reduce the numbers of aphid and SLWF adults landing on plants and in reducing or delaying the spread of TMoV (Kring and Schuster, 1992; Csizinszky et al., 1995). They were recommended for grower use early in the outbreak (Schuster et al., 1989) and are now used on an estimated 15% of the tomato acreage in Florida.

In spite of the successful use of crop-free periods and UV-reflective mulches in reducing movement of the SLWF and TMoV into crops, suppression of whitefly populations is still a necessity. This is accomplished with insecticides by commercial vegetable growers, although studies in an isolated organic vegetable farm have demonstrated the potential of biological control (Stansly et al., 1994). A limited number of chemical alternatives were identified from screening over 45 products or product combinations in the laboratory and greenhouse (Schuster et al., 1989). These chemical options were limited to foliar applications of generally broad-spectrum insecticides, although oils and household detergents were also used. Tank mixes of organophosphates and pyrethroids became increasingly popular as SLWF pressure increased over the season and over the years. Growers were recommended to rotate among chemical classes in order to avoid the development of insecticide resistance in the whitefly (Schuster et al., 1989). Abaxial leaf surfaces must receive good coverage in order for whitefly control to be effective. Hydraulic sprayers are most commonly used, although air-assisted sprayers have

also demonstrated their ability to achieve better underleaf coverage and whitefly control in some cases (Stansly et al., 1991). Booms are equipped with drops for spraying staked tomato and up to eight nozzles per row are required to cover the entire plant canopy.

While this technology has generally been adequate to control in-field populations, susceptibility to some insecticidal products has declined (Stansly et al., 1991) and late season control of populations has become increasingly difficult, especially under large-scale immigration of whiteflies from adjacent crops. This latter scenario has become more common as market temptations override pest control considerations (Schuster et al., 1993). Fortunately for many growers, the systemic insecticide imidacloprid was made available in 1994 for soil application. Tests have shown that imidacloprid can provide effective suppression of SLWF populations and TMoV movement for up to 60 days after a single at transplant application (Stansly and Cawley, 1994). Label restrictions allow for only small amounts per crop applied in the field, although growers are hopeful that the necessary regulations and technology will someday be in place so that seedlings may be treated preplant. For now, imidacloprid is best applied at or soon after transplanting directly to the root ball. Efficacy and/or duration of activity could be a function of plant population.

Imidacloprid is a powerful chemical tool for SLWF control which must be used wisely to avoid development of resistant populations. The restriction to one application per crop at a rate too low to give season-long control is necessary to limit exposure to the chemical to only part of the crop cycle, preferably the early part when protection is most critical and imidacloprid most effective. Different chemistry should be used in the latter portion of the crop cycle if necessary. This strategy should help preserve all our presently available insecticides.

Ultimately, we must find non-chemical or less disruptive means of managing the SLWF and other insect pests. Surveys of natural enemies attacking the SLWF in Florida have identified 11 species of tiny parasitic wasps (Evans, 1993) and 12 species of predators (Dean, 1994). Biological control by these natural enemies is one of the major factors in the reduction of whitefly populations on weeds during the crop-free period in Florida (Schuster et al., 1992), and has been shown to provide effective control there in organically grown vegetables and unsprayed peanuts (Stansly et al., 1994). We are seeking ways of realizing the potential of biological control in commercial tomato production in Florida through the use of habitat manipulation to provide trap crops for the whitefly and refugia for whitefly natural enemies (Schuster et al., 1994). Perhaps imidacloprid and other specifically targeted biorational insecticides for both whitefly and other pests like armyworms and non-chemical controls such as mating disruption for the tomato pinworm (Jenkins et al., 1990) can provide a transition toward the goal of full biological control of SLWF.

Thrips and tomato spotted wilt virus

Tomato spotted wilt virus (TSWV) affects both yield and fruit quality. TSWV is a world-wide problem affecting most Solanaceous crops and has reached epidemic proportions in the southeastern United States. TSWV was first observed in North Florida in 1986. Currently, tomato crops in this area of the world receive up to 30 applications of insecticide a season to control the thrips vectors.

A multidisciplinary research program has been initiated to understand the ecology of TSWV and it's vectors in North Florida (Chellemi et al., 1994a, 1994c; Salguero et al., 1991). This is a necessary first step in the development of long-term sustainable management program.

