Epidemiology and control of groundnut bud necrosis and other diseases of legume crops in India caused by tomato spotted wilt virus

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INTRODUCTION

Tomato spotted wilt virus (TSWV) was first reported in India in tomato in 1964 (Todd *et al.*, 1975). The occurrence of TSWV on a legume in India was first recorded in 1968 (Reddy *et al.*, 1968). The "bud necrosis disease" of groundnut, caused by TSWV, is now considered to be one of the most damaging groundnut diseases in India (Ghanekar *et al.*, 1979a; Reddy, 1980). Bud necrosis is likely to have been present in India for some time although it has only recently become economically important. TSWV has also been reported on groundnuts in Brazil (Costa, 1941), the United States of America (Halliwell & Philley, 1974), South Africa (Klesser, 1966) and Australia (Helms *et al.*, 1961). This chapter considers the epidemiology and control of bud necrosis and gives a brief account of other economically important diseases of legumes in India caused by TSWV.

OCCURRENCE AND DISTRIBUTION OF LEGUME DISEASES CAUSED BY TSWV IN INDIA

Our surveys show that bud necrosis is widely distributed in the main groundnut-growing regions of India and that it is endemic in the states of Andhra Pradesh and Tamilnadu. Extensive infection has also been seen in parts of the states of Maharashtra, Gujarat, Rajasthan and western Uttar Pradesh. The greater incidence of bud necrosis in recent years may be related to the expansion of irrigation projects which has led to continuous cropping of groundnuts and other hosts of TSWV. Until recently most groundnuts were grown in the rainy season but increased demand has caused an expansion of the post-rainy season, irrigated crop.

The economically important leaf curl diseases of green and black gram (*Vigna radiata*) (Nene, 1972) have recently been shown to be caused by TSWV (Ghanekar *et al.*, 1979b) and field trials showed that TSWV can also cause economically important diseases of pea (cultivar Bonneville) broad bean (cultivar Local), cowpea (cultivar C-152) and soyabean (cultivar Bragg).

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ROLE OF THRIPS IN TSWV TRANSMISSION

The isolate of TSWV infecting groundnut is transmitted by two thrips species, *Frankliniella schultzei* and *Scirtothrips dorsalis*. The former is the most efficient vector and is chiefly responsible for disease spread in the field (Amin *et al.*, 1981). Nearly 50% of individuals of laboratory-bred *F. schultzei* transmitted TSWV when tested in the laboratory. *Thrips tabaci* had been presumed to transmit TSWV in tomato crops (Todd *et al.*, 1975) but was not found on groundnuts in our survey. In addition, our attempts to transmit the TSWV isolate that causes bud necrosis from groundnut to groundnut and from groundnut to the highly susceptible green and black gram and cowpea by *T. tabaci* were unsuccessful.

Larvae of *F. schultzei* require a minimum acquisition access time of 30 min but the frequency of transmission increases up to an optimum acquisition time of 48 h. Adults cannot acquire the virus, but can transmit it if it is acquired when they are larvae. The incubation period is 8-9 days, which is the time required for the thrips to complete the larval and pupal instars and become adults. The virus is retained in adults throughout their life, irrespective of acquisition time. Males and females transmit the virus equally efficiently.

Hosts of thrips and TSWV

F. schultzei infests many different host plants, including crops, ornamentals and weeds many of which are also susceptible to TSWV (Table 1). Crop plants such as green and black gram are highly susceptible to both the virus and the vector, and cropping with these short-duration legumes helps to perpetuate virus and vector. Tomato, egg plant, groundnut and ornamentals such as zinnia and chrysanthemum which are susceptible to both TSWV and *F. schultzei* are commonly grown during the summer season. *Ageratum conyzoides* and *Cassia tora*, two common weeds in groundnut fields, harbour numerous *F. schultzei* and more than 50% are infected with TSWV. These weeds are usually abundant soon after monsoon showers and are likely to provide sources of inoculum.

