Know-how for Horticulture™

IPM Strategy to reduce tomato spotted wilt virus (TSWV) in the dry tropics

Dale Abbott
Bowen Crop Monitoring Services Pty Ltd

Project Number: VG98006

VG98006

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry and Queensland Fruit and Vegetable Growers.

ISBN 0 7341 0525 8

Published and distributed by:
Horticultural Australia Ltd
Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

Horticulture Australia

IPM STRATEGY TO REDUCE TOMATO SPOTTED WILT VIRUS (TSWV) IN THE DRY TROPICS VG98006

Dry Tropics Region
North Queensland
1998 - 2001

BOWEN CROP MONITORING SERVICES PTY LTD

A Project Funded by

Queensland Fruit & Vegetable Growers

Horticulture Australia Ltd

VG98006

Principal Investigator

Dale V. Abbott
Principal Consultant
Bowen Crop Monitoring Services Pty Ltd
P.O. Box 4
BOWEN QLD 4805

Ph : 07 47 866 100
Fax: 07 47 866 099
Email: bowcrop@tpg.com.au

The purpose of this report is to inform growers and industry that integrated pest management centred on cultural management tactics can effectively reduce crop loss from Tomato spotted wilt virus in tomatoes and capsicums.

Bowen Crop Monitoring Services Pty Ltd wish to express their thanks for the support and financial commitment given by

Queensland Fruit & Vegetable Growers

Horticulture Australia Ltd

HRDC Project Number: VG98006

Principal Investigator:	Dale V.Abbott Bowen Crop Monitoring Services Pty Ltd 7 West Street Bowen QLD 4805
Key Researchers:	Sally Abbott Bowen Crop Monitoring Services Pty Ltd 7 West Street Bowen QLD 4805
	Chris Monsour Bowen Crop Monitoring Services Pty Ltd 7 West Street Bowen QLD 4805

Funding Sources and Acknowledgements:

Voluntary contributions for a Pilot Study, the precursor of this project, were received from the Bowen District Growers Association Incorporated. Taxonomist John Donaldson, (Queensland Department of Primary Industries, Indooroopilly) and his staff gave valuable instruction and information on thrips taxonomy. The ELISA and pathogen testing services of TAS Ag and the assistance given by Peter Cross made a valuable contribution to this project. The communications and personal contact with thrips expert Laurence Mound (CSIRO) was of excellent benefit to the project along with the co-operation and assistance of virologist Dennis Persley (Queensland Department of Primary Industries, Indooroopilly).

Horticulture Australia

Queensland Fruit & Vegetable Growers

TABLE OF CONTENTS

1. INDUSTRY SUMMARY

Management of TSWV is dependent on a sound understanding of the relationship between thrips dynamics and TSWV infection. The transmission of TSWV depends on the species of Thysanoptera vector, their ecotype and developmental stages, and the interaction between vector, infected host and the virus isolates in a particular region.

Tomato spotted wilt virus (TSWV) has become an increasing problem in solanaceous crops in the Dry Tropics. In 1997 some fresh market tomato, capsicum and chilli crops were infected at critically high levels, up to 75% infection. The Dry Tropics region (Bowen, Gumlu and the Burdekin) is Australia's major winter producer of these crops. Tomatoes have an estimated value of \$80 million; capsicums and chillies have an estimated value of \$30 million.

Control procedures based solely on chemical management have contributed to rapid resistance buildup in thrips populations. Host plant resistance and the development and incorporation of resistant cultivars are the ideal management strategy. However at the instigation of this project there were minimal selection programmes for TSWV resistant lines in tomatoes, capsicums and chillies. Breeding programmes take time. The TSWV problem was immediate and a rapid action research response was required.

An integrated pest management system for *F.schultzei* and TSWV was developed to interrupt the relationship between the virus, tomato spotted wilt virus (TSWV), the predominant thrips vector, *Frankliniella schultzei* and the main crop and weed hosts. These dynamics included the identification and determination of *F. schultzei* as the predominant thrips species, its seasonal incidence and pattern, the symptom expression in crop, the identification of alternate crop and weed hosts and the identification of TSWV reservoir plants. To achieve these objectives, the researchers, in collaboration with local growers, examined the biology and distribution of *F.schultzei* and TSWV in and surrounding the crop, and incorporated cultural and chemical management options. A series of Best Management Options (BMO) were designed and implemented to incorporate new techniques rapidly into commercial operations.

The key outcome of this project has been a reduction in TSWV incidence in tomato and capsicum (and chillies) crops in the Dry Tropics over the last three years. This equates to less than 5 percent crop loss in the 2000/2001 seasons. This was achieved by the adoption of an integrated crop management programme concentrating on cultural management tactics to reduce the population of *F.schultzei* and consequently the incidence of TSWV. As a result of this project there has been minimal impact to crops with yields being maintained.

Grower awareness and adoption of these practices was achieved rapidly due to the daily communication between the consultants/researchers and growers. The degree of influence to which the consultants/researchers have on the pest management of approximately 3000 hectares of tomatoes, capsicums, chillies in the region had a significant effect on the implementation of cultural and chemical management tactics.

The researchers have detected and positively identified western flower thrips (*Frankliniella occindentalis*) in capsicums in the Burdekin region in October 2001.The researchers have identified, in conjunction with QDPI virologists, a second tospovirus in the Dry Tropics region. Capsicum chlorosis virus (CaCV) was identified in the Burdekin region in 2001. This presents a change of focus for future thrips management. The crop management tactics employed for tomato thrips will be useful and directly applicable for WFT management.

2. TECHNICAL SUMMARY

During 1996 and 1997 the incidence of TSWV in tomatoes, capsicums and chillies grown in the Dry Tropics (Bowen and Burdekin) reached levels that threatened an industry worth $110 million a year. A project aimed at reducing the incidence of TSWV in susceptible crops in the Dry Tropics was initiated in 1999. The key objectives of the project were to identify local TSWV vector(s), establish their seasonal pattern of incidence, and to develop and implement an integrated pest management strategy to reduce the incidence of TSWV in the Dry Tropics.

A network of sticky traps was established throughout the production area to monitor thrips activity over a three-year period. Qualified taxonomists identified the thrips species trapped and the seasonal incidence pattern of thrips vectors of TSWV was established. Studies incorporating routine monitoring and ELISA testing were undertaken in nurseries and in commercial crops to determine the time at which thrips infected crop hosts.

Surveys of weeds and alternate crop hosts were conducted on-farm and in conjunction with field trials. Twenty-one local weed species from throughout the Dry Tropics were screened for the presence of TSWV using ELISA testing.

The tomato thrips, *Frankliniella shultzei*, was identified as the dominant TSWV vector in the region. The seasonal pattern of *F. schultzei* activity in the region was highly variable and correlated with TSWV incidence in commercial crops.

Nursery studies failed to record any TSWV infection in seedlings prior to planting, primarily due to the frequent application of insecticides that effectively control *F. shultzei*. In-field studies identified the main 'infection-window' as the period between planting of seedlings and the initiation of spraying for other insect pests around flowering. Frequent monitoring from plant-out identified thrips infestations prior to flowering as the primary cause of TSWV infection. Application of registered organophosphate, synthetic pyrethroid, organochlorine, and spinosad insecticides were highly effective in controlling *F. shultzei* and reducing the incidence of TSVW infection in all crop hosts.

Weed surveys identified only isolated individual weed samples infected with TSWV. The range of weed hosts and reservoir plants found in the cropping areas of the Dry Tropics has been narrowed down to a small number of weed species; *Sonchus oleraceus, Nicandra physalodes, Stachytorpheta urticifolia, Coronopus didymus*, *Ipomeae lonchophylla.*

Cultural management tactics based on a series of cumulative on farm-applied practices or best management options (BMO's) were developed. These were tested, refined and incorporated very rapidly into commercial practice.

The key outcome was a reduction in TSWV incidence in crop in the Dry Tropics over the last three years to less than 5 percent crop loss in 2000/2001 seasons. This was achieved by the adoption of an integrated crop management programme concentrating on cultural management tactics to reduce the population of *F.schultzei* and the incidence of TSWV in the Dry Tropics. This has resulted in minimal impact to crops and ultimately yields are being maintained.

