# FIELD GUIDE TO INTEGRATED PEST MANAGEMENT


Updated 22 October, 2015

# FOREWORD

## CORESTA Integrated Pest Management Taskforce

The tenets of good agricultural practice are to provide the world's populace with affordable food now, and into the future. This will only be realized if agricultural production is both profitable and sustainable. Integrated pest management is one of the many components necessary achieve this.

The only crop protection resources available to the first farmers about 12 000 years ago was some form of biological control, such as picking insects off the crop by hand. Perhaps the first IPM practice was securing the harvested grain in insect-proof earthen jars. Crops were first dusted with powdered sulphur 4 500 years ago, and selecting the best quality seed for the following season's crop was the first inadvertent plant breeding program. Through experience, agricultural practices progressed slowly until more recent times when science accelerated our understanding of crop production including pest and disease management. Early forays into pesticide use included mercury, arsenic and lead until as recently as the 1950's and then the over use of DDT caused a major revision of policy by the agricultural community. Quite apart from any potential damage to the environment by the liberal use of pesticides, there are many other methods of reducing the impact of pest and diseases that have been used, often in local communities with some particular problem.

To this end, the CORESTA membership saw the need for an avenue of sharing this information within the tobacco community. Many of the world's leading tobacco specialists have been corralled into providing a resource that is intended as a practical guide that field technologists can use to provide advice to growers in all aspects of integrated pest management.

The information provided is not definitive because any recommendations to growers must take cognizance of socio-economic constraints unique to a specific production area, and must be adjusted for new developments.

Anne Jack, University of Kentucky, USA
Taskforce Coordinator
Editor

Colin Fisher, University of Kentucky, USA
Editor

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# INTEGRATED DISEASE MANAGEMENT

Updated 22 October, 2015

# FOREWORD

## Integrated Disease Management

Tobacco may become infected by a number of different pathogens, from viruses to bacteria to fungi and oomycetes, at every stage of production. Integrated disease management combines cultural and chemical approaches to provide reliable disease reduction. Since no single practice is guaranteed to reduce disease, a broad, integrated approach helps safeguard crops from total failure. Truly integrated disease management applies one or more control tactics to each of the three components of the plant disease triangle: the pathogen, the tobacco host, and the environment.

Pathogen-centric control tactics focus on preventing the introduction of the pathogen to transplant production or the field, reducing new plant infections once pathogens have been identified, and minimizing disease severity. The most obvious pathogen-centric control is fungicide application, which depending on the mode of action, can prevent new infections or slow disease development. In all cases, however, fungicides are most effective when applied preventatively to otherwise healthy, unstressed plants. Active cultural management can reduce or even eliminate the need to introduce chemical tactics for select common diseases. For instance, the soilborne oomycete pathogen *Phytophthora nicotianae*, which causes black shank, may be spread by moving infested soil from field to field on tractors, setters, or boots. Combined with an understanding of farm-specific disease history, simple cleaning of these materials between fields can significantly reduce the potential to spread *P. nicotianae* to an uninfested field.

Host-centric control tactics focus largely on varieties bred for resistance to common diseases, in addition to minimizing injury from insects, herbivores, and equipment. New tobacco variety releases have been bred for different resistance “packages,” simultaneously possessing resistance to several plant diseases. For example, the burley tobacco variety KT206 has high resistance to black shank, black root rot, viruses, and TMV. Starting transplants with a stacked resistance package gives tobacco an advantage over yield-limiting diseases before plants are even set in the field. Insect management not only improves quality, but also reduces viral and bacterial diseases, which may be vectored by insects or need a wound for infection, respectively.

Finally, environment-focused tactics center on reducing plant stresses through proper fertility, water management, and weed control. As examples, tobacco stressed for boron, a trace micronutrient, is more susceptible to leaf breakage, which can in turn increase hollow stalk and other bacterial diseases. Standing water should be avoided in fields at all times, which can also be oriented in the direction of best wind flow to minimize leaf wetness, given site history. Weeds not only compete with tobacco for nutrients, but also serve as pathogen and insect reservoirs.

By taking a diversified, preventative approach, growers can safeguard their tobacco crops from yield-damaging diseases. While integrated tactics may involve more labor than strictly fungicide-based disease management, higher quality tobacco crops may be produced with fewer concerns about chemical residues.

Emily Pfeufer, University of Kentucky, USA
Disease Group Coordinator

A. Diseases

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## 1. <u>Brown Spot / Alternaria Leaf Spot</u> *Alternaria alternata*

Susan Dimbi, Tobacco Research Board, Zimbabwe

### General

Completed by author
Reviewed
Being edited

## 2. **Frogeye** *Cercospora nicotianae*

Kenny Seebold, University of Kentucky, USA

### General

Completed by author
Awating review

## 3. **Anthracnose** *Colletotrichum* spp.

Kenny Seebold, University of Kentucky, USA

**General**

Completed by author

Awating review

## 4. **Powdery Mildew / White Mould** *Erysiphe cichoracearum, Erysiphe orontii*

Jean-Louis Verrier & Bernard Cailleteau, Altadis-Imperial Tobacco Group
(now Bergerac Seed & Breeding), France

### General

Powdery mildew is, or has been, severe on tobacco in southern Africa, southeastern Europe, the Middle-East and Asia. It usually only affects tobacco in the field. The causal agent is either *Erysiphe cichoracearum* DC ex Mérat or the closely related *Erysiphe orontii* Castagne. These fungi are obligate biotrophs i.e. they cannot multiply in the absence of a suitable living host plant.

### Symptoms

Powdery white lesions (Fig. 4.1) first appear on the lower leaves. These enlarge and merge (Fig 4.2), and the infection progresses to leaves up the plant (Fig. 4.3). The mycelium forms numerous conidiophores that bear chains of ellipsoidal conidia which give the powdery appearance. Infected tissues turn dull brown. Severe infection leads to leaf chlorosis and premature senescence. Late in the season, tiny pinhead-sized black spherical structures called cleistothecia may appear on infected leaves.

### Source and Transmission

Transmission during the season occurs through dispersal of airborne conidia. Cleistothecia can survive several years in soil, and produce airborne infectious ascospores. It is also possible for the fungus to overwinter on weeds (Ch. 61).

### Site Selection and Rotation

Wind-protected locations (shading, hedges, etc.) are more favorable to powdery mildew. Due to the production of cleistothecia, powdery mildew is favored by a lack of crop rotation (Ch. 77).

### Alternate Hosts

*E. orontii* affects Solanaceous plants, whereas *E. cichoracearum* may infect as many as 300 species from 23 families of which many belong to the *Cucurbitaceae*, *Asteraceae* and *Brassicaceae* (Ch. 61). It seems, however, that strains of *E. orontii* or *E. cichoracearum* that infect tobacco are not always able to infect other plant species.

### Resistant Varieties

This is one of the main means of controlling powdery mildew. The double recessive resistance from *N. tabacum* Kuo Fan (syn. Kokobu) has been transferred to flue-cured, oriental and burley cultivars, mostly in Zimbabwe, Japan and Europe. Resistance to powdery mildew is not fully expressed in young plants. Dominant monogenic resistance from *N. tomentosiformis* was transferred to flue-cured and burley cultivars mostly in Zimbabwe and Europe. These sources confer high resistance and seem durable, with no adverse effects on leaf quality (Smeeton and Ternouth, 1990). Two other resistance sources come from *N. debneyi* (oriental variety Pobeda 3) and *N. glutinosa* (flue-cured variety Hicks 55, oriental variety Trapezunt).

### Sanitation

Early removal of sand leaves and early harvest of lower leaves may help in controlling the disease. Tobacco stalks should be ploughed under at the end of the season.

## Fertility

Excessive N fertilization promotes a dense canopy, sucker growth, and delayed leaf maturity which all contribute to favorable conditions for powdery mildew. The powdery mildew fungus grows poorly on K deficient leaves. Topping will delay infection of upper leaves.

## Scouting and Climatic Effects

In Zimbabwe, new leaves that appear after transplanting are not susceptible until they reach full expansion, i.e. not earlier than four weeks after transplanting (Cole, 1966). Powdery mildew development is dependent on climatic conditions. In tobacco, it has long been observed that the disease may appear and disappear within the same season, or from one year to the next, depending on local weather conditions. Forecasting models based on temperatures, relative humidity and leaf wetness have been developed for powdery mildews of tomato and pepper, (University of California: http://www.ipm.ucdavis.edu/index.html), but the validity for tobacco has not been checked.

The germination of *Erysiphe* conidia requires relative humidity lower than 80%, and is impeded by liquid water. Conducive temperatures for powdery mildew range from 19 to 26 °C. Mild, dry conditions with few rains will favor the disease, whereas average temperatures higher than 26°C may prevent it.

Recording of climatic conditions that prevail in the field may help assessing the likelihood of an outbreak. The field should be scouted regularly, particularly in problematic areas such as shady or air-confined (hedges) spaces.

**Chemical Control** *Use only locally registered chemicals, use only according to the label*

Water, surfactants and inorganic salts: water spray may reduce severity of powdery mildew (Yarwood, 1939). Surfactants enhanced this effect in greenhouse grown crops. Salts that may be used for foliar fertilization ($KNO_3$, $K_2HPO_4$, $Ca(NO_3)_2$) further enhanced this effect (Ehret et al. 2002). On tobacco, $NaHCO_3$ (baking soda) at 5 g/L has shown some efficiency both in the field and the greenhouse (Lahoz et al., 2001).

The effect of these salts on the chemical leaf composition (in particular, on conversion of nicotine to nornicotine) should be assessed before any use on tobacco. If there are no adverse effects, such methods could be an alternative to conventional fungicides, with a likely lower cost, and absence of residues in case of fertilizer salts. These alternatives will require more frequent sprays than systemic fungicides. Salts comprised of chlorine ions, which diminishes the burning rate of cured leaf, **must not be applied** to tobacco.