SEED TRANSMISSION

Groundnut plants infected when young (50-60 days after sowing) produce shrivelled seeds of which only 30% germinate. However, when plants at least 10 weeks old were infected, 85% of the seed they produced germinated normally. The virus was not detected in seedlings raised from seed collected from plants infected when young (2800 seeds) or when older (1600 seeds). Infective virus was recovered from the testa of immature and freshly harvested mature seeds, but virus could only be detected serologically in the testas of dried seeds. Neither serologically detectable nor infective virus was recovered from the cotyledons and embryos of freshly harvested or dried seeds. Freshly harvested mature seeds with testas containing infective virus, failed ɔ transmit TSWV when grown on (A.M. Ghanekar & R. Rajeshwari, ıpublished data).

Table 1. Some hosts of *Frankliniella schultzei* and tomato spotted wilt virus (TSWV).

Papilionaceae:	*Arachis hypogaea* (C) (T) (V), *Canavalia gladiata* (C) (T) (V), *Crotalaria juncea* (C) (T) (V), *Desmodium triflorum* (W) (T) (V), *Glycine max* (C) (T) (V), *Pisum sativum* (C) (T) (V), *Tephrosia purpurea* (W) (T), *Vicia faba* (C) (T) (V), *Vigna mungo* (C) (T) (V), *V. radiata* (C) (T) (V), *V. unguiculata* (C) (T) (V).
Compositae:	*Acanthospermum hispidum* (W) (T) (V), *Ageratum conyzoides* (W) (T) (V), *Carthamus tinctorius* (C) (T), *Chrysanthemum indicum* (O) (T), *Cosmos bipinstatus* (O) (T) (V), *Helianthus annuus* (C) (T), *Lagasca mollis* (W) (T) (V), *Tridax procumbens* (W) (T), *Xanthium strumorium* (W) (T) (V), *Zinnia elegans* (O) (T) (V).
Solanaceae:	*Lycopersicon esculentum* (C) (T) (V), *Nicotiana tabacum* (C) (T), *Solanum melongena* (C) (T) (V), *S. tuberosum* (C) (T) (V).
Caesalpiniceae:	*Cassia tora* (W) (T) (V), *C. obtusifolia* (W) (T) (V), *C. occidentalis* (W) (T).
Liliaceae:	*Allium cepa* (C) (T).
Convolvulaceae:	*Datura stramonium* (W) (T).
Labiateae:	*Leucas aspara* (W) (T).
Papaveraceae:	*Papaver* sp. (W) (T).
Zygophyllaceae:	*Tribulus triticus* (W) (T).
Asclepidaceae:	*Calotropis gigantica* (W) (T) (V).
Amaranthaceae:	*Celosia argentea* (W) (T).

C = Crop V = Host of TSWV
O = Ornamental T = Host of *F. schultzei*
W = Weed

INCIDENCE OF BUD NECROSIS

Figs. 1 & 2 show the population fluctuations of *F. schultzei*, the principal vector of TSWV, on groundnuts in the rainy (June-September) and post-rainy (January-March) seasons in Hyderabad. The first