Western flower thrips (*Frankliniella occindentalis*) was identified in crop by the researchers during the project. A second tospovirus, Capsicum chlorosis virus (CaCV) was also identified. This is a significant change of focus for future thrips pest management. The crop management tactics already adopted for tomato thrips can be directly applied to western flower thrips.

3. INTRODUCTION

Management of TSWV is dependent on a sound understanding of the relationship between thrips dynamics and TSWV infection. The transmission of TSWV depends on the species of Thysanoptera vector, their ecotype and developmental stages, the interaction between vector, infected host and the virus isolates in a particular region.

Tomato spotted wilt virus (TSWV) has become an increasing problem in solanaceous crops in the Dry Tropics. In 1997 some fresh market tomato, capsicum and chilli crops were infected at critically high levels, up to 75% infection. The Dry Tropics region (Bowen, Gumlu and the Burdekin) is Australia's major winter producer of these crops. Tomatoes have an estimated value of $80 million; capsicums and chillies have an estimated value of $30 million.

A failure to develop effective control methods would severely affect the regions producers and reduce supply to domestic and export markets. The development of an effective thrips/TSWV management system for the Dry Tropics was the objective of this project.

An integrated pest management system for *F.schultzei* and TSWV must aim to interrupt the relationship between the virus, predominant thrips vector and the plant hosts. To achieve this we must look at the biology and distribution of *F.schultzei* in and surrounding the crop, and incorporate cultural and chemical management options. Control procedures based solely on chemical management have contributed to rapid resistance buildup in thrips populations. The sole reliance on chemicals for thrips control will almost inevitably lead to resistance, as has happened with other crop pests ((Lewis, 1997). Repeated applications of pesticides have caused high levels of resistance and cross resistance (Parella and Lewis, 1997).

Host plant resistance and the development and incorporation of resistant cultivars are the ideal management strategy. However at the instigation of this project there were minimal selection programmes for TSWV resistant lines in tomatoes, capsicums and chillies. Breeding programmes take time and the TSWV problem was immediate and a rapid action research response was required.

Prior to the instigation of this project standard practice for the control of TSWV in the Dry Tropics region involved:

a. All thrips species were not considered a pest management issue in capsicums, chillies and tomatoes

b. It was generally accepted that the thrips species, *Thrips tabaci* (onion thrips) was the main species in the region

c. Limited crop monitoring from transplanting to 2 weeks of age for vector pests in the early growth stages of capsicums and tomatoes

d. Broad-spectrum organophosphates were applied in the early growth stages on a routine basis whether thrips were present or absent

e. Surrounding on- and off -farm weed habitats were not considered in overall farm and pest management systems.

To develop a management system for this pest it is critical to have an understanding of regional population dynamics of the predominant thrips species in affected and surrounding crops and weeds. These dynamics include the identification and determination of a predominant thrips species, its seasonal incidence and pattern, the symptom expression in crop, the identification of alternate crop and weed hosts and the identification of reservoir plants.

4. IDENTIFICATION OF PREDOMINANT THRIPS SPECIES

INTRODUCTION

The Order Thysanoptera contains almost 5000 species of thrips worldwide with more than 95% of all thrips species placed in one of two families, the Phlaeothripidae or the Thripidae. Thripids have a saw-like ovipositor at the apex of the abdomen with which the females insert their eggs into plant tissue; members of this family usually feed on plant tissues, although a few are predatory on other small arthropods (Mound and Gillespie, 1997). Within this family, there are a number of species that are known vectors of tomato spotted wilt virus (TSWV). The transmission effectiveness of TSWV depends on the species, the ecotype, the developmental stage and the interaction between the vector, virus isolates and infected hosts in a particular area.

In the Dry Tropics region, specifically Bowen, Gumlu and the Burdekin, tomato spotted wilt virus (TSWV) of tomatoes, capsicums and chillies can be a significant production problem. In 1997 some tomato and capsicum crops suffered up to 75% TSWV infection. Several thrips species were known to be common to the Dry Tropics but no formal studies had been undertaken to determine if there was a predominant thrips species vector. The Bowen District Growers Association supported a pilot study in 1998 to make initial investigations into the cause of TSWV. Preliminary trapping suggested one predominant vector, *Franklinella schultzei*, commonly known as tomato thrips. Correct identification of the predominant thrips species was vital to developing effective crop management tactics to reduce crop loss from TSWV.

MATERIALS AND METHODS

Thrips trapping sites were located throughout the production area, specifically in areas with a history of thrips activity and TSWV infection in field plantings of tomatoes, capsicums and chillies. Trapping for thrips commenced in October 1997. Initially there were 5 key sites, Gumlu, Euri Creek, Bootooloo, Inverdon and Collinsville Road. The number of sites was increased to nine sites and the location of the traps was reassessed in October 1998. Two trapping sites were located at Gumlu and Euri Creek and single sites were located at Bootooloo, Duck Creek, Upper Collinsville Road, Inverdon and in the Burdekin region.

One trap was located at each site. A trap consists of 2 petri dishes, the bases of which contain a sticky layer of 'Tangle trap'. The dishes are attached vertically to each side of a wooden tomato stake with at least one dish facing into the prevailing wind (South-east). Each dish is placed in its white painted lid with the sticky surface facing outwards. Traps were collected and replaced approximately every 2 weeks.

Traps were initially screened in Bowen using a Stereo zoom microscope with a magnification of 80X. The total number of thrips and the species were recorded. Samples of traps and each thrips species were sent to taxonomist, John Donaldson, Queensland Department of Primary Industries (Indooroopilly, Brisbane), to confirm the identification of all thrips species.

RESULTS

The thrips species trapped and identified in Bowen, Gumlu and the Burdekin from October 1997 to March 1999 are presented in Table 1. Of the thrips trapped, three are known vectors of TSWV. The number of thrips of each species trapped was recorded and graphed for each location over the trapping period and an abundance rating was given for each species. *Frankliniella schultzei* (tomato thrips) has been the predominant thrips species recorded for all locations. The second most abundant species has been *Arorathrips mexicanus*, which is not a vector of TSWV, but is a forage grass dweller. Two other known vectors of TSWV have been trapped in this region, *Thrips tabaci* (onion thrips) and *Scirtothrips dorsalis* (chilli thrips), both in very low numbers and on sporadic occasions.

Continued surveillance for any unknown species or variation in species appearance were collected and sent to Laurence Mound (CSIRO, Canberra) for verification. Specimens were identified as the adult females of the pale form of *F.schultzei*. Mound (1999, *pers.comm.*) states that overseas research has found that, in contrast to the dark form, the pale form of *F.schultzei* is not an efficient vector of TSWV. However, in the absence of the dark form of this species, it appears conclusive that the pale form of *F.schultzei,* as observed at all trap sites, is the primary vector responsible for the transmission of TSWV in the Dry Tropics.

DISCUSSION

The abundance of *Frankliniella schultzei* at all trapping sites from October 1997 to March 1999 is graphically presented in Figure 1 and Figure 2. *F.schultzei* activity was markedly higher during the early part of the growing season, February 1998 to April 1998. Trap counts were significantly less late season, October 1997 through to January 1998 and during the winter production period, May 1998 to July 1998. This pattern of activity was similar for all sites, with the Bootooloo (Bowen) area recording the highest trap counts.

Late season, (November/December 1998) tomato and capsicum crops grown in close proximity to the Upper Collinsville Road and Euri Creek Eatough sites suffered crop losses due to TSWV. *F.schultzei* activity was recorded at both sites as indicated in Figure 2. Increasing thrips activity in the early part of the 1999 cropping season was recorded at the Bootooloo site.

The results of this research were presented at a Bowen District Growers Association meeting in March 1999. Tomato and capsicum growers were present, QDPI personnel, speedling nursery operators and chemical company representatives. The Principal investigator gave ABC Rural Radio reports every fortnight on thrips activity and prevailing levels of TSWV infection levels in crop. Research results were included in the March/April 1999 issue of the 'Western Flower Thrips Newsletter'. This newsletter is for scientists and researchers working with the National strategy for the management of western flower thrips and TSWV. An editorial written by the researchers titled "*Round the Traps*" appeared in the North Queensland Horticultural Journal, November 1998.

The identification and confirmation of *F.schultzei* as the predominant thrips vector was an essential step towards designing an effective crop management strategy for the control of TSWV in the Dry Tropics.