Fungicides: Some active ingredients that control diseases like brown spot (*Alternaria alternate*) or frogeye (*Cercospora nicotianae*), may also control *Erysiphe*.
*E. graminis*, causal agent of powdery mildew of cereals, is classified by the Fungicide Resistance Action Committee (FRAC) as a high risk species for the development of resistance to certain fungicides and this risk applies equally to *E. cichoracearum* and *E. orontii*. The mechanism by which this occurs is explained in FRAC Monograph 1.

The following table shows some active ingredients reported to be effective against *Erysiphe* spp.; those underlined have been reported for tobacco. This list is neither exhaustive, nor constitutes a recommendation. **Use only locally registered products.** Application of fungicides for control of powdery mildew is done mainly by spray treatment. Good wetting of the plant on all leaf levels is needed to obtain the desired effect.

| FRAC* target site codes | FRAC* risk category for fungus resistance build-up | Active ingredients |
|---|---|---|
| A2 | Medium | Bupirimate, Ethirimol |
| B1 | High | Benomyl, Carbendazim, Thiophanate |
| C3 | High | Azoxystrobin, Trifloxystrobin |
| C5 | Unknown | Dinocap |
| G1 | Medium | Fenarimol, Myclobutanyl, Penconazole, Tebuconazole, Triadimefon |

* Fungicide Resistance Action Committee

Products containing sulfur are efficient against *Erysiphe* spp, but these **must not be used** on tobacco due to residue problems and their adverse effect on smoke quality.

Other products: There is no indication that systemic resistance inducers (Ch.71) have any action against powdery mildew in the field.

## Biological Control

**Use only locally registered products.** Biofungicides based on *Bacillus subtilis* QST713 e.g. Serenade® is highly efficacious in the greenhouse (Olsen et al. 2001) (Ch. 74c). In some countries, this product is registered for protecting tomato and pepper against *E. orontii* and *Leivellula taurica* in the greenhouse and field.

## Summary

An integrated approach (Ch. 68) to the management and control of powdery mildew includes the following:

- Plough the stalks under the soil after the last harvest
- Select field to avoid shade and poor air circulation.
- Avoid applying excessive N fertilization
- If conditions are conducive to the disease, remove sand leaves
- If the tobacco is leaf-harvested, harvest the lower leaves as soon as possible.
- Scout regularly, particularly if conditions are conducive
- Use resistant cultivars if available
- When climatic conditions and plant development are conducive to the disease and cultivars are susceptible, field sprays of registered fungicides, preventatively or when indicated by scouting:
  - avoid fungicides containing sulfur
  - if another fungal leaf disease also needs to be controlled, choose a fungicide that controls both of them if possible.

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Yarwood C.E. 1939. Control of powdery mildews with a water spray. Phytopathology, 29:288-290.

D. Narraway, JTI, Iran

**Fig. 4.1:** Powdery mildew symptoms in the field

B. Cailleteau, ITG-Alttadis, France

**Fig. 4.2:** A tobacco leaf covered with powdery mildew

B. Cailleteau, ITG-Alttadis, France

**Fig. 4.3:** Progress from lower to upper leaves

## 5. **Blue Mould** *Peronospora tabacina*

Ernesto Lahoz, Agricultural Research Council, Italy

### General

Completed by author
Being edited, awaiting review

## 6. <u>Target Spot / Rhizoctonia Leaf Spot</u> *Thanatephorus cucumeris* (perf), *Rhizoctonia solani* (imperf)

Emily Pfeufer, University of Kentucky, USA

### General

Reassigned to new author

## 7. **Fusarium Wilt** *Fusarium oxysporum* fs. *nicotianae*

Brenda Kennedy, University of Kentucky, USA

### General

Completed by author
Awaiting review by David Shew, NCSU, USA

## 8. **Big Yellows** *Phytophthora glovera*

tba, Brazil

**General**

To be reassigned to new author in Brazil

## 9. **Black Shank** *Phytophthora nicotianae*

David Shew, North Carolina State University, USA

### General

Completed by author

Reviewed

Awaiting corrections by author David Shew, NCSU, USA

## 10. **<u>Pythium Damping-Off</u>** *Pythium* spp.

Chrissie Mainjeni, Agricultural Research & Extension Trust, Malawi

### General

Completed by author
Awaiting editing

## 11. Soreshin / Rhizoctonia Damping-Off *Rhizoctonia solani*

Ernesto Lahoz, Agricultural Research Council, Italy

**General**

Completed by author
Awaiting review

## 12. <u>Collar Rot</u> *Sclerotinia sclerotiorum*

tba

### General

Author needed

## 13. <u>Southern Blight / Southern Stem Rot</u> *Sclerotium rolfsii*

David Shew, North Carolina State University, USA

### General

Not received from author David Shew, NCSU, USA

## 14. **Black Root Rot** *Thielaviopsis basicola*

David Shew, North Carolina State University, USA

### General

Not received from author David Shew, NCSU, USA

## 15. **Wildfire, Angular Leaf Spot** *Pseudomonas syringae* pv. *tabaci* tox+, tox-

(formerly known as *P. tabaci, P. angulata;* also *P. syringae* pv. *tabaci, P. syringae* pv. *angulata)*

Anne Jack, University of Kentucky, USA

### General

Wildfire and angular leaf spot can affect tobacco in both the seedbeds / float trays and the field, although wildfire tends to be more of a problem in the seedbed and angular leaf spot in the field. Wildfire and angular leaf spot are not major problems in many tobacco producing areas, such as the USA, Brazil and Europe. In Africa, they are diseases of major importance which can cause devastating losses, especially in wet seasons. The bacteria that cause wildfire and angular leaf spot are identical in all respects except that the wildfire bacteria produce a toxin and the angular bacteria do not. Wildfire is therefore caused by the "tox+" strain and angular leaf spot by the "tox-" strain.

### Symptoms

The symptoms of the tox+ (toxin producing) and tox- (non-toxin producing) forms of this disease are quite different.

Wildfire (tox+) is characterized by a small brown or black watersoaked lesion, surrounded by a broad chlorotic halo (Figs. 15.1A, 15.2). The lesions increase in diameter and may coalesce until the diseased tissue eventually falls out leaving ragged holes. Wildfire can be systemic in seedlings, causing distortion (Fig. 15.4) of the apical bud and leaves.

The angular (tox-) lesion is brown, dark brown or black, much larger than the wildfire lesion, has little or no chlorotic halo, and has angular margins because the lesion is confined by the lateral veins (Figs.15.1B, 15.3, 15.5). In Africa, both diseases tend to be more severe at the top of the plant (Figs. 15.2, 15.3).

### Source and Transmission

The bacteria are spread in wind-driven water droplets, from leaf to leaf and plant to plant within the field, from field to field and from infected weed hosts or tobacco regrowth. Driving rains and sand blasting winds exacerbate the problem considerably. These diseases can also be seed transmitted. Tobacco regrowth and debris from infected plants should always be destroyed at the end of the season, as they are sources of inoculum to infect overwintering weed hosts. In the semi-tropical areas where these diseases are a problem, winters are seldom cold enough to kill overwintering weeds and tobacco regrowth. Wildfire and angular leaf spot are favoured by cloudy wet weather.

### Rotation and Site Selection

Disease spread is reduced by planting earlier fields downwind of later planted fields; the earlier planted fields often serve as an inoculum source. These diseases are generally worse in intensively used fields, and can be minimised by suitable rotations (Ch. 77).

### Alternate Hosts

Many solanaceous weeds are hosts of this pathogen (Ch. 61). Examples are Apple of Peru (*Nicandra physaloides*) and Jimson weed / stinkblaar (*Datura stramonium*), shown in Fig.15.6. Such weeds should be removed from the proximity of the fields and especially seedbeds / greenhouses. This is particularly important in areas which do not have killing winter frosts, where weeds overwinter.

### Resistant Varieties

Resistance to wildfire (race 0), derived from *N. longiflora* via Burley 21, is monogenic, complete and fully dominant. This resistance has proved very durable in most parts of the world, but in Africa, it broke down in the 1970s, with the emergence of race 1.

*N. rustica* derived resistance to races 0 and 1 of wildfire and angular leaf spot is also monogenic, complete and fully dominant. Race 1 resistant varieties were released in Zimbabwe in the early 1990s, but this resistance broke down in a relatively short time, with the emergence of race 2 of both wildfire and angular leaf spot in the late 1990s. No resistance to race 2 has been identified.

Polygenic resistance is generally low, but some of the newer multi-resistant Zimbabwean varieties have some polygenic resistance to race 2. The high level of monogenic resistance is shown in Fig. 15.7.

### Sanitation

All seedbed tools, particularly those used for clipping / mowing, should be regularly sterilised with bleach or a copper-based compound.

Disease spread is minimised if clean fields are reaped before infected ones.

Plant debris should be ploughed under at the end of the season, and all regrowth destroyed. Any exposed infected plant material may serve as a source of next season's inoculum. To be effective, this should be done by all growers in an area.

### Fertility and pH

These diseases are favored by excessive fertility, particularly with high N and low K fertilisation. The use of excessive amounts of lime, which interferes with K uptake, can also increase disease severity.

### Chemical Control *Use only locally registered chemicals, use only according to the label*

<u>Seedbeds / float beds</u>: Fumigation of seedbeds will usually eliminate initial inoculum in the seedbeds; float beds will generally be free of initial inoculum. Streptomycin is registered for use on tobacco in some countries. However, because of the potential for developing antibiotic resistance and the human/animal health issues, it should be used with extreme caution. Streptomycin is not registered for tobacco in Africa.