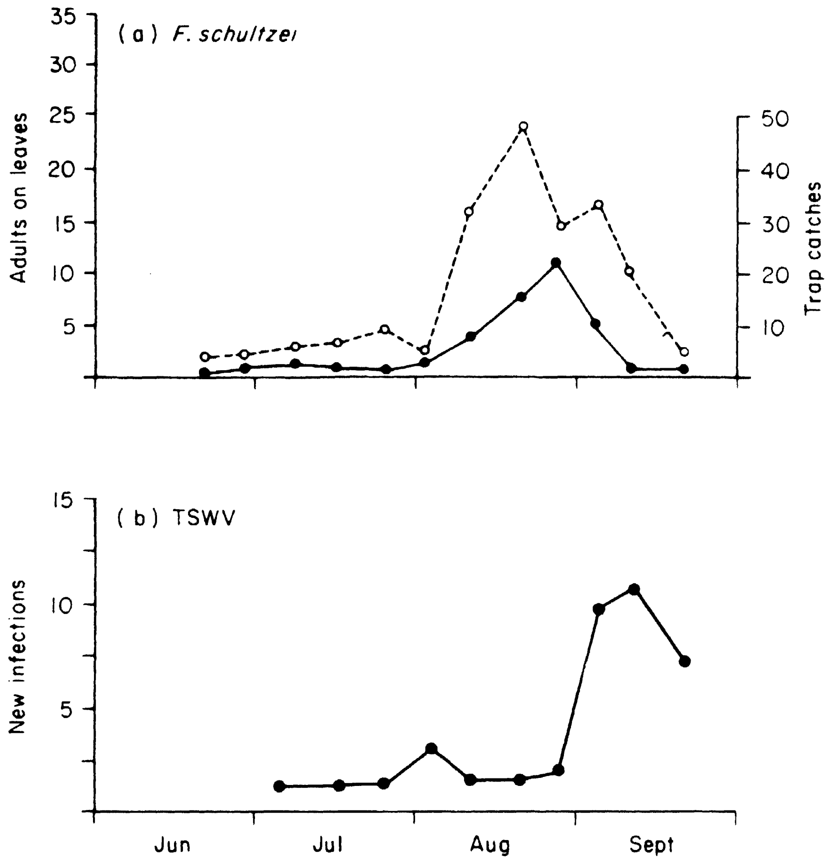

Figure 1. (a) Adult *F. schultzei* collected during June-September, 1979, on the ICRISAT farm. In suction traps O---O and on ten terminal leaves ●——●.
(b) Percentage of crop stand first showing symptoms of tomato spotted wilt virus.

invasion of *F. schultzei* occurred in the first week of July to weeds such as *C. tora* and *A. conyzoides*, which emerge soon after the first rain. The *F. schultzei* populations were low until the second week of July but subsequently increased rapidly to reach a maximum in the last week of August and early September. By mid-September populations on the crop declined sharply (Fig. 1a). The maximum disease incidence, which ranged from 50 to 100%, occurred in the rainy season, 2-3 weeks after the maximum number of *F. schultzei* was recorded (Table 2) whereas in the post-rainy season crop in the Hyderabad region disease incidence was only 20-30%. In the post-rainy season crop, maximum numbers of *F. schultzei* occurred in January and February and most new infections of TSWV were in February (Fig. 2). *F. schultzei* populations declined sharply from March to July when they