Table 1. Thrips species trapped in Bowen/Gumlu/Burdekin, October 1997 to March 1999.

Thrips Trapped and Identified		Common Name	Vector of TSWV	Abundance Rating
Family	***Genus/Species***			
THRIPIDAE	*Frankliniella schultzei*	Tomato thrips	Yes	*****
	Arorathrips mexicanus			**
	Anaphothrips sudanensis			*
	Thrips hawaiiensis	Banana flower thrips		*
	Thrips imaginis Bagnall	Plague thrips		*
	Thrips tabaci	Onion thrips	Yes	*
	Megalurothrips usitatus	Bean blossom thrips		*
	Caliothrips striatopterus			*
	Chirothrips spiniceps	*First record in Australia*		*
	Neohydatothrips sp.			*
	Philalothrips longiceps			*
	Scirtothrips dorsalis	Chilli thrips	Yes	*
	Scolothrips sp.			*
	Selenothrips rubrocinctus	Red-banded thrips		*
	Microcephalothrips abdominalis	Composite thrips		*
	Unidentified species			*
AEOLOTHRIPIDAE	*Aeolothrips sp.*			*
	Desmothrips sp.			*
	Gelothrips cinctus			*
	Pseudanaphothrips sp.			*
PHLAEOTHRIPIDAE	Unidentified species			*

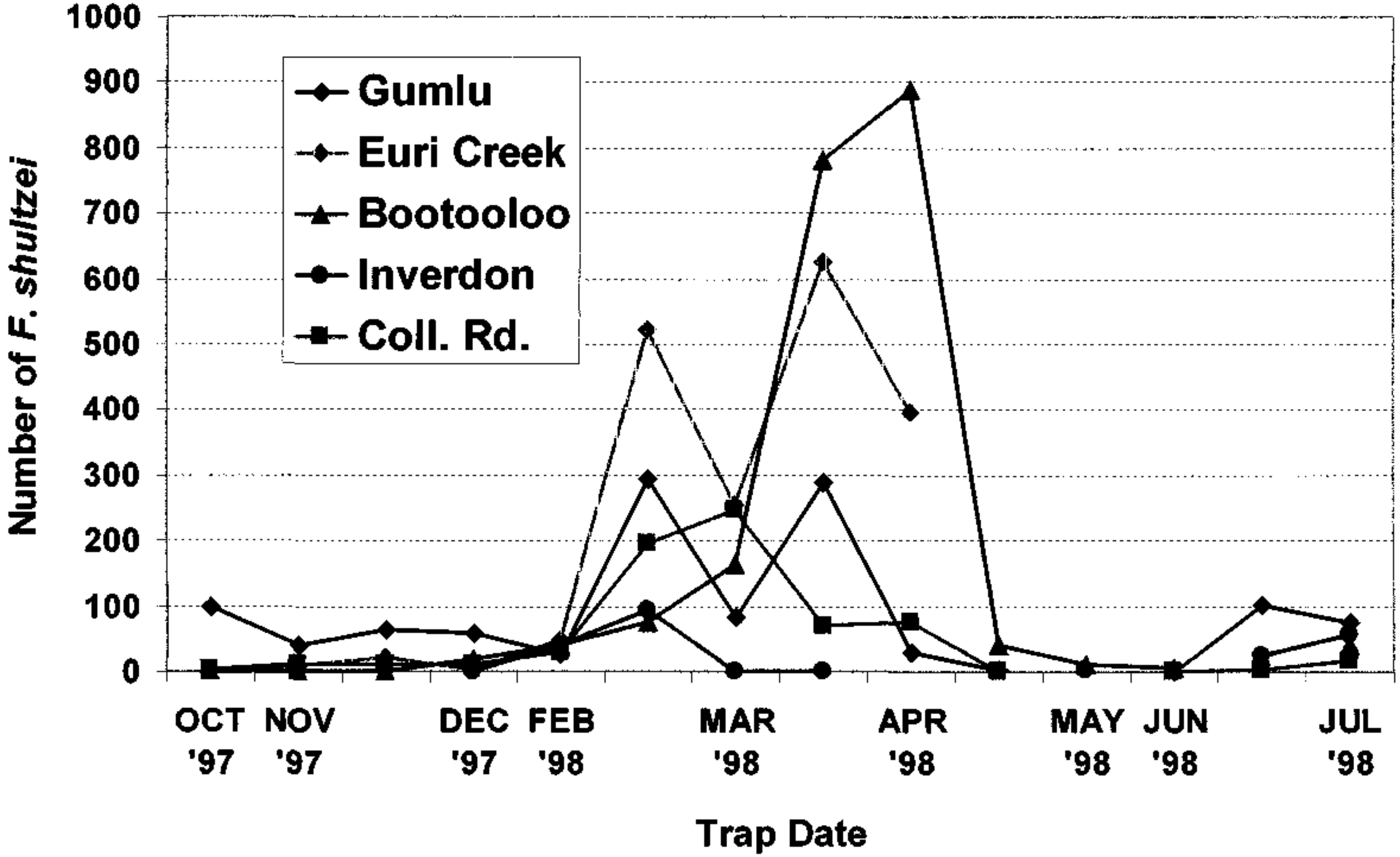

Figure 1. Abundance of *Frankliniella shultzei* at five sites in the Dry Tropics, 1997/98

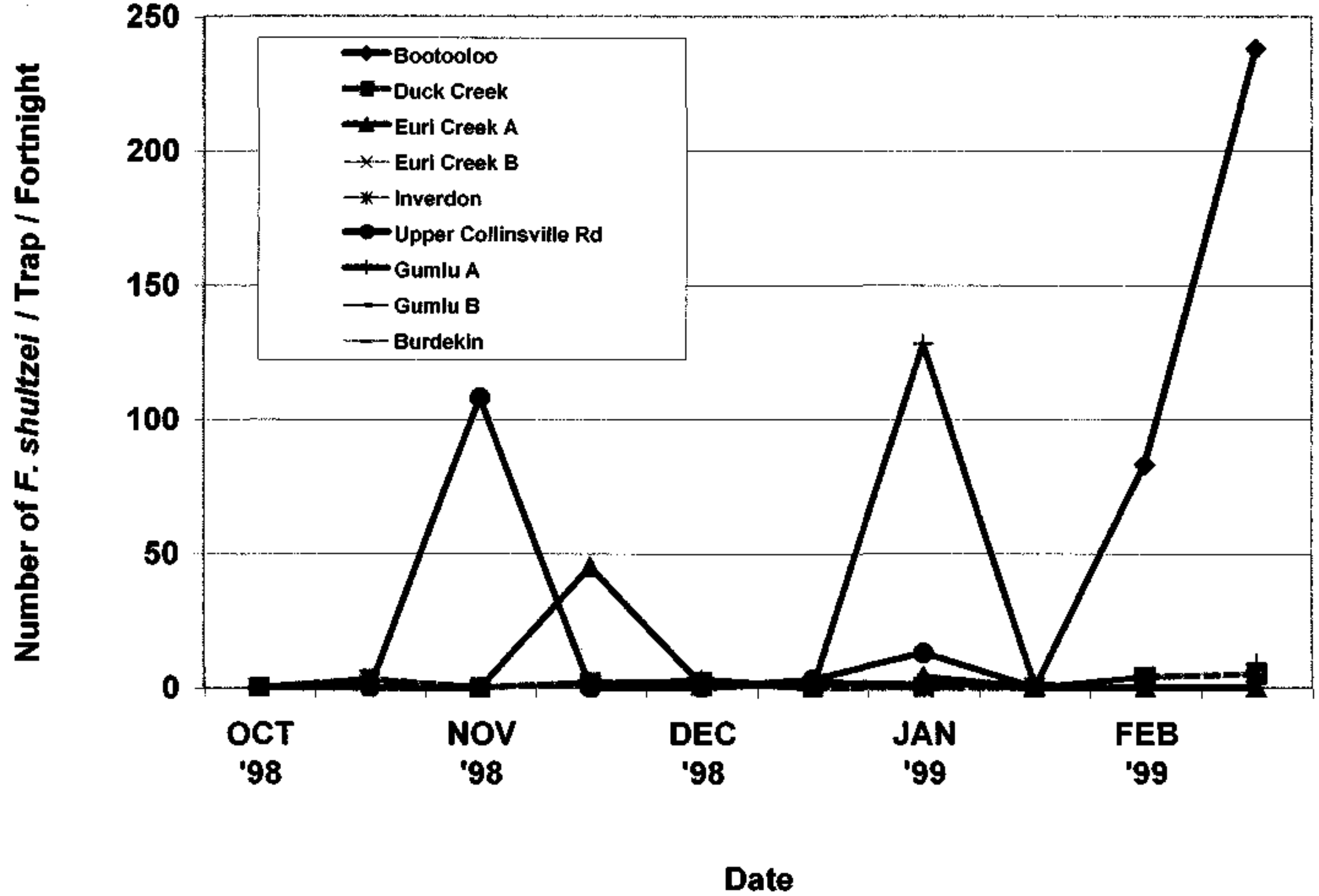

Figure 2. Abundance of *Frankliniella shultzei* at nine sites in the Dry Tropics, 1998/1999.