Seedlings should be preventatively sprayed (Ch. 70) with a combination of a copper-based compound and the SAR (systemic acquired resistance) compound, acibenzolar-S-methyl (A-S-M), if locally registered (Ch. 71). *Note:* in some countries, A-S-M is not registered for seedlings.

As always, use the registered rate, but with A-S-M, it is particularly important not to exceed the recommended rate because this product can be phytotoxic. Young plants are most vulnerable, and burley is more sensitive than other tobacco types. A-S-M should be used on burley seedlings with caution and only when necessary, as it can cause stunting.

<u>Field</u>: Copper sprays are not registered for field use because of residues; copper sprays applied in the field <u>will</u> result in unacceptable residues. The only chemical which can be used to control these diseases in the field is A-S-M (if locally registered). Field sprays (Ch. 69, Ch. 70) are more effective when used in combination with seedbed sprays. A-S-M is most effective when used as a preventative spray, but because of the cost, many growers only use it when symptoms appear.

### Scouting

Both the seedbeds / float beds and the field should be scouted regularly. Particular attention should be paid to low-lying areas.

Seedbeds / float beds: Remove and destroy any infected seedlings, and all others within 1 m of an infected plant. Drench the surrounding area with disinfectant (e.g. bleach).

Field: Acibenzolar-S-methyl (A-S-M) applications should commence as soon as symptoms are observed if it is not already being used as a preventative measure.

### Biological Control

No biological control agents have been found effective against these diseases.

### Other

Wildfire and angular leaf spot can be transmitted by seed, so seed should not be collected from infected plants. Seed treatment with silver nitrate should be a routine precaution, and is required in many countries where these diseases are a problem. Use of certified seed will minimise the chances of starting a crop with infected seed.

Disease severity is increased by any practice resulting in thick, heavy leaves, such as low topping and excessive N, and by any practice which can injure the leaves, such as mowing the grass surrounding tobacco fields.

### Summary

An integrated approach (Ch. 68) to the management and control of wildfire and angular leaf spot includes:

- Seed treatment with silver nitrate, ideally as part of the seed certification requirement
- Use of certified tobacco seed
- Rotation of seedbed sites
- Proper fumigation of the seedbed areas
- Preventative seedbed / floatbed sprays, correctly applied, of a combination of a copper-based compound and acibenzolar-S-methyl (if locally registered). *Note:* A-S-M should be used on burley seedlings with caution and only when necessary
- Scouting seedbeds and removing all seedlings within 1 m of an infected plant
- Eradication of alternate host weeds, particularly those near the seedbeds / floatbeds
- Sterilization of seedbed tools
- Site selection to avoid later planted crops downwind of earlier planted ones
- Correct fertilization and pH; avoiding excessive N, low K and high pH
- Minimizing of leaf injury; avoiding leaf breakage and not mowing too close to the field
- Correct topping, particularly avoiding low topping
- Regular scouting, particularly under conducive conditions (wet, cloudy, after rain)
- Field sprays of acibenzolar-S-methyl, preventatively or when indicated by scouting
- Minimizing spread by reaping clean fields before infected ones
- Destruction of all plant residue and regrowth at the end of the season

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**A** Susan Dimbi, TRB, Zimbabwe

**B** Anton Scholtz, LARSS, South Africa

**Fig. 15.1:** Wildfire and angular lesions. **A:** Wildfire; with chlorotic halo surrounding lesion **B:** Angular; with no chlorotic halo and angular margins

Michelle du Toit, Zimbabwe

Chrissie Mainjeni, ARET, Malawi

**Fig. 15.2:** Wildfire; *Pseudomonas syringae* pv. *tabaci* (tox +)

Michelle du Toit, Zimbabwe

Susan Dimbi, TRB, Zimbabwe

**Fig. 15.3:** Angular; *Pseudomonas syringae* pv. *tabaci* (tox -)

Michelle du Toit, Zimbabwe

**Fig. 15.4:** Systemic wildfire on seedlings

Susan Dimbi, TRB, Zimbabwe

**Fig. 15.5:** Severe angular leaf spot

**A** Anton Scholtz, LARSS, South Africa

**B** Anne Jack, UK, USA

**Fig. 15.6:** Weed hosts of angular and wildfire. **A:** Apple of Peru (*Nicandra physaloides*) **B:** Jimson weed / stinkblaar (*Datura stramonium*)

**A** Michelle du Toit, Zimbabwe

**B** Michelle du Toit, Zimbabwe

**Fig. 15.7:** Susceptible variety (left), resistant variety (right). **A:** angular **B:** wildfire

## 16. <u>Stolbur, Aster Yellows, Big Bud</u> *Phytoplasma* spp.

Fabienne Mornet, ANITTA, France

### General

Completed by author

One review, second reviewer needed

## 17. <u>Black Leg, Hollow Stalk</u> *Erwinia carotovora* subsp*. carotovora*

Bruce Fortnum, Clemson University, USA

### General

Not received from author Bruce Fortnum, Clemson University, USA

## 18. <u>Granville Wilt / Bacterial Wilt</u> *Ralstonia solanacearum*

Bruce Fortnum, Clemson University, USA

### General

Not received from author Bruce Fortnum, Clemson University, USA

## 19. **Potato Virus Y** PVY

Norbert Billenkamp, Agricultural Technology Centre Augustenberg, Germany

### General

Completed by author
Awaiting review

## 20. <u>**Etch**</u> TEV

Brenda Kennedy, University of Kentucky, USA

### General

TEV is a member of the potyviridae (potyvirus) family of plant viruses. Found primarily in North and South America, it is one of the more prevalent viruses affecting burley and flue-cured tobacco throughout the southeastern USA. It has also been reported in tobacco producing regions of South Africa and the Far East.

### Symptoms

Initial symptoms of TEV on tobacco are very subtle. Veins of inoculated leaves begin to clear which gradually develops into an etching pattern (Fig. 20.1). Mosaic symptoms are found on newly developed leaves as the virus becomes systemic (Fig. 20.2). Disease severity depends greatly upon the strain of the virus. In general, older infections typically result in breakdown of interveinal tissue by necrotic spotting and occasional browning of veins. Infected plants are often lighter in color (Figs. 20.3, 20.4). Like many virus infections, symptom expression is increased significantly when young plants become infected soon after transplant. Even though the etching symptom of TEV is a distinctive characteristic, TEV symptoms can often resemble symptoms of TVMV (Ch. 21) and PVY (Ch. 19). These viruses are often found in combination and are often referred to as the tobacco virus complex. For this reason visual identification can often become misleading. A correct diagnosis is only possible by immunological tests (ELISA), PCR or host range differentiation.

### Source and Transmission

TEV is widely distributed in perennial solanaceous weeds and is transmitted by over 10 species of aphids (Ch. 51) in a non-persistent manner. Transient aphids are believed to play a significant role in moving the virus from weed hosts to tobacco. Seed transmission has not been reported.

### Site Selection and Planting Date

Proper site selection helps eliminate the risk of introducing virus inoculum to tobacco. Avoid planting tobacco near weedy sites in which the virus overwinters and near TEV-susceptible crops. These hosts serve as potential inoculum reservoirs. Eliminate the potential for greater disease pressure by not setting tobacco late when the aphid and weed populations are at their peak.

### Alternate Hosts

TEV has a wide host range infecting over 120 species in 19 dicotyledonous plant families including several economically important solanaceous crops such as tobacco, tomato, sweet pepper, tobasco pepper and potato. Many solanaceous weeds, such as Jimson weed (*Datura stramonium*) are hosts (Ch. 61). A list of hosts can be found at the website http://www.agls.uidaho.edu/ebi/vdie/descr799.htm

### Resistant Varieties

Those tobacco cultivars which possess the monogenic recessive “va” gene derived from Virgin A Mutant (VAM) are moderate to highly resistant to most strains of TEV. The first commercially acceptable virus resistant burley tobacco cultivar was ‘TN 86’. This cultivar continues to be the most widely used source of virus resistance to date.

## Sanitation

Eliminate overwintering weed hosts which harbor the virus. Rogue infected virus plants when practical.

## Scouting

Both the seedbeds/floatbeds and fields should be scouted regularly for aphid infestations. This is especially important for late-set fields which are at greater risk for infestations because the aphids have had time to reproduce on earlier plantings. Virus infected seedlings should always be destroyed prior to transplant to avoid introducing inoculum into production areas.

**Chemical Control** *Use only locally registered chemicals, use only according to the label*

There are no chemicals available for control of virus diseases. Because the aphid vector can acquire and transmit the virus within a very short period of time; insecticide sprays are not effective in preventing the initial introduction of virus inoculum to a field. An insecticide application (Ch. 70) is recommended if aphid colonies are found on 20% more of the plants that are examined to prevent colonizing aphids from causing secondary spread of the virus within a field. Use systemic insecticides such as imidacloprid and acephate if locally registered.

## Biological Control

No biological control agents have been reported for the control of virus diseases.