There are four species of thrips present in Florida which are known to vector TSWV. They are the onion thrips [*Thrips tabaci* (Lindeman)], the western flower thrips [(*Frankliniella occidentalis* (Pergande)], the tobacco thrips [(*F. fusca* (Hinds)], and *F. schultzei* (Trybom). Transmission of TSWV by the melon thrips (*Thrips palmi* (Karny) and the eastern flower thrips (*F. bispinosa*) has not been determined using Florida isolates of the virus. *Thrips palmi* does not transmit TSWV in Hawaii but does transmit similar type viruses in Brazil and Japan. The seasonal dynamics of TSWV vectors in a North Florida ecosystem were studied by sampling all plant species within a 0.5 km radius of two commercial tomato production fields for presence of flower-inhabiting thrips species (Chellemi et al., 1994a). The survey consisted of weekly samples taken over an 18 month period. A total of 37 wild plant species were sampled from which 2583 specimen were collected from 32 of those plants species.

Approximately 87% of all adult thrips collected belonged to the genus *Frankliniella*. Six plant species were responsible for the majority of thrips collected in north Florida, but the situation is reverse in south Florida, where 90-95% of the collected thrips were *T. palmi*.

Studies were also undertaken to access the impact of insecticide applications on the epidemiology of TSWV. In unsprayed plots, *F. occidentalis* (the Western flower thrips and the primary vector of TSWV in spring production) was the dominant species (other than tomato, *T. palmi* is the most dominate one in south Florida) (Chellemi et al., 1994c). However, it was soon replaced by two endemic thrips species that are not vectors of TSWV. In plots receiving frequent insecticide applications, *F. occidentalis* remained the dominant species throughout the season. Thus, frequent insecticide applications were shown to alter the species assemblage of flower-inhabiting thrips in favor of the principal vector of TSWV. In summary, this process selects for the very pest we are trying to control.

Frequent insecticide applications can slow the rate of epidemic development by preventing secondary spreads within fields. However, they can not prevent epidemics from occurring due to the abundance of wild hosts for the virus and its vectors and the failure of insecticide

programs to eliminate populations of the vector. The greatest weapon against the effects of TSWV will be plant resistance to the virus.

Bacterial wilt

Bacterial tomato wilt, caused by *Pseudomonas solanacearum*, is a limiting factor for tomato production in many tropical, sub-tropical, and warm temperate regions of the world (Hayward, 1991). In Florida, bacterial wilt of tomato was first reported in 1897 (Rolfs, 1898) and has caused sporadic losses in the southern region of the state (Sonoda et al., 1979). In the 2000-ha Quincy tomato production area in northern Florida, recent crop losses due to bacterial wilt have been especially severe and in some cases have forced growers to abandon entire fields.

Crop rotation is not a viable alternative because the bacterium is indigenous to soils of Florida and Georgia (Jaworski and Morton, 1964; Sonoda, 1978) and can persist indefinitely in infested fields. Soil fumigation does not provide acceptable levels of season-long disease control (Enfinger et al., 1979). Developing resistant cultivars is the most logical solution for suppressing bacterial wilt epidemics. Although the emphasis of bacterial wilt research in Florida has been on developing resistant cultivars, a cultivar having resistance to *P. solanacearum* and good horticultural characteristics has been difficult to obtain (Scott et al., 1993; Sonoda et al., 1979).

Several bacterial wilt-tolerant genotypes have been released (Anais, 1986; Henderson and Jenkins, 1972; Jaworski et al., 1987), but the resistance often breaks down outside the specific region in which they were developed (Scott et al., 1993). The inability of resistant genotypes to perform consistently in different locations has been attributed to environmental influences such as temperature (Krausz and Thurston, 1975; Mew and Ho, 1977; Sonoda, 1978) and variability among *P. solanacearum* strains (McLaughlin and Sequeira, 1989; Prior et al., 1990). One way to overcome this problem is to develop a screening process that accounts for the various factors affecting resistance. Assessing pathogen diversity and using a combination of resistance screening techniques can facilitate the evaluation of many genotypes, account for potential regional variability in the pathogen, and differentiate levels of field resistance to tomato bacterial wilt (Chellemi et al., 1994).

Concluding Remarks

Solanacea produced for fresh market must be harvested, transported, and sold to the consumer at their peak of quality (internal and external). Many problems continue to face producers wherein economical returns can be greatly reduced. Generally, at present, pests (insect and disease) and their control head the list of these potential problems. Hard to control insects such as thrips and whiteflies, various viruses, and soiborne diseases all threaten world production of many commonly marketed Solanacea species.

Regardless of the threat of outside problems over the years, producers have increased yields and quality of Solanacea crops to the point wherein yields are in excess of 4-fold of average quantities 25 years ago. The use of chemicals, improved plant practices, new irrigation and fertility management have all contributed to these increases. By far however, a major contribution to these increases can be attributed to improved germplasm and the widespread use of hybrid varieties on a world-wide basis. Continued improvements in germplasm through traditional plant breeding, use of wild species, and new improvements via modern plant molecular biological techniques give a bright future for Solanacea crop producers.

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