5. SEASONAL INCIDENCE AND PATTERN OF *Franklinella shultzei.*

INTRODUCTION

This project has identified tomato thrips, *Franklinella shultzei* as the dominant thrips species and major thrips vector of tomato spotted wilt virus in tomatoes and capsicums in the Dry Tropics of North Queensland. The objective of identifying the seasonal pattern of *F.shultzei* was to relate thrips incidence with the following factors:

- Primary host sources, TSWV 'Reservoir' plant species and alternate crop hosts.
- TSWV incidence in adjacent plantings.
- Presence of weed hosts.

The seasonal incidence and pattern of this pest will dictate the design and implementation of the best management practices of this disease.

MATERIALS AND METHODS

Six trapping sites were located throughout the production district, specifically in areas with a history of thrips activity and TSWV infection in field plantings of tomatoes, capsicums and chillies. Where possible, traps were located adjacent to field plantings of tomatoes or capsicums. These sites were at Gumlu, Euri Creek A and B, Upper Collinsville Road, Inverdon and Bootooloo Road. Trapping of thrips using white petri dish sticky traps ('Tangle trap') was undertaken in six locations for the life of the project. Traps were collected and replaced approximately every 2 weeks. The researchers used an 80X Stereo zoom microscope to screen all traps. Thrips species that could not be identified as *F.schultzei* were sent to John Donaldson (QDPI taxonomist) for positive identification. Total numbers of *F.schultzei* were counted and recorded for each location.

RESULTS

The abundance of *F.shultzei* at six trapping sites from 1997 to 2001 is graphically presented in Figure 3. During the 1998/1999 seasons, *F.schultzei* continued to be the dominant thrips species and the only known vector of TWSV trapped. Continued surveillance for any unknown species or variation in species appearance were collected and sent to Laurence Mound (CSIRO, Canberra) for verification. High levels of tomato thrips were recorded in 1998, February to June. This equates to over 900 thrips per trap per month. The high thrips activity in this late Summer and Autumn period also corresponded to high levels of tomato spotted wilt virus (TSWV) in crops being monitored by consultants during this time. This period corresponds to early season cropping, with tomatoes and capsicums seeded in nurseries from January onwards and field transplanting commencing in mid–February.

Thrips activity in 1999 and 2000 decreased significantly to approximately 30% of the previous years' trap catches. Thrips counts peaked at 320 per trap per month in February 1999 with a similar peak of 420 thrips in August 2000. Thrips activity from August 2000 to June 2001 continued to decline to a very low level. A trap catch of 7 tomato thrips for the month was the highest recording during this period. Regular crop monitoring by consultants, during this time, revealed that in crops of tomatoes and capsicums, TSWV infection was not greater than 5%.

DISCUSSION

High levels of *F.schultzei* were recorded between February and June in 1998. This equates to over 900 thrips per trap per month. This high thrips activity also corresponded to high levels of tomato spotted wilt virus (TSWV). Several peaks in *F. schultzei* activity occurred from October 1998 to the end of September 1999 with significant variation in the time of the peaks recorded at various sites. The first peak occurred during late November/early December 1998 at two Bowen sites only.

In 1999, an early peak was recorded at Bootooloo site in late February, but this was prior to any planting of crop at the site. Peaks were recorded in Gumlu in January 1999 and early April, however for the remainder of the year, thrips numbers were very low. In 1999, *F. schultzei* activity in Bowen was highest in the Euri Creek district from May through to August. During the same period, the Inverdon site recorded low levels of *F. schultzei* activity. *F. schultzei* numbers in the Burdekin have been very low at all times and this has been reflected in very low levels of TSWV in capsicums in the district.

Compared to the 1997/98 trap data generated during the Pilot Study, *F. schultzei* activity was significantly lower and the seasonal pattern quite different during 1998/99 (Figure 2). A prolonged period of high *F. schultzei* activity occurred at a number of sites early in 1998, however in 1999, a single smaller peak was recorded at one Bowen site only. The majority of *F schultzei* activity has been recorded at two Euri Creek sites during the winter months (May to August), which have traditionally been a period of low thrips activity and TSWV infection. Tomato thrips activity in 1999 and 2000 decreased significantly with a peak of 320 thrips per month in February 1999 and a peak of 420 thrips per month in August 2000. Thrips activity from August 2000 to June 2001 was very low with the highest trap count per month recording 7 thrips. This also corresponded to a very low level of TSWV, less than 5 percent crop loss in tomatoes and capsicums.

The trap data in conjunction with regular crop monitoring conducted throughout the Dry Tropics has shown that the bursts in activity during 1998/99 were not sustained for any length of time. The seasonal pattern of *F.schultzei* to date has been a short burst of high activity followed by a period of sustained low activity. The 1999 and 2000 seasons were typical of this trend, characterized by a short burst of activity in July/August 1999 followed by a sustained low activity period from October 1999 to August 2000.

The level of TSWV in crop has also decreased over this 3-year period. This is possibly a result of the dry conditions experienced over the last 2 years. A return to a normal wet season would help to confirm this trend. The 1999/2000 seasons recorded very low levels of tomato spotted wilt virus, less than 5% crop loss due to the virus. This directly correlates with the lower levels of *F. schultzei* activity recorded during this period.

Three years of trapping of trapping has shown the variability in the seasonal pattern of *F. schultzei* activity in the region. It has also indicated that when *F.shultzei* numbers are low TSWV incidence in crop is also low. This correlation can be factored into the development of cultural management tactics for TSWV in the Dry Tropics.

The identification and confirmation of *F.schultzei* as the predominant thrips vector was an essential step towards designing an effective crop management strategy for the control of TSWV in the Dry Tropics.

The results of this research were presented at a Bowen District Growers Association meeting in September 1999. Tomato and capsicum growers were present, QDPI personnel, speedling nursery operators and chemical company representatives. The Principal Investigator on ABC Rural Radio presented updates on thrips activity in the district and the progress of the research every fortnight. Research results were included in the March/April 1999 issue of the 'Western Flower Thrips Newsletter'.