## Summary

An integrated approach (Ch. 68) to the management and control of TEV includes:

- Grow a resistant variety
- Avoid planting near weedy sites in which the virus overwinters and there is a history of virus incidence
- Avoid planting tobacco near TEV-susceptible crops such as tomato, sweet pepper, tobacco pepper and potatoes
- Eliminate overwintering weed hosts which harbor the virus
- Avoid setting tobacco late when the aphid and weed populations are at their peak.
- Destroy virus infected seedlings prior to transplant
- Spray insecticides when aphid colonies reach unacceptable thresholds

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Brenda Kennedy, UK, USA

**Fig. 20.1:** Initial etching symptoms of TEV

Brenda Kennedy, UK, USA

**Fig. 20.2:** TEV etching symptoms on burley tobacco

Brenda Kennedy, UK, USA

**Fig. 20.3:** Symptoms of TEV in field inoculated burley tobacco

Brenda Kennedy, UK, USA

**Fig. 20.4:** TEV inoculated burley field Resistant cultivars to the left and right of susceptible cultivar

## 21. Vein Mottling TVMV

Brenda Kennedy, University of Kentucky, USA

### General

Tobacco vein mottling virus (TVMV) is a member of the potyviridae (potyvirus) family of plant viruses and was first reported in 1972 in the southeastern United States on burley tobacco, the only known host of economic importance. It has been reported to occur on occasion in Portugal, Columbia and China.

### Symptoms

Veins of TVMV infected leaves become clear and develop irregular green patterns or mottling as the disease progresses (Figs. 21.1, B; 21.2). This mottling symptom can often be seen on the ruffles of older leaves (Fig. 21.2). Infected plants are often lighter in color (Fig. 21.3). Some leaves may also exhibit extensive necrotic spotting, depending upon the severity of the strain involved (Fig. 21.4). Symptom expression is increased significantly when young plants become infected soon after transplant. Those transplants are often slower growing and occasionally become stunted in comparison to healthy transplants. TVMV symptoms can be very similar to other tobacco potyviruses: tobacco etch virus (TEV) (Ch. 20) and potato virus Y (PVY) (Ch. 19). These viruses are often found in combination and are often referred to as the tobacco virus complex. For this reason visual identification can often become misleading. A correct diagnosis is only possible by immunological tests (ELISA), PCR or host range differentiation.

### Source and Transmission

TVMV is widely distributed in perennial solanaceous weeds; ground cherry is believed to be the primary source of overwintering inoculum (Fig.21.5). TVMV is transmitted at a high rate of efficiency by several aphid species in the nonpersistent manner. Transient aphids Ch. 51 are believed to play a significant role in moving the virus from weed hosts to tobacco. TVMV is not seed borne.

### Planting Date and Site Selection

Avoid planting near weedy sites in which the virus overwinters. Avoid setting tobacco late when the aphid and weed populations are at their peak.

### Alternate Hosts and Vectors

TVMV has a relatively narrow host range and is limited to species of Solanaceae, including some solanaceaous weeds (Ch. 61). Ground cherry is one of the main alternate hosts (Fig.21.5). TVMV can be distinguished from other tobacco potyviruses: TEV, by its inability to produce wilting symptoms on tobasco pepper, *Capsicum frutescens,* and from PVY on the basis of inability to infect nightshade, *Solanum demissum.* A list of hosts can be found at the website
http://www.agls.uidaho.edu/ebi/vdie/descr799.htm

### Resistant Varieties

Those tobacco cultivars which possess the monogenic recessive “va” gene derived from Virgin A Mutant (VAM) are highly resistant to TVMV infections. The first commercially available virus resistant burley tobacco cultivar was ‘TN 86’ (Fig. 21.6). This cultivar continues to be the most widely used source of virus resistance to date.

### Sanitation

Eliminate overwintering weed hosts which harbor the virus. Rogue infected virus plants when practical. Virus infected seedlings should always be destroyed prior to transplant to avoid introducing inoculum into field production areas.

### Scouting

Both the seedbeds/floatbeds and fields should be scouted regularly for aphid infestations. This is especially important for late-set fields which are at greater risk for infestations because the vector has had time to reproduce on earlier plantings.

### Chemical Control *Use only locally registered chemicals, use only according to the label*

There are no chemicals available for control of virus diseases. Because the aphid vector can acquire and transmit the virus within a very short period of time; insecticide sprays are not effective in preventing the initial introduction of virus inoculum to a field. Insecticide sprays are recommended to prevent colonizing aphids from causing secondary spread of the virus within a field.

An insecticide application (Ch. 70) is recommended if aphid colonies are found on 20% or more of the plants that are examined. Use systemic insecticides such as imidacloprid and acephate if locally registered.

### Biological Control

No biological control agents have been reported for the control of virus diseases.

### Summary

An integrated approach (Ch. 68) to the management and control of TVMV includes:

- Grow a virus resistant variety
- Avoid planting near weedy sites in which the virus overwinters and there is a history of virus incidence
- Eliminate overwintering weed hosts which harbor the virus
- Avoid setting tobacco late when the aphid and weed populations are at their peak
- Destroy virus infected seedlings prior to transplant
- Spray insecticides when aphid colonies reach unacceptable thresholds

### References

**Blancard, D., R. Delon, B.W. Blair and T. Glover. 1999**. Virus Diseases. Pages 198-215 in: Tobacco production, Chemistry and Technology. Blackwell Science Ltd.

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**Seebold, K., J.D. Green and L. Townsend. 2008**. Insect Control. Pages 36-37 in: 2008 Kentucky Tobacco Production Guide. University of Kentucky Cooperative Extension Service Publications ID-160, Lexington, KY.

**Shew, H. D. and G.B. Lucas. Eds. 1991.** Compendium of Tobacco Diseases. APS Press ISBN: 0-89054-117-5.

**A** Brenda Kennedy, UK, USA **B** Brenda Kennedy, UK, USA

**Fig. 21.1:** TVMV symptoms on greenhouse inoculated susceptible plants
**A:** Vein clearing **B:** Vein mottling

Brenda Kennedy, UK, USA Brenda Kennedy, UK, USA

**Fig. 21.2:** Close-up of TVMV mottling symptoms

Robert Miller, UK,UT, USA

**Fig. 21.3:** TVMV symptoms in field inoculated plants

Robert Miller, UK,UT, USA

**Fig. 21.4:** Necrotic spotting and breakdown of leaf tissue from a severe strain of TVMV

Anne Jack, UK, USA

**Fig 21.5:** Ground cherry, main weed host for TVMV

Robert Miller, UK,UT, USA

**Fig 21.6:** TVMV resistant burley variety 'TN 86' on left, susceptible variety on right

## 22. <u>Geminiviruses</u>

Tobacco leaf curl virus (TbLCV)
Tobacco curly shoot virus (TbCSV)
Tobacco apical stunt virus (TbASV)
Tobacco yellow dwarf virus (TbYDV)

Velitchka Nikolaeva, Consultant, Bulgaria

### General

The geminiviruses infecting tobacco belong to the second largest family of plant viruses, the Geminiviridae, genus *Begomovirus* (TbLCV, TbASV, and TbCSV) and genus *Mastrevirus* (TbYDV). These diseases can be a severe problem for tobacco in the tropical and sub-tropical regions and also in the temperate areas of Japan, parts of Europe, and the USA. TbLCV was first identified as a disease on tobacco. It occurs worldwide but causes significant losses in the tropical regions of China, India, Japan, Taiwan, South Africa, Zimbabwe, etc. TbCSV was first isolated in the Yunnan Province, China and has not yet been reported in any other country. TbASV was isolated from Mexico and described as a new begomovirus widely spread in Mexico, Venezuela, and Brazil. Its closest relative is the cabbage leaf curl virus (CLCV). TbYDV was first reported in tobacco from Australia and has not yet been reported in any other country.

### Symptoms

The symptoms induced by tobacco geminiviruses differ in appearance and severity and vary depending on the type of tobacco, the time of infection, the virus strains and the presence of mixed infections. Common symptoms are stunting, curling, and twisting of the leaves (Fig. 22.1). Short internodes and stunted appearance can often be seen on plants with no apical growth caused by early infection (Fig. 22.2), yellowing of the infected plants (Fig. 22.3), very small, down-curled tips and margins of the youngest leaves, chlorosis and stunting (Fig. 22.4).

### Source/Transmission

None of these geminiviruses are transmitted through seed or mechanically. TbLCV, TbCSV and TbASV are transmitted within the tobacco field, from field to field and from infected weed hosts by the sweet potato whitefly, *Bemisia tabaci* (Gennadius) biotype B, which is common in tropical and subtropical regions. Whitefly has a wide host range and feeds on many crops such as tobacco, tomato, pepper, cucumber, potato and some weeds. Hot and dry conditions in tropical and sub-tropical regions favor whitefly feeding, high reproductive rates, and help the spread of the geminiviruses. Winds and temperature deviations have a big impact on the spread of whitefly-transmitted infections. TbYDV is transmitted by the leafhopper vector *Orosius argentatus*, Cicadellidae and causes a severe dwarfing disease in Australian tobacco.

### Site Selection

Infection by geminiviruses can be drastically reduced by either early or late transplanting in the field to avoid the heaviest insect migration period. Avoid overlapping of tobacco and other Solanaceae crops that permitted the whitefly to subsist and develop new populations.

### Alternate hosts

Tobacco geminiviruses have a rather narrow host range, basically restricted to Solanaceae family, and some Caprifoliaceae and Compositae. Naturally infected hosts are reported to include papaya and tomato and weed species *Ageratum conyzoides*, *Eupatorium odoratum*, *Euphorbia hirta*, *Nicotiana benthamiana, , Lunicera* spp*., Sida rhombifolia, Solanum nigrum, Veronica cinerea* and *Withania somnifera* (Ch. 61).

## Resistant varieties

Many studies on development of resistant tobacco lines to geminivirus have been done. There are no commercially available tobacco varieties or hybrids that are resistant or tolerant to geminiviruses.

## Sanitation

Post-harvest practices are very important in controlling geminivirus spread because the whitefly *B. tabaci* continues to develop on infected plants. Tobacco residues should be rapidly and completely destroyed at the end of the season to eliminate dispersal of whitefly and next season's source of inoculum. Establishing a host-free period will also reduce the whitefly population. These practices require regional coordination and should be practiced by all growers in the area. Tobacco seedlings have to be free from whiteflies and virus infections and transplanted in the field away and upwind from other key *B. tabaci* hosts such as melons, cole crops, and tomato.