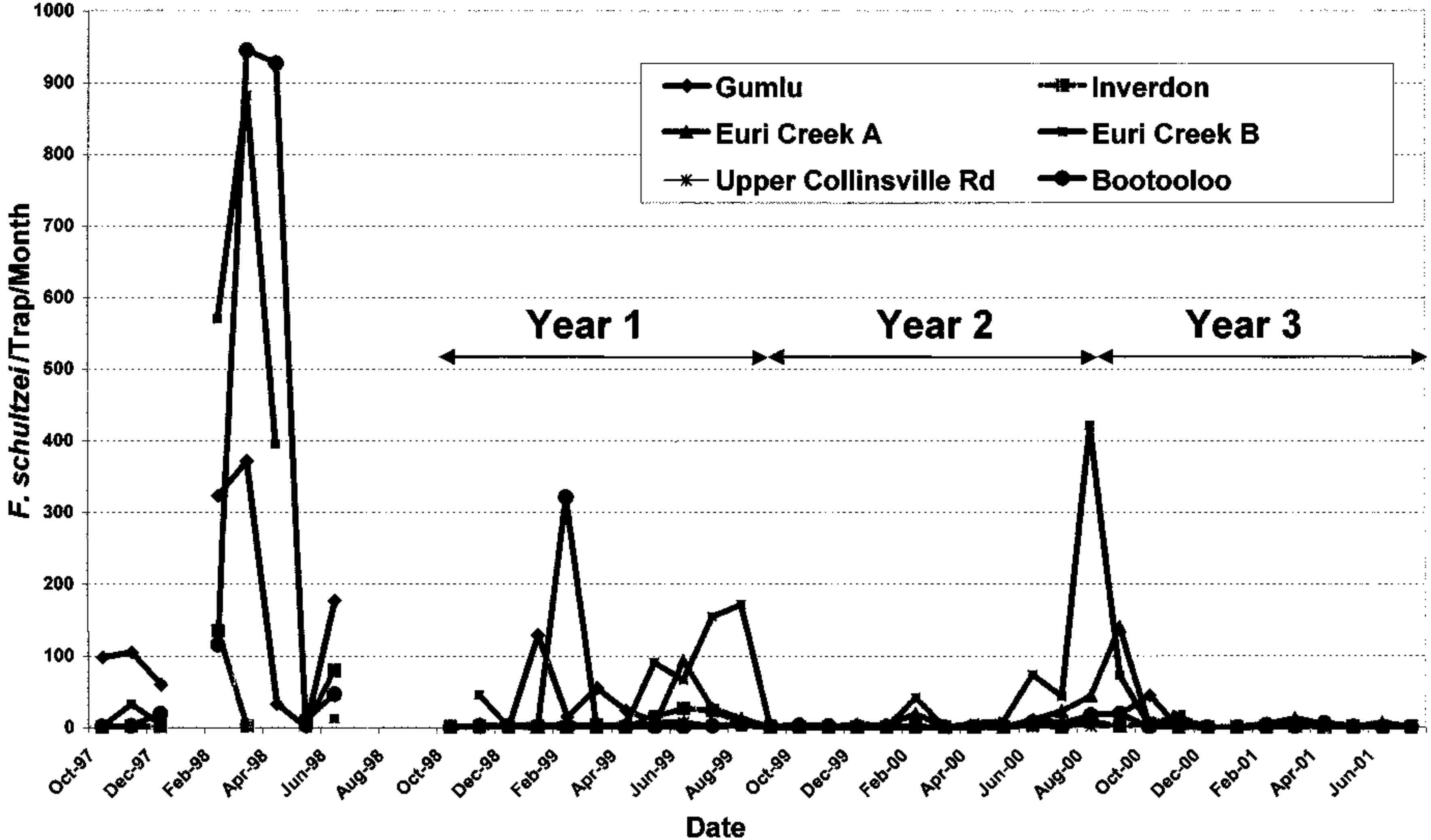

Figure 3. Abundance of *Frankliniella schultzei* at 6 sites in the Dry Tropics, October 1997 to June 2001.

6. Nursery and Field Symptom Expression Studies

INTRODUCTION

Understanding the interactions between plant, vector and disease is critical to the prevention of TSWV-infection in host plants. Extensive trapping throughout the Dry Tropics production area has identified *F. shultzei* as the dominant vector of TSWV in tomatoes, capsicums and chillies, all hosts of this thrips species. Field observations in the Dry Tropics have shown *F. shultzei* is highly susceptible to insecticides (organophosphates, carbamates, synthetic pyrethroids, spinosads) applied to control the tomato fruitworm, *Helicoverpa armigera*, and other insect pests in these crops.

Despite this, high levels of TSWV infection were recorded in 1996 and 1997, prompting the suggestion that although symptoms of TSWV-infection were not visible until later in the crop's development, infection of host plants was occurring prior to initial insecticide applications. A subsequent review of standard grower practice revealed that insecticides were often not applied prior to flowering, clearly identifying a potential 'infection-window' from when seedlings germinated in the nursery to the time that the first insecticides were applied in the field.

Studies were initiated to improve the understanding of the interactions between *F. shultzei*, TSWV and host plants in the Dry Tropics. The objectives of these studies were:

(i) to determine whether TSWV infection is occurring in seedling nurseries prior to planting seedlings in the field
(ii) to determine the impact of timing of insecticide applications in response to *F. shultzei* infestations in-crop
(iii) to investigate the relationship between the of expression of TSWV symptoms and the timing of infection
(iv) to formulate recommendations to minimise the incidence of TSWV infection.

MATERIALS AND METHODS

Nursery Studies

Sticky petri-dish traps were set up in four seedling nurseries (2 private and 2 commercial) at various locations within the Bowen production area. Traps were replaced fortnightly between March and September, 1999. Traps were inspected microscopically and counts of *F. shultzei* and other thrips species were recorded.

In addition to the routine monitoring, five trials were conducted in seedlings sampled from private and commercial nurseries in Bowen (Table 2). Leaves from 100 plants within a 'seeding' were sampled at random prior to plant-out. Sampled leaves were sent to the Tasmanian Department of Agriculture (TASAG) ELISA and Pathogen Testing Service to ELISA (Enzyme Linked Immunosorbent Assay) test for TSWV. The fields in which the each of the tested seedings was planted were monitored for TSWV incidence throughout the life of the crop.

In the nursery trials conducted in May at the Collinsville Rd and Delta private nurseries, sampled plants were allocated a number and transferred to a separate seedling tray to be planted out in two in-field symptom expression trials.

Symptom Expression Studies

A series of in-field symptom expression trials were conducted to determine when the majority of TSWV infection is occurring in the crop. Two tomato trials were conducted at Upper Collinsville Rd (Trial #1) and Euri Creek (Trial #2) in conjunction with the Collinsville Rd and Delta nursery studies. A third trial was conducted at Dry Creek (Trial #3) in response to infestations of *F. schultzei* in three adjacent plantings of tomato.

In Trials #1 and #2, the plants sampled for ELISA testing in the nursery were planted at random positions within a field and marked with a coloured plot marker with the plant's allocated number. All marked plants were inspected twice weekly for the presence of thrips and the development of any TSWV symptoms. In addition, one leaflet per plant was sampled weekly (for 6 weeks) for ELISA testing for TSWV infection by TASAG. Both blocks were monitored for insect and disease activity as per normal monitoring procedures and spray applications were made according to standard practice.

Trial #3 was conducted in three consecutive plantings of tomatoes at Dry Creek. A small infestation of *F. shultzei* was detected in Planting 1 on 21 May but no insecticide was applied. A second small infestation was recorded in Plantings 1 and 2 on 31 May, followed by a large infestation in all three plantings on 3 June. At this point, twenty plants infested with actively feeding *F. schultzei* (Table 2) in each of three consecutive plantings were marked and sampled weekly (for 5 weeks) for ELISA testing. All three plantings were sprayed with a Bulldock (beta-cyfluthrin) on June 4. The three plantings were all regularly monitored for the development of TSWV symptoms. The location of TSWV-infected plants throughout each planting was mapped just prior to harvest.

Table 2. Incidence of TSWV in three tomato plantings at Dry Creek Rd, Bowen, June 1999.

Planting	Date Planted	% plants infested with *F. schultzei*	Mean *F. schultzei* per plant (SE)
1	18/5/99	100%	5.6 (3.0)
2	25/5/99	100%	4.5 (1.8)
3	1/6/99	62.5%	1.5 (0.7)

Potted Plant Trials

Two potted plant trials, one in tomatoes and one in capsicums, were undertaken to overcome the problems of lack of infection in sampled plants in previous trials. In each trial, one hundred seedlings were planted in pots and placed adjacent to the corresponding field planting. Trial plants were not sprayed with insecticide at any time. Plants were monitored twice weekly for the presence of thrips. Leaves were sampled weekly and sent to TASAG for ELISA testing for TSWV. The timing of expression of TSWV symptoms was recorded.

RESULTS

Nursery Studies

The fortnightly catches of *F. schultzei* on sticky traps in two commercial and two private seedling nurseries in Bowen is shown in Figure 4. Numbers *of F. schultzei* were very low during most of 1999 with small bursts of activity recorded during May and then again in August/September.

All samples from the five study sites (total of 500 samples) were negative for TSWV (Table 3). Monitoring of the blocks where these seedlings were planted in field recorded low levels (<1%) of TSWV. Symptoms of TSWV became visible in these blocks approximately two to three weeks after plant-out in the field.

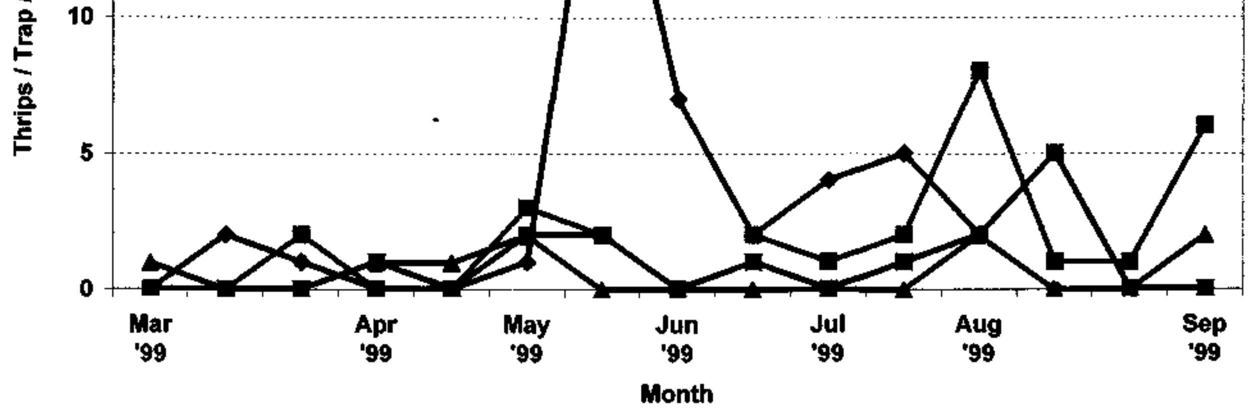

Figure 4. Abundance of *Frankliniella schultzei* at four nurseries in Bowen, 1999.

Table 3. Incidence (%) of TSWV infection in tomato and capsicum seedlings at nurseries in Bowen, 1999.

Location	Nursery	Crop	Month	Plants Sampled	TSWV Positive (%)
Collinsville Rd	**Private**	**Tomato**	**April**	**100**	**0**
Collinsville Rd	**Private**	**Tomato**	**May**	**100**	**0**
Delta	**Private**	**Tomato**	**May**	**100**	**0**
Delta	**Commercial**	**Capsicum**	**July**	**100**	**0**
Delta	**Private**	**Tomato**	**August**	**100**	**0**

Symptom Expression Studies

In-Field Trials

In Trials #1 and #2, very low levels of in-field thrips activity were recorded during the monitoring period. No *F.shultzei* were recorded on marked plants throughout both trials and accordingly none returned a positive result for TSWV. *F. shultzei* were first detected in Trial #1 in very low numbers eight days after plant-out. The first signs of TSWV in infected plants were visible 10-14 days later and ultimately <1% TSWV was recorded at this site.

F.shultzei were not recorded until 14 days after plant-out in Trial #2. The low infestation was quickly controlled by an insecticide application applied for heliothis control. No further infestations were recorded, and <1% TSWV incidence was recorded.

In Trial #3, despite very high levels of *F.shultzei* activity throughout the trial site, all 60 marked plants returned a negative result for TSWV on each of the five sample dates. During the course of the trial, TSWV infection was recorded throughout the trial site. The distribution of TSWV-infected plants across the trial site is shown in Figure 5. Planting 1 had the highest level of TSWV (1% infection), Planting 2 had 0.2% infection, and no infected plants were recorded in Planting 3.

Initial TSWV symptoms were recorded in unmarked plants in Plant 1 and 2 within days of the June 4 insecticide application. Symptoms in infected plants throughout both plantings became visible in an increasing number of plants in the following two weeks, after which time no further plants displayed symptoms.

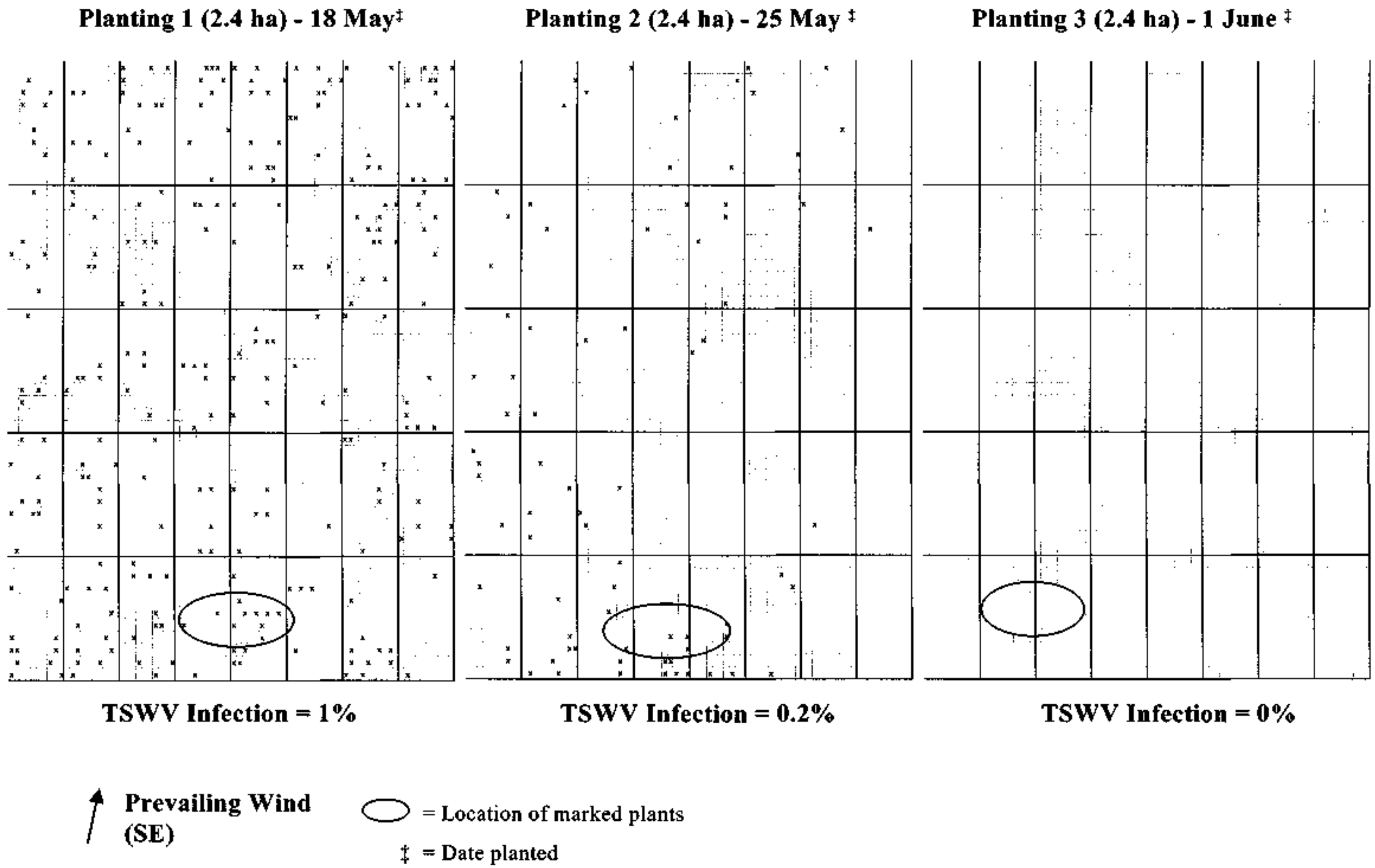

Figure 5. Distribution of TSWV-infected plants in three tomato plantings at the Dry Creek Rd trial site, June 1999.

Potted Plant Trials

Six plants in the capsicum trial returned positive results for TSWV. One plant was infected 3 weeks after transplant while the remainder returned positive results 5 weeks after plant out.

In the tomato trial, four plants returned positive results for TSWV, all in the first three weeks after transplant. In both trials, infection corresponded to the presence of *F.shultzei* detected on plants and initial TSWV symptoms were expressed within a week of the plant returning a positive TSWV ELISA result. In all cases, ELISA testing confirmed the visual symptoms.

DISCUSSION

Because of their ability to migrate long distances, rapidly infest crop hosts and for viruliferous adult *F. shultzei* to transmit TSWV, effective prevention of TSWV infection in susceptible crops in the Dry Tropics centres around early detection of *F. shultzei* infestations, particularly in young plants, and application of appropriate control measures. The period from seedling emergence in nurseries to the initial insecticide application in field was identified as a 'window' in which susceptible hosts are the most vulnerable to TSWV infection.