## Fertility

Soil fertility affects the growth rate of plants and their ability to protect themselves against pathogen attack. Either excessive or inadequate nitrogen fertilization can stress plants and predispose them to infection. It is important to maintain good tobacco vigor by using a balanced fertilization regime to reduce the impact of virus diseases.

## Scouting

Scouting to assess whitefly populations is an important criteria for integrated pest management programs. Scouting can be done by using yellow sticky traps or inspecting the underside of leaves routinely to monitor the activities of migrating adult whiteflies. Special attention has to be paid when nearby host crops are in decline or already abandoned. Insecticide applications should begin once whitefly adults appear. In warm tropical and sub-tropical conditions the life cycle of *B. tabaci* from eggs to adults requires only two to three weeks. There is no established threshold for whitefly in tobacco because the incidence of geminiviruses depends on the number of adults carrying the virus.

**Chemical Control** *Use only locally registered chemicals, use only according to the label*

Systemic insecticides such as imidacloprid, thiamethoxam, and dinotefuron control *B. tabaci* and also aphids, leafhoppers and thrips. They can reduce the population of whiteflies and the onset of infection. Soap solutions of 1-2% can be used to effectively control to the adult vector. Insect growth regulators such as azadirachtin, buprofezin and pyriproxyfen are effective against immature stages of *B. tabaci.* Avoid whitefly insecticide resistance by ensuring a full spray coverage of the plant, especially the under surfaces of the leaves, and by rotating products from different insecticide classes when possible.

Seed beds/float beds: To maintain good whitefly control and prevent entry and early infection, seedlings should be drenched or sprayed preventively with a systemic insecticide such as imidacloprid or thiamethoxam if these are locally registered. Read the insecticide labeled rates before the application.

Field: If scouting indicates that whitefly is present then use foliar spray with systemic insecticides (Ch. 70) (if locally registered) such as imidacloprid or thiamethoxam against the adults, or IGRs, such as neem-based formulations azadirachtin or buprofezin and pyriproxyfen against nymphs. Chemical control is not effective if the diseases incidence is high.

## Biological control

Biological control does not seem to be effective in reducing *B. tabaci* in the field.

## Summary

Integrated management (Ch. 68) and control of tobacco geminiviruses and their vectors includes:

- Rapid destruction of crop residues and alternate hosts at the end of the growing season.
- Maintain good control of insect vectors from seeding to transplanting; grow seedlings in insect-proof structures; preventatively treat seedlings with systemic insecticides such as imidacloprid, thiamethoxam or dinotefuron (if locally registered) before or immediately following transplanting to provide early season control which is important for tobacco production in the tropics.
- Plant earlier and upwind of previously planted crops to avoid the heaviest insect migration periods.
- Scout routinely for infestations of insect vectors and watch attentively for nearby host crops which begin to decline or become abandoned so immediate action can be taken if whitefly infestations are probable.
- Avoid excessive use of nitrogen; follow a balanced fertilization plan.
- Spray fields with systemic insecticides: imidacloprid or thiamethoxam (if locally registered) against adults preventively or if indicated by scouting. Insect growth regulators such as azadirachtin (if locally registered) should be applied to control immature stages of whiteflies. Always read and follow the pesticide label directions.
- Avoid insecticide resistance by ensuring complete spray coverage, especially lower surfaces of the leaf, and by rotating products from different insecticide classes when possible.
- Insecticide spray programs should incorporate detergents or 1 to 2 % oil mixtures.

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A Velitchka B. Nikolaeva, Bulgaria

B Velitchka B. Nikolaeva, Bulgaria

C Velitchka B. Nikolaeva, Bulgaria

D Velitchka B. Nikolaeva, Bulgaria

**Fig 22.1:** Tobacco leaf curl virus (TbLCV) symptoms: **A**, **B**, **C, D** stunted plants, leaves curled downward, rolled, twisted, vein thickening

A Velitchka B. Nikolaeva, Bulgaria

B Velitchka B. Nikolaeva, Bulgaria

**Fig 22.2:** Tobacco apical stunt virus (TbASV).symptoms: **A, B** Early infection, apical stunt, leaf distortion, no growth

Velitchka B. Nikolaeva, Bulgaria

**Fig 22.3:** Tobacco apical stunt virus (TbASV) symptoms: Yellowing of the leaves, loss of vigor.

Gary Baxter, Dept. Primary Industries,Victoria, Australia

**Fig 22.4**: Tobacco yellow dwarf virus (TbYDV): Chlorosis and stunting

A.3. Viral Diseases

## 23. <u>Tomato Spotted Wilt</u> TSWV

Alex Csinos, University of Georgia, USA

### General

Completed by author

One review, awaiting second review

## 24. **Cucumber Mosaic** CMV

Kazuharu Koga & Haruyasu Harada, Japan Tobacco, Japan

### General

Completed by author

One review, awaiting editing and second review

## 25. Alfalfa Mosaic AMV

Dongmei Xu, Altria Client Services, USA

### General

In general, alfalfa mosaic virus (AMV) is not a major problem in tobacco, although local incidences of infection occur each year. It can affect all tobacco types, but typically is more of a problem on burley. It infects a wide range of plant species. Although tobacco is not a major host, an increasing number of cases of AMV infection has been observed in burley tobacco growing regions in recent years (Fig. 25.1). Infections typically occur early in the growing season, and infected plants are stunted and the leaves are not harvestable.

### Symptoms and Detection

The best diagnostic symptom of AMV infection is a bright yellow mosaic of the affected leaves (Fig. 25.2) but not all strains of the virus produce this symptom. Chlorotic blotches and vein clearing of expanding leaves are often present (Fig. 25.3). Chlorotic line patterns similar to the symptoms of tobacco ringspot are common (Fig. 25.5). Stunting of AMV-infected burley tobacco plants is usually mild, but foliar damage can be severe (Fig. 25.6). The leaves from heavily infected plants are totally destroyed by late season.

The genome of AMV consists of three molecules of RNA contained in three capsids. The virus is infectious only if all three particles are present and the coat protein is necessary to initiate the infection process.

Detection methods commonly used on other viruses are all applicable on AMV. These include ELISA, PCR, and mechanical sap re-inoculation onto typical AMV hosts or tobacco.

### Source and Transmission

AMV over-winters in weed hosts (Ch. 61) and is transmitted to tobacco by aphids, *Myzus persicae* (Ch. 51). It is transmittable in other hosts by at least 13 other species in Aphididae in a non-persistent manner. It can be transmitted by mechanical inoculation and grafting, but not by contact between plants, and through by seed via infected pollen.

### Rotation and Site Selection

Legume weeds or crops, such as alfalfa, and volunteer tobacco plants can serve as AMV reservoirs. Therefore, rotation (Ch. 77) and site selection are important aids in preventing AMV infection of tobacco.

### Alternate Hosts

AMV is vectored by aphids and infects plants in over 50 plant families. Legumes are the main hosts in the burley tobacco growing area. A list of the range of alternate hosts can be found at the website http://www.agls.uidaho.edu/ebi/vdie/descr009.htm.

### Resistant Varieties

There are no commercial tobacco cultivars with resistance to AMV. There are transgenic tobacco lines which have a high tolerance to AMV, but these are not commercially available.

### Sanitation

Mechanical transmission of AMV can be minimised by good sanitation practices during seedling production and transplanting. All tools, particularly those used for mowing and clipping, should be frequently cleaned and disinfected.

### Scouting

Scouting tobacco fields and removing infected plants early in the season could be an effective means of minimizing the secondary spread of the virus.

### Chemical Control *Use only locally registered chemicals, use only according to the label*

No totally effective chemical control strategies are currently available, and aphid control measures (Ch. 51, Ch. 70) are inconsistent in their effect on virus spread. Insecticides to control the aphid vectors cannot prevent infection from incoming aphids because they will not kill the aphids before virus transmission occurs. However, a good aphid control strategy, ideally including soil-applied systemic insecticides, can minimise virus spread in the field.

### Biological Control

No biological control agent is available.

### Summary

An integrated approach (Ch. 68) to the management and control of AMV includes the following:

- Avoid planting tobacco near alfalfa fields
- Use virus-free transplants
- Use intensive sanitation practices during seedling production and transplanting
- Practice early season field scouting and removal of infected plants
- Apply insecticides, ideally soil-applied systemics, to minimise further disease spread

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Brenda Kennedy, UK, USA

**Fig. 25.1:** An increasing number of cases of AMV infection have been observed in burley tobacco growing regions in recent years

Kenny Seebold, UK, USA

Kenny Seebold, UK, USA

**Fig. 25.2:** Bright yellow mosaic symptoms of burley plants infected with AMV

Kenny Seebold, UK, USA

**Fig. 25.3:** Chlorotic blotches in an expanding leaf infected with AMV

Kenny Seebold, UK, USA

**Fig. 25.4:** AMV-infected plant in row with healthy burley tobacco plants

Anne Jack, UK, USA

Anne Jack, UK, USA

**Fig. 25.5:** Chlorotic line patterns of AMV-infected leaves of burley tobacco.

**A** Colin Fisher, UK, USA

**B** Brenda Kennedy, UK, USA

**Fig. 25.6:** Foliar damage can be severe. **A:** severe distortion of the leaf tips **B:** hooking of the leaf tips

## 26. **Streak** TSV

Tatiana Lima & Fernanda Viana, Souza Cruz, Brazil

### General

Tobacco streak virus causes only minor losses of tobacco in Canada, China, France, Iran, Italy, Japan, Sumatra, the United States and Venezuela, but losses as high as 50 percent have been reported in Brazil. Although it has a very wide host range of both weeds and crops, serious losses to this virus occur only on peanuts and sunflower in India, and sunflower in Australia. TSV can affect tobacco in the seedbeds and in the field. At the beginning of spring, the vectors multiply quickly and infest the crops.