Low levels of *F.shultzei* activity were detected during routine monitoring in five nurseries in 1999, however no TSWV was detected in random samples of plants in these nurseries. *F.shultzei* is highly susceptible to the organophosphate and carbamate insecticides routinely sprayed on a frequent basis (every two or three days) in seedling nurseries in the Dry Tropics. Therefore, under normal conditions nurseries are unlikely to be a source of TSWV-infected seedlings.

In field situations, plants appear to be most susceptible during early vegetative growth due to the lack of insecticides applied to control other insect pests prior to flowering. The results of the symptom expression studies show that even low levels of *F. shultzei* can result in economically important levels of TSWV if left untreated. In the course of these trials, TSWV-infected plants generally started to show symptoms one to two weeks after infection. While the symptoms of TSWV infection can be easily detected in the field, by this stage it is too late to prevent crop loss due to the disease.

Early detection as part of regular crop monitoring is critical to minimising TSWV infection. The results of the Dry Creek trial indicate that although the highest density of thrips occurred on June 3, no TSWV-infected plants were recorded in the 60 marked plants and no TSWV was recorded at all in Planting 3. In contrast, the assessment at harvest across the trial site recorded TSWV in both Planting 1 (1%) and Planting 2 (0.2%) and is likely to have been the result of the low *F. shultzei* infestations recorded on 21 and 31 May (before Planting 3 was planted) and which were not treated. The expression of symptoms in infected plants in the few days following the June 3 infestation also suggests that the earlier infestations were responsible for the TSWV recorded in Plantings 1 and 2.

The effectiveness of the June 4 insecticide application in preventing TSWV infection is encouraging and highlights the susceptibility of *F. shultzei*, the major vector of TSWV in the Dry Tropics, to registered insecticides. *F. shultzei* have been found to be highly susceptible to organophosphate, carbamate, synthetic pyrethroid and spinosad insecticides and if detected early, proper timing of the application of these insecticides can significantly reduce the incidence of TSWV.

To effectively minimise the incidence of TSWV infection, the following practices are recommended:

- Monitor susceptible hosts regularly from plant-out for the presence of *F.shultzei* and other suspected TSWV vectors
- Apply an appropriate insecticide when TSWV vectors are detected, since the tolerance level for these pests is very low
- Assess efficacy of applied insecticides and levels of TSWV in-field as a means of monitoring insecticide resistance levels in *F. shultzei* and detecting the presence of other thrips species vectoring TSWV

7. THE IDENTIFICATION OF ALTERNATE CROP HOSTS, WEED HOSTS AND RESEVOIR PLANTS

INTRODUCTION

In order to develop effective management strategies for the control of *F.schultzei* and TSWV it is critical to have an understanding of regional population dynamics of the predominant pest thrips species in surrounding crops and weeds. It is necessary to identify the primary sources of TSWV inoculum and the virus "reservoirs" outside of the target crops (tomatoes, capsicums and chillies). It is equally necessary to identify the plant species that support *F.schultzei*. These reservoirs and host plants can be divided into three plant groups:

1. Alternate crop hosts
2. Weed hosts
3. Reservoir plants.

MATERIALS AND METHODS

Random sampling of weeds and alternate crop hosts were conducted on farms and in conjunction with field trials. Weed surveys were conducted in areas of known TSWV infected cropping areas. Twenty-one different weed species have been screened for the presence of TSWV. The initial surveys have been conducted when the majority of the weed species have been flowering and the presence of thrips had been detected in the surveyed area. Individual weed species were sampled more than once at some sites.

Native plant species were not sampled due to prior work carried out by the W.A. Department of Agriculture, where 1590 samples only revealed 1 plant with TSWV (Latham and Jones, 1997) Weed samples were initially identified by the researchers and samples of unidentified weed species were sent to Queensland Herbarium for identification.

Plant samples were screened for the presence of TSWV with ELISA (Enzyme Linked Immunosorbent Assay). Peter Cross of TASAG's Elisa and Pathogen testing service, conducted screening for the presence of TSWV. The tests were done according to TASAG Laboratory ETIKET Manual (protocol #TSWV-1) using purified anti-virus immunoglobulins and alkaline-phosphate conjugates from Agria, Indiana. Appropriate positive and negative controls were also included in all tests.

RESULTS

1. ALTERNATIVE CROP HOSTS

TSWV has been identified and confirmed in the following crops in this region:

(i) Tomato (*Lycopersicum esculentum*). All commercial varieties except the resistant species, 'Guardian', have tested positive for TSWV. Traditional round, roma type and gourmet varieties exhibited varying levels of infection.

(ii) Capsicum (*Capsicum annuum*). All known commercial varieties have confirmed TSVW.

(iii) French beans (*Phaseolus vulgaris*).

(iv) Peanuts (*Arachis hypogaea*). Although not a commercial crop in the Bowen-Burdekin areas for the last 2 years, TSWV has been isolated from volunteer peanut plants.

2. WEED HOSTS

Weed surveys were conducted in areas adjacent to known TSWV infected crops. Twenty-one different weed species were screened for the presence of TSWV. Surveys were conducted when the majority of the weed species were flowering and the presence of thrips has been detected in the surveyed area (Table 4). It is important to note that only isolated weed samples were detected with TSWV. Individual weed species have been sampled more than once at some sites.

3. RESERVOIR PLANTS

Sampling of weeds in managed habitats (on farm) and unmanaged habitats (surrounding bush land) were conducted. The following weed species in the Dry Tropics region have been identified as a source of TSWV inoculum and are able to support tomato thrips (*F. schultzei)*

1. Sow Thistle (*Sonchus oleraceus)*
2. Apple of Peru (*Nicandra physalodes)*

The following weed species have tested positive for TSWV.

1. Purple snakeweed (*Stachytorpheta urticifolia)*
2. Swinecress/Bittercress (*Coronopus didymus)*
3. Cowvine (*Ipomeae lonchophylla)*

Table 4. Weed species recorded as alternate hosts of *Frankliniella schultzei* and known reservoirs of TSWV in the Dry Tropics.

Weed	Growth Stage [a]	Abundance Rating [b]	Thrips Present [c]
Volunteer tomatoes (***Lycopersicon esculentum***)§	V/F	2	Y (Fs)
Wild passionfruit	F	2	Y (Fs)
Blackberry nightshade (*Solanum nigrum*)	F	4	N
Caltrop (*Tribulus terristris*)	F	4	N
Dolichos lablab	V/F	1	Y (Fs)
Tinaroo glycine (*Neonotonia wightii*)	F	2	N
Cowvine (*Ipomeae lonchophylla*) §	F	4	Y (Fs)
Flowering acacia (*Acacia* sp.)	F	2	Y (Fs)
Phasey bean (*Phaseolus lathyroides*)	F	7	Y (Fs)
Bladder ketmia (*Hibiscus trianum*)	F	5	Y (Fs)
Swinecress/Bittercress (Brassicaceae family) §	V/F	3	Y (Fs)
Morning glory (*Ipomeae purpurea*)	F	5	Y (Fs)
Sesbania pea (*Sesbania cannabine*)	F	4	Y (Fs)
Snakeweed (*Stachytarpheta urticifolia*) §	F	9	Y (Fs)

[a] V = vegetative, F = flowering
[b] Abundance rating: 1 (limited distribution) to 10 (widespread distribution)
[c] Fs. = *Frankliniella schultzei*
§ = confirmed host of TSWV

DISCUSSION

The following weed species support tomato thrips, *Frankliniella shultzei* and are strongly suspected to carry TSWV but have not returned positive results in any of the screening samples. The presence of tomato thrips is clearly related to the flowering of particular broadleaf weeds.

1. Phasey bean *(Macroptilium lathyroides)*
2. Blue butterfly pea *(Clitoria ternatea)*
3. Spiked sida *(Sida subspicata)*
4. Green berry nightshade *(Solanum opacum)*
5. *Abutilon asiaticum*
6. Waltheria *(Waltheria indica)*

The range of weed hosts and reservoir plants found in the cropping areas of the Dry Tropics has been narrowed down to a small number of common weed species (*Sonchus oleaceous, Nicandra physalodes, Stachytorpheta urticifolia, Coronopus didymus, Ipomeae lonchophylla.)* It is most likely there are more weed species in this region that are possible sources of inoculum. We are confident that the predominant sources of TSWV have been surveyed and identified in the major farming areas. The presence of *F.shultzei* on these key species is closely related to the vegetative and flowering periods growth. These results can assist in designing cultural management strategies to reduce TSWV in the Dry Tropics region.