### Symptoms

TSV symptoms show three distinct stages: **1:** the acute or necrotic stage – local lesions appear as rings, solid necrotic spots or diamond-shaped patterns (Fig. 26.1); **2:** the early recovery stage – new leaves develop which appear normal except for chlorotic veins (Fig. 26.2); and **3:** the chronic or late recovery stage – the leaf is thicker than normal with a smoother texture and the tubular corolla splits with the petals becoming separated, especially the upper half (Fig. 26.3).

Symptoms are strongly influenced by temperature. At mild temperatures (around 20°C), only small necrotic spots develop. At temperatures above 30°C, the symptoms are more severe and appear as large necrotic arcs, broken rings and lines and dots around the necrotic secondary veins.

In advanced stages, the disease can be confused with other viruses due to the similarity of some symptoms. In some cases it can be confused with TSWV (Ch. 23) because of the presence of broken rings and leaf deformation. In other cases it can be confused with PVY$^n$ (Ch. 19) because of the presence of advanced necrosis at the basal end of the midrib. The presence of other viruses associated with TSV in the field is quite common.

### Source and Transmission

TSV is transmitted by infected pollen from alternate hosts and the only known mechanism of insect transmission is ingress of the virus from the pollen through wounds made by the action of thrips feeding on the leaf. The thrips do not transmit the virus directly through feeding, as with most other insect-vectored viruses. Seed transmission has not been demonstrated in tobacco, although it does occur in some other weed and crop species. It is also transmitted mechanically and through grafts, but neither of these has been demonstrated as important in the spread of the disease.

### Site Selection and Planting Date

Sites near possible host crops of TSV should be avoided. In warmer areas where this is possible, early planting is recommended.

### Alternate Hosts

The host range of TSV includes at least 200 species in more than 31 monocotyledonous and dicotyledonous families, both weeds and other crops. There are many weed hosts; a few examples are Jimson weed (*Datura stramonium*), field bindweed (*Convolvulus arvensis* L.), black nightshade (*Solanum nigrum)* and several other *Solanum* species (Ch. 61). All weed hosts should be removed from the vicinity of the crop.

Crop hosts include bean, clover, cotton, crotalaria, pea, peanut, sunflower, tomato and soyabean. The website http://www.agls.uidaho.edu/ebi/vdie/descr811.htm lists some of the identified hosts.

### Resistant Varieties

No resistant varieties been developed to date.

### Sanitation

Plant debris should be destroyed at the end of the tobacco harvest. Any exposed infected plant material may serve as a source of inoculum, and isolated infected plants in a field should be removed. As long as temperatures are cool enough, leave the plastic covers on the seedbeds to prevent thrips from moving onto the seedlings.

### Chemical Control *Use only locally registered chemicals, use only according to the label*

Infection during the seedbed stage is critical for the occurrence and dissemination of this virus. Preventative chemical control of the thrips vector should be done in the seedbeds, to reduce the incidence after planting, and in the field (Ch. 69, Ch. 70). No isolated control is sufficient to control the transmission of TSV in seedbeds or in the field. Some insecticides control the vector better than others. Examples are acephate and bifenthrin during the seedling development, and imidacloprid plus a synthetic pyrethroid (or a combination product) pre-planting.

### Biological Control and Barrier Crops

No biological control agents have been reported for the control of this disease.

Suitable barrier crops, such as sugar cane or Cameron grass (a cultivar of Napier grass), can decrease infection by providing barriers to thrips movement. A 1 m barrier crop protects 10 m of tobacco.

### Chemical Control

Infection during the seedbed stage is critical for the occurrence and dissemination of this virus. Preventative chemical control of the thrips vector should be done in the seedbeds, to reduce the incidence after planting, and in the field (Ch. 69, Ch. 70). No isolated control is sufficient to control the transmission of TSV in seedbeds or in the field. Some insecticides control the vector better than others e.g. acephate (e.g. Orthene, Matrix) and bifenthrin (e.g. Talstar) during the seedling development, and imidacloprid + cyfluthrin (e.g. Confidor S, Leverage) pre-planting.

### Biological Control and Barrier Crops

No biological control agents have been reported for the control of this disease.

Suitable barrier crops, such as sugar cane or Cameron grass (a cultivar of Napier grass), can decrease infection by providing barriers to thrips movement. A 1 m barrier crop protects 10 m of tobacco.

### Summary

An integrated approach (Ch. 68) to the management and control of TSV includes:

- Do not remove the covered plastic sheet off the seedbeds in any stage, as it will prevent the thrips from moving into the seedbeds
- Use good farm hygiene practices

- Control weeds in and near the crop
- Plant a quick growing barrier crop
- Destroy all plant residues at the end of the season
- Select the site in order to avoid late planted crops near other solanaceous crops
- Avoid planting in dry and windy periods
- Control thrips in the seedbed and field with insecticide if necessary

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Souza Cruz S.A., Brazil

Souza Cruz S.A., Brazil

**Fig. 26.1:** Necrotic stages of TSV

Souza Cruz S.A., Brazil

**Fig. 26.2:** Veinal discoloration of greenhouse seedling during the recovery phase of TSV

Souza Cruz S.A., Brazil

Souza Cruz S.A., Brazil

**Fig. 26.3:** Separated petals are a symptom of the chronic stage of TSV

## 27. <u>Bushy Top</u> TBTV

tba

### General

Author needed

## 28. <u>Mosaic</u> TMV

Julie Beale, University of Kentucky, USA

### General

Not received from author Julie Beale, UK, USA

## 29. <u>Ringspot</u> TRSV

Maros Lusso, Altria Client Services, USA

### General

Tobacco ringspot virus (TRSV) is found in a wide range of herbaceous and woody hosts including fruit plants, vegetables and ornamentals. It can infect tobacco plants in the seed bed and in the field. Economic damage is generally negligible and there does not warrant implementing any control measures. TRSV is found in North, Central and South America, Asia, Africa and Oceania. Although it has been identified in some isolated cases and there are several unconfirmed reports in Europe, it is not endemic in the region. The instances of TSRV in Kentucky burley appears to increased during recent years.

### Symptoms

TRSV has one of the most distinctive symptoms of the tobacco virus diseases although some symptoms are similar to those of alfalfa mosaic virus, AMV (Ch. 25) (Fig. 29.1). It first appears as circular line patterns of chlorotic and necrotic rings on young leaves (Fig. 29.2). These line patterns may follow the leaf veins and form the outline of an oak leaf (Fig. 29.3). Some of the tissue may die, resulting in a "shot-hole" appearance. Symptom severity varies from a few ringspots to a dwarfed plant with numerous patterns (Fig. 29.4) and ragged leaves in rare occasions. Most infected plants recover as new symptomless leaves develop. Ringspot usually appears on scattered plants and causes little or no economic loss, although it can cause serious losses in soybean in the USA.

### Source and Transmission

TRSV is transmitted from plant to plant by the nematode *Xiphinema americanum* and also by *X. rivesi*. The virus is acquired within 24 h and is transmitted by both adult and larval stages. The nematode can transmit to many different host species, at high efficiency. In the case of tobacco, a number of other non-nematode vectors have been suggested such as *Thrips tabaci* and aphids. Seed transmission has been reported in several hosts, such as cucumber and soybean. It probably occurs to some extent in most hosts. It is transmitted by contaminated pollen to the seed. Long-range dispersal occurs through trade of host plants and parts of plants, including seeds; accompanying soil may harbour infective seeds and the nematode vector.

### Alternate Hosts

Like many other viruses of the Nepovirus group, TRSV occurs in a wide range of herbaceous and woody hosts. It causes significant disease in soybeans and Cucurbitaceae. Many other hosts have been found naturally infected, including tobacco, apples, blackberries, cherries, grapes, tomato and various weeds.

### Resistant Varieties

There are no known sources of resistance to TSRV.

### Summary

The low economic losses to TRSV in tobacco do not warrant specific control measures. However, an integrated approach (Ch. 68) to the management and control of TSRV may include:

- Use certified seed

- Avoid fields with known *Xiphenema* nematode populations and avoid transfer of such soil to other fields.
- Monitor other crops in the area for the presence of the virus and avoid using these fields.

## References

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**Stace-Smith R. 1987.** Tobacco ringspot virus in *Rubus.* In: *Viruses Diseases of Small Fruits, Agriculture Handbook Number* no. 631, pp. 227-228. USDA/ARS, Washington (US).