A special meeting of the Bowen District Growers Association held in July 2000 gave the researchers the opportunity to inform growers and other industry personnel of the latest research findings. QFVG personnel were also present. ABC Rural Radio reports were being continued with updates and prevailing thrips pressure communicated. A novel Quiz on TSWV and the predominant thrips weed hosts was organized and circulated in the local newspaper with a prize for the first correct grower response. This created awareness and amusement!

8. DEVELOPMENT OF CULTURAL MANAGEMENT TACTICS

INTRODUCTION

An integrated pest management programme for *F.schultzei* and TSWV must aim to interrupt the relationship between the virus, predominant thrips vector and the plant hosts. To achieve this we must look at the biology and distribution of *F.schultzei* in and surrounding the crop, and incorporate cultural and chemical management options.

Control procedures based solely on chemical management have contributed to rapid resistance buildup in thrips populations. The sole reliance on chemicals for thrips control will almost inevitably lead to resistance, as has happened with other crop pests (Lewis, 1997). Repeated applications of pesticides have caused high levels of resistance and cross resistance (Parella et al., 1997).

Host plant resistance and the development and incorporation of resistant cultivars are the ideal management strategy. However at the instigation of this project there were minimal selection programmes for TSWV resistant lines in tomatoes, capsicums and chillies. Breeding programmes take time. The TSWV problem was immediate and a rapid action research response was required.

Prior to the instigation of this project standard practice for the control of TSWV in the Dry Tropics region involved the following guidelines:

- All thrips species were not considered a pest management issue in capsicums, chillies and tomatoes
- It was generally accepted that the thrips species, *Thrips tabaci* (onion thrips) was the main species in the region
- Limited crop monitoring for vector pests in the early growth stages of capsicums and tomatoes. That is, from transplanting to 2 weeks of age
- Broad spectrum organophosphates were applied in the early growth stages on a routine basis whether thrips were present or absent.
- Surrounding on- and off -farm weed habitats were not considered in overall farm and pest management systems.

MATERIALS AND METHODS

The method of research involved in the development of cultural management tactics was based on a series of on farm-applied techniques or best management options (BMO's). A review of current registrations, research results and information from other areas of Australia and overseas was undertaken. This research along with current information was incorporated into the BMO's. Thrips activity and its related TSWV incidence can be localized and sporadic and infect certain areas due to prevailing conditions as already discussed in this project. Thus formal replicated field studies are extremely difficult to maintain whereas the BMO technique is much more flexible and dynamic. Techniques could be tested, refined and incorporated very rapidly into commercial practice. Because of the close relationship between the consultants/researchers and growers in the region new techniques and products could be rapidly implemented into commercial operations. These BMO's were reviewed every 6 months and formed the basis of IPM crop tactics. As new information was accessed it was incorporated into the BMO's.

RESULTS

The result is an integrated crop management program concentrating on cultural management tactics to reduce the population of *F.schultzei* and the incidence of TSWV in the Dry Tropics. This program encompasses the following management practices:

I. Weed Management

i. Preplant survey of the surrounding weed complex for broadleaf flowering weeds

ii. Elimination of all weed hosts and flowering broadleaf plants from crop and crop environs.

iii. Identify all known host plants and remove. The key is early detection of thrips in surrounding vegetation and within crop. Thrips trapping (yellow sticky traps) is a useful guide for presence or absence of thrips.

II. Planting of TSWV resistant varieties, of tomatoes and capsicums.

III. Timely Crop Monitoring.

i. Seedlings must be closely monitored in the nursery and post transplanting for at least 3 -4 weeks of age for thrips presence. Examine the tops of leaves, stems of plants and early flowers for the presence of thrips and identify .The emphasis is on early detection. Examine a minimum of 20 plants (5 plants per 0.4 ha.) with two inspections per week.

ii. Concentrate inspection on the outside edges of the cropping area, especially on the prevailing wind side and crop areas close to surrounding vegetation and windbreaks.

iii. Treatment threshold is presence or absence. If thrips are detected application of an appropriate insecticide, soap or mineral oil is required.

IV. Application of mineral oils and soaps.

These reduced risk insecticides for the early control of *F.schultzei* have minimal impact on the applicator and the environment. Oils and soaps are applied singularly or in combination with other insecticides and fungicides.

V. Rotation of insecticide groups

The combination of early crop monitoring and the use of mineral oils and soaps will reduce the dependence on organophosphate insecticides. The introduction and registration of the naturalyte compound, spinosad

Table 5. Typical insecticide rotation for tomatoes and capsicums in the Dry Tropics under conditions of high and low *F. shultzei* activity.

Growth Stage	Product	Active Ingredient	Spray Interval (Days)	
			Low *F. shultzei*	High *F. shultzei*
Planting	Bulldock/Talstar DCTron	beta-cyfluthrin/bifenthrin petroleum oil	7-10	3
Early Vegetative	Success DCTron	spinosad petroleum oil	7	3
Budding	Various DCTron	various petroleum oil	7	3
Early Flowering	Nitofol/Monitor DCTron	methamidophos petroleum oil	7	3

(Success®) has enabled a successful insecticide rotation to be implemented (Table 5).

VI. Crop Hygiene

Prompt removal and destruction of harvested crops. Remove or rogue out virus affected plant material in crop to eliminate virus reservoirs and reduce the spread of TSWV by *F.schultzei*.

VII. Farm Planning

Prior to commencement of the season, develop a strategic farm plan. Consideration should be given to adjacent crops, prevailing wind direction, and weed habitats when locating field plantings. Avoid sequential planting of susceptible crops so the spread of the virus does not move from one crop to the next. Do not plant new blocks adjacent to older blocks.

VIII. Seasonal Break in Production

Promotion and adherence to the seasonal break in production in the Dry Tropics region from December 15th to February 15th. A fallow break between seasons will act as a virus disease break which also aims for a lack of crop host.

DISCUSSION

F.schultzei numbers have decreased significantly over the life of the project. A factor associated with this population decrease is the dry weather conditions. A return of a normal wet season would assist in validating this factor. The level of TSWV has also decreased over the life of the project from field infections of up to 75 percent in the 1997/1998 seasons to less than 5 percent field infection in 2000/2001 seasons. This directly correlates with lower levels of *F.schultzei* activity recorded.

Field observations and anecdotal evidence have highlighted that a lack or absence of early in-crop monitoring and appropriate spray applications associated with poor application timing and farm hygiene has resulted in high levels of TSWV incidence.

Grower awareness and adoption of these practices was achieved rapidly due to the daily communication between the consultants/researchers and growers. The degree of influence to which the consultants/researchers have on the pest management of approximately 3000 hectares of tomatoes, capsicums, chillies in the region had a significant effect on the implementation of cultural and chemical management tactics.

Updates on thrips activity, the level of TSWV, and cultural management tactics have been presented in fortnightly radio reports, given by the Principal Investigator on the ABC Rural Radio Report. These reports have been presented continuously for the past 3 years and have been considered by a wide audience as an invaluable source of information.

Growers, in this region, who have observed and adopted the integrated crop management tactics promoted in this project, have successfully reduced the incidence of *F.schultzei* in crop and crop loss from TSWV.

10. REFERENCES

Clift, A. (2001). Aspects of vector thrips biology and epidemiology of tospoviruses in Australia. In *Western Flower Thrips Newsletter No. 21*, Medhurst, A. and Swanson, B. (Eds.)

Latham, L.J. and Jones, R.A.C. (1997). Occurrence of tomato spotted wilt tospovirus in native flora, weeds, and horticultural crops. *Australian Journal of Agricultural Research* **48**, 359-369.

Lewis, T. (1997). Chemical control. In *Thrips as crop pests*, Lewis, T. (Ed.). CAB International, New York.

Mound, L.A. and Gillespie, P. (1997). Identification guide to thrips associated with crops in Australia. NSW Agriculture, Orange, NSW.

Parrella, M.P. and Lewis, T. (1997). Integrated pest management (IPM) in field crops. In *Thrips as crop pests*, Lewis, T. (Ed.). CAB International, New York.