Gary Palmer, UK, USA

**Fig. 29.1:** Advanced TRSV symptoms Note similarity to AMV.

Colin Fisher, UK

Kenny Seebold, UK, USA

**Fig. 29.2:** Circular, chlorotic and necrotic TRSV symptoms on burley tobacco leaves.

Colin Fisher, UK, USA

Colin Fisher, UK, USA

**Fig. 29.3:** Oakleaf pattern of TRSV symptoms.

Kenny Seebold, UK, USA

Kenny Seebold, UK, USA

**Fig. 29.4:** Ring spot and oakleaf TRSV symptoms

## 30. Management of Seedling Diseases

tba

**General**

Author needed

## 31. <u>Fungal Barn Rot</u> *Rhizopus* spp., *Pythium* spp.

Susan Dimbi, Tobacco Research Board, Zimbabwe

### General

Completed by author
Awiting review and ediitng

## 32. <u>Bacterial Barn Rot</u> *Erwinia carotovora* subsp. *carotovora*

Bruce Fortnum, Clemson University, USA

### General

Not received from author Bruce Fortnum, Clemson University, USA

## 33. <u>Barn and Storage Mould</u> *Aspergillus* spp., *Penicillium* spp.

Colin Fisher, University of Kentucky, USA

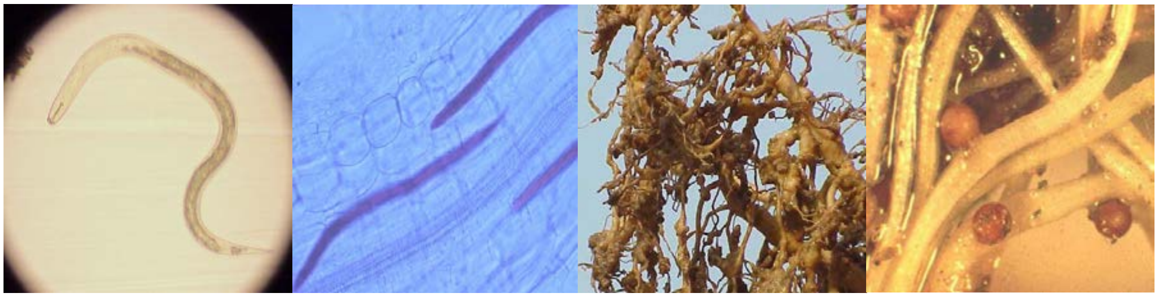
### General

Not received from author Colin Fisher, UK, USA

## 34. List of Minor Diseases

Anne Jack, University of Kentucky, USA

Not received from author Anne Jack, UK, USA



# INTEGRATED NEMATODE MANAGEMENT

# FOREWORD

## Integrated Nematode Management

Plant-parasitic nematodes occur virtually everywhere tobacco is grown, and reduce tobacco yield and quality directly by stunting the crop and delaying maturity, but also by increasing the incidence of other tobacco diseases, such as black shank, bacterial wilt, Fusarium wilt, some leaf spots, and even some viruses. Although root-knot nematodes are the most common nematodes damaging tobacco around the world, other endoparasites such as lesion (*Pratylenchus*) and cyst (*Globodera*) nematodes are also common problems. Nematodes that feed from outside tobacco roots are usually considered less damaging, but significantly damage tobacco in some regions.

Some nematodes tend to predominate in tobacco fields, but more commonly, various genera and species occur concomitantly and interact in various ways. Although nematode management options are limited for tobacco growers, they may actually have options that producers of other crops do not have, because the tobacco industry has invested significantly in disease and nematode management research. Cultural practices such as crop rotation and early root destruction are often highly effective in reducing nematode populations, and can be used with nematode-resistant cultivars to manage root-knot and/or cyst nematodes in many areas. Even when insufficient to provide complete nematode control, these tactics provide a foundation for improved and more reliable control even with nematicide use.

Tobacco farmers face continuing challenges in managing plant-parasitic nematodes, chiefly because many of the most effective nematicides used in the past are no longer available, and because nematode communities are adapting to our current management practices. We hope that the information provided here will not only help improve current management of tobacco nematodes, but also provide the industry with a more accurate understanding of the nematode occurring in tobacco fields. As for all other pests and pathogens, of all crops, future improvements in management will depend on such an understanding.

Chuck Johnson, Virginia Tech, USA
Nematode Group Coordinator

B. Nematodes

## TABLE OF CONTENTS – NEMATODES

## 35. <u>Javanese Rootknot Nematode</u> *Meloidogyne javanica*

Jennifer Way, Zimbabwe

### General

Completed by author
Being edited, awaiting review

**36. <u>Other Root-Knot Nematodes</u>** *Meloidogyne* spp.

Southern rootknot nematode: *M. incognita*
Peanut rootknot nematode: *M. arenaria*
Northern rootknot nematode: *M. hapla*
Pacara earpod rootknot nematode: *M. enterolobii*

J. D. Eisenback, Virginia Tech, USA

## General

Completed by author

Awaiting review by Natalia Martinez, UK, USA and Roberto Vargas, University of Puerto Rico

## 37. <u>Tobacco Cyst Nematodes</u> *Globodera* spp.

Jean-Louis Verrier, Altadis-Imperial Tobacco Group, France

### General

Not received from author Jean-Louis Verrier

**38. <u>Lesion Nematodes / Brown Root Rot</u>** *Pratylenchus* spp.

*P. alleni, P. brachyurus, P. crenatus, P. hexincus, P. neglectus, P. scribneri, P. penetrans, P. pratensis, P. thornei, P. vulnus, P. zeae*

Jonathan Eisenback, Virginia Tech, USA

**General**

Completed by author, one review, awaiting review by Jose Chavarria, University of Puerto Rico

## 39. Migratory Ectoparasitic Nematodes

Dagger Nematode: *Xiphinema americanum*
Needle Nematode: *Longidorus elongatus*
Spiral Nematode: *Helicotylenchus* and *Scutellonema* spp.
Lance Nematode: *Hoplolaimus* spp.
Stubby Root Nematode: *Trichodorus* and *Paratrichodorus* spp.
Stunt Nematode: *Tylenchorhynchus* and *Merlinius* spp.
Ring Nematode: *Mesocriconema* spp.
*Tetylenchus nicotianae*

Jonathan Eisenback, Virginia Tech, USA

### General

Completed by author, awaiting review by Natalia Martinez, UK, USA and Jose Chavarria, University of Puerto Rico

B.2. Other Nematodes

## 40. Ecologically Restricted Nematodes

Stem and Bulb Nematode: *Ditylenchus dipsaci*
Foliar Nematode: *Aphelenchoides ritzemabosi*
Reniform Nematode: *Rotylenchulus reniformis*

Jonathan Eisenback, Virginia Tech, USA

### General

Completed by author, awaiting review by Natalia Martinez, UK, USA and Jose Chavarria, University of Puerto Rico




# INTEGRATED INSECT MANAGEMENT




# FOREWORD

## Integrated Insect Management

Foreword not recived

Paul Semtner, Virginia Tech, USA
Insect Group Coordinator

C. Insects

## TABLE OF CONTENTS – INSECTS

**TABLE OF CONTENTS – INSECTS** cont

**TABLE OF CONTENTS – INSECTS** cont

## 41. <u>Wireworms and False Wireworms</u> *Conoderus* spp., *Gonocephalum* spp., *Trachynotus* spp., *Psammodess* spp.

Catia Sazaki, Souza Cruz, Brazil

**General**

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 42. <u>Cutworms</u> *Agrotis, Feltia, Peridroma* spp.

Luigi Sannino, Agricultural Research Council, Italy

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 43. **Whitefringed Beetles** *Graphonathus (Naupactus)* spp.

Paul Semtner, Virginia Tech, USA

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

# 44. Minor Stem and Root Insect Pests

## 44a. Crickets and Mole Crickets *Scapteriscus, Gryllotalpa* spp.

Bob McPherson, University of Georgia, USA

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44b. Vegetable Weevil *Listroderes costirostris obliquus* (Klug)

Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44c. Termites *Isoptera,* many species

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44d. Ants *Solenopsis, Tetramorium* spp.

Name, Affilliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44e. Dusty Surface Beetle *Gonocephalum simplex* (F.)

Name, Affilliation, Country

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## 44f. Tobacco Stem Borer *Scrobipalpa heliopa*

Name, Affilliation, Country

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## 44g. Sod Webworms *Crambus* spp.

Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44h. Root Maggots *Hylemya* spp. [Delia platura (Meigen)]

Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 44i. White Grubs *Cotinis nitida* (L.), *Popillia japonica, Phyllophaga* spp.

Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 45. **<u>Budworms</u>** *Heliothis, Helicoverpa* spp.

Francis Reay-Jones, Clemson University, USA

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 46. **Hornworms** *Manduca* spp.

Micheal D. Jackson, USDA Vegetable Lab, USA

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 47. **<u>Grasshoppers and Locusts</u>** *Melanoplus, Schistocerca, Zonocerus* spp.

Name, Affiliation, Country

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 48. <u>Potato Tuber Moth</u> *Phthorimaea operculella*

Anton Scholtz, Lowveld Agricultural Research and Support Services, South Africa

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 49. **<u>Tobacco Flea Beetle</u>** *Epitrix hirtipennis* (Melsheimer)

Luigi Sannino, Agricultural Research Council, Italy

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

# 50.  Minor Chewing Insect Pests

**50a.  Armyworms**  *Spodoptera* spp.

Name, Affiliation, Country

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

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**50b.  Laceworm (African Cotton Leafworm)**  *Spodoptera littoralis* (Boisduval, 1833)

Name, Affiliation, Country

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**50c.  Japanese Beetle**  *Popillia japonica* Newman

Name, Affiliation, Country

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**50d.  Tobacco Slug**  *Lema (Oulema) bilineata*

Name, Affiliation, Country

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**50e.  Climbing Cutworm**  *Peridroma saucia* (Hubner)

Paul Semtner, Virginia Tech, USA

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**50f.  Spotted Cucumber Beetle**  *Diabrotica undecimpunctata howardi* Barber.

Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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**50g.  Salt Marsh Caterpillar**  *Estigmene acrea* (Drury)

Paul Semtner, Virginia Tech, USA

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**50h.  Tree Crickets**  *Oecanthus* spp.

Paul Semtner, Virginia Tech, USA

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**50i.  Loopers and Semi-Loopers**  *Trichoplusa ni* (Hubner)

Name, Affiliation, Country

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**50j.  Tobacco Leaf Beetle**  *Gastrophysa atrocyanea*

Name, Affiliation, Country

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**50k.  Slugs**  *Deroceras* spp., *Arion* spp., and others

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 51. <u>Aphids</u> *Myzus* spp.

Clyde Sorenson, North Carolina State University, USA

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

**52. <u>Stinkbugs</u>** *Nezara, Eushistus* spp.

Bob McPherson, University of Georgia, USA

**General**

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 53. <u>Whiteflies</u> *Bemisia, Trialeurodes* spp.

Catia Sazaki, Souza Cruz, Brazil

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## **54. <u>Thrips</u>** *Franklinella, Thrips* spp.

Bob McPherson, University of Georgia, USA
Catia Anton, Alliance One International, Turkey

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

# 55. Minor Sucking Insect Pests

### 55a. Red Spider Mite *Tetranychus evansi* Baker & Pritchard

Name, Affiliation, Country

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

### 55b. Suckfly *Cyrtopelis notatus* (Distant)

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

### 55c. Tarnished Plant Bug *Lygus lineolaris* (Palisot de Beauvois)

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

# 56. Specific Seedling Insect Pests

## 56a. Fungus Gnats *Bradysia* spp.

Paul Semtner, Virginia Tech, USA

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 56b. Shoreflies *Scutella stagnalis* and others

Paul Semtner, Virginia Tech, USA

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## 56c. Earwigs *Forficula, Euborellia, Labidura* spp.

Paul Semtner, Virginia Tech, USA

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# 57. Insect Pests of Field and Seedlings

**57a. White Grubs** *Cotinis nitida* (L.), *Popillia japonica, Phyllophaga* spp.
See Chapter 44i

**57b. Cutworms** *Agrotis, Feltia, Peridroma* spp.
See Chapter 42

**57c. Crickets and Mole Crickets** *Scapteriscus, Gryllotalpa* spp.
See Chapter 44a

**57d. Ants** *Solenopsis, Tetramorium* spp.
See Chapter 44d

**57e. Tobacco Flea Beetle** *Epitrix hirtipennis* (Melsheimer)
See Chapter 49

**57f. Armyworms** *Spodoptera* spp.
See Chapter 50a

**57g. Slugs** *Deroceras* spp., *Arion* spp., and others
See Chapter 50k

**57h. Aphids** *Myzus* spp.
See Chapter 51

**57i. Whiteflies** *Bemisia, Trialeurodes* spp.
See Chapter 53

## 58. **Tobacco Moth** *Ephestia elutella* (Hubner)

Vernon Schmidt, RJ Reynolds, USA

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

## 59. **Cigarette Beetle** *Lasioderma serricorne* (F.)

Haruyasu Harada, JT, Japan

### General

All insect chapters still with group leader, Paul Semtner, Virginia Tech, USA

# INTEGRATED WEED MANAGEMENT

# FOREWORD

## Integrated Weed Management

The current accepted definition of a "weed" is simply a plant growing where it is not desired or, more simply put, a plant out of place. Needless to say, past and current agricultural production systems have created a rather long list of plants out of place. Modern methods of weed control, primarily through the use of herbicides, have been a major contributing factor toward improving the efficiency of crop production. Herbicides are, however, not the only method of weed control; cultural practices such as good seedbed preparation, tillage, crop rotation, cultivation, and hand weeding are important. Their relative importance varies with the crop situation. While the small-scale tobacco grower may still rely heavily on cultural practices, the large commercial producer of tobacco depends on herbicides to ensure the production of the large weed-free acreages so common in more developed countries. More recently, larger producers may incorporate several of the above agricultural practices as a means of a more integrated weed control program or approach.

Weed pests may be almost any of 250,000 species of plants known to man. Their potential for invading our agricultural areas is significant. Several million weed seeds can be found per acre in many of our agricultural soils. If, after seedbed preparation, only 10% of these weed seeds germinated, this would produce a weed population of several hundred per square meter—extreme competition for any crop.

Weedy species of both dicots (broadleaf) and monocots (grasses) are competitive with tobacco and can dramatically impact tobacco growth and development. An effective as well as environmentally sound weed management program is a critical component of profitable and sustainable tobacco production.

Integrated weed management involves employing as many methods as possible for control of the target weed species. For weed pests of tobacco, these methods primarily include chemical and cultural control, and to a much lesser extent biological control. Effective use of these methods in combination allows for the most effective weed control at the least cost and least environmental impact.

Andy Bailey, University of Kentucky, USA
Weed Group Coordinator

D. Weeds

## TABLE OF CONTENTS – WEEDS

## 60. Competitive Effects of Weeds

Andy Bailey, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 61. Weeds as Alternate Hosts to Other Pests

Andy Bailey, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 62. Cultural Practices for Weed Control

Andy Bailey and Bob Pearce, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 63. Chemical Weed Control

Davis Martin, Profigen, USA
Andy Bailey, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 64. Biological Weed Control

Andy Bailey, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 65. Descriptions of Common and Troublesome Weeds in Tobacco

Andy Bailey, University of Kentucky, USA

### General

Completed by author
Reviewed and edited
Ready for website review

## 66. Broomrape *Orobanche* spp.

Jean-Louis Verrier, Altadis-Imperial Tobacco Group, France

### General

Completed by author
Reviewed
Ready for website review

## 67. Minor Parasitic Weeds

Anne Jack, University of Kentucky, USA

### General

Not received from author Anne Jack, UK, USA

# IPM
# STRATEGIES

# FOREWORD

## IPM Strategies

Integrated Pest Management (IPM) has become a fundamentally integrated aspect of how tobacco is produced worldwide, since pests, diseases and weeds affect crop yield and quality, as well as lower income for the growers in the event of uncontrolled pest or disease outbreak.

To sustain a crop production in a business operating environment that is (and will be) ever more strictly regulated, the pursuit of more comprehensive adoption of Good Agricultural Practices (GAP) and the promotion and adoption of preventive and integrated measures to reduce the risk of pest and disease occurrence is crucial for an efficient tobacco production that meets the requirements of yield, quality and integrity, while also complying with environmental requirements and regulations.

An insect, a bacteria or a virus is not a pest or disease agent *per se* – they only become pests or diseases when optimal conditions for their development are provided. The fundamental concept of IPM is that each aspect of and within the agricultural ecosystem has a role to play and there is a tolerance limit that should be accepted before more extreme measures are required.

IPM strategies should take into account the environment, cultivation practices, and local socio-economic constraints, prioritizing the adoption of techniques that promote, enhance and or/protect the health and good quality of the agro environment as a whole thus contributing to the maintenance of ecological balance with reduced risk of pest/disease outbreaks. These techniques include the selection of suitable varieties, adoption of locally recommended cultural practices, soil and water conservation practices, use of biological control agents or other alternative methods in combination with responsible and rational use of Crop Protection Agents (CPAs).

Adequate and correct use of CPAs is a fundamental component of IPM. When CPAs are used only when necessary and in the recommended manner, following appropriate application rates and methods, as well as complying with health and safety requirements, the challenges from pests and diseases are confined, there is reduced risk of pest and diseases developing resistance and minimized risk of excessive residue accumulation in the leaf. Selective products also allow natural enemy populations (predators and parasitoids) to develop to the detriment of pests.

Moreover, the effective implementation of any IPM strategy starts from raising awareness, training and engagement of field staff and the tobacco grower base.

Cecilia Dorfey, JT International Germany GmbH
IPM Strategies Group Coordinator

E. IPM Strategies

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## 68. IPM and Pest Epidemics

Colin Fisher, University of Kentucky, USA

### General

Group under new leadership

## 69. Pesticides

Colin Fisher, University of Kentucky, USA

### General

Group under new leadership

## 70. Application of Pesticides

Colin Fisher, University of Kentucky, USA

### General

Group under new leadership

## 71. History, Principles and Applications of SAR

Andrea B. da Rocha, Universal Leaf, Brazil

### General

Group under new leadership

# 72. Predators and Parasitoids

## 72a. General

Fabienne Mornet, ANITTA, France

Group under new leadership

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72b. Parasitoid Wasps

Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72c. Ladybugs / Ladybeetles

Bob McPherson, University of Georgia, USA
Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72d. Syrphid Larvae

Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72e. Stilt Bugs

Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72f. Tachinid Flies

Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 72g. Summary and References

Fabienne Mornet, ANITTA, France

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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# 73. Fungal Biocontrol Agents

## 73a. Introduction

Name, Affiliation, Country

Group under new leadership

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 73b. *Trichoderma*

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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## 73c. *Beauveria*

Name, Affiliation, Country

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## 73d. *Metarhizium*

Name, Affiliation, Country

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## 73e. Summary and References

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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# 74. Bacterial Biocontrol Agents

## 74a. Introduction

Name, Affiliation, Country

Group under new leadership

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 74b. *Bacillus thurigiensis*

Name, Affiliation, Country

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## 74c. *Bacillus subtillis*

Name, Affiliation, Country

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## 74d. *Bacillus spinosa*

Name, Affiliation, Country

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## 74e. Summary and References

Name, Affiliation, Country

Xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

## 75. Trap Crops and Companion Plants

Anderson Biersdorf, Premium Tobacco, Brazil
Andrea B. da Rocha, Universal Leaf, Brazil

### General

Group under new leadership

## 76. Barrier Crops

Anderson Biersdorf, Premium Tobacco, Brazil

### General

Group under new leadership

## 77. Rotation Crops and Cover Crops

Henri Papenfus, AOI, United Kingdom

### General

Group under new leadership

## 78.  Cigar Wrapper

Michael Hartley, Lancaster Leaf, USA

### General

Group under new leadership

## 79. Cigar Filler

Michael Hartley, Lancaster Leaf, USA

### General

Group under new leadership

## 80. Economic Thresholds for Cigar Tobacco

Michael Hartley, Lancaster Leaf, USA

### General

Group under new leadership