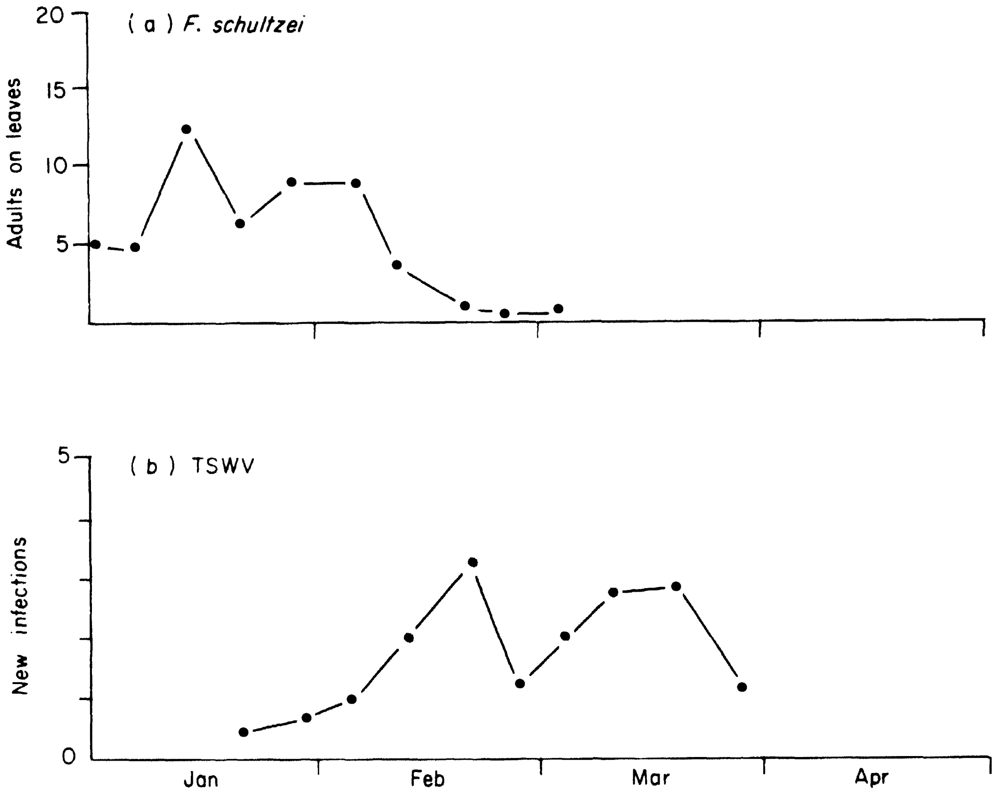

Figure 2. (a) Adult *F. schultzei* counted on plants during January-April, 1980, on the ICRISAT farm.
(b) Percentage of crop stand first showing symptoms of tomato spotted wilt virus.

were found on the flowers of summer crops such as chrysanthemum, zinnia, tomato, egg plant, onions and weeds such as *Calotropis gigantica, C. tora* and *Tribulus triticus.*

The number of *F. schultzei* caught in suction traps and recorded on young terminal buds followed similar patterns (Fig. 1a). Factors that contribute to the massive build-up and migration of *F. schultzei* are unknown, although from initial observations it seems that temperature and wind speed may be important. Seventeen of the 22 mass flights recorded from June 1980 to April 1981 occurred when the wind velocity at 3 m above the crop at 14.00 h was less than 10 km/h, and 5 flights occurred at wind speeds of 10-15 km/h. Few thrips were caught when the wind speed exceeded 15 km/h and none when wind speed was greater than 20 km/h. Twenty of 22 mass flights occurred when the maximum tempera-

Table 2. Effect of sowing date on the incidence of bud necrosis in groundnuts on the ICRISAT farm.

Sowing date	Disease incidence (%)		Yield (kg/ha)	
	At 50 days	At 100 days	Dry pods	Seeds
15 June 1979	14.1	59.2	917	668
10 July 1979	82.3	99.3	121	49
S.E.	±1.77	±0.76	±44	±30.6

tures were 20°-35°C and none occurred above 40°C. Körting (1930) and Johansson (1946) have also stressed the influence of temperature on mass flights of thrips. Relative humidity differed greatly (13-86%) when mass flights occurred, indicating that it may be less important than wind speed and temperature. Körting (1930) also showed that relative humidity and atmospheric pressure did not affect thrips migration.

Most infections by TSWV were recorded shortly after mass invasions by *F. schultzei* and this may indicate that primary infection is more important than secondary spread. However, limited secondary spread within the groundnut crop by the progeny of migrant thrips may occur.

CONTROL OF BUD NECROSIS DISEASE

Husbandry

Since high incidence of bud necrosis disease in Hyderabad is primarily associated with infestation by immigrant thrips during August-Septembe and January-February, sowing dates could be expected to affect disease incidence and subsequent crop loss. Groundnuts sown in mid-June, with the onset of the rains, were infected less and yielded more than crops sown later (Table 2). Disease incidence was lower in the November-sow than in the December-sown crop but overall disease incidence in post-rainy season crops was much lower than in rainy season crops and different sowing dates did not give yield advantages.

An increase in plant density decreased the proportion of infected plants, although the number of infected plants per unit area was unaffected (Table 3).

Table 3. Effect of plant spacing on the incidence of bud necrosis in groundnuts on the ICRISAT farm.

Spacing (cm)	Post-rainy season 1978-79		Post-rainy season 1979-80	
	Disease %	Yield (kg/ha)	Disease %	Yield (kg/ha)
37.5 x 5.0	10	3493	7	2153
37.5 x 15.0	23	2855	16	1524
75.0 x 5.0	20	2289	9	1570
75.0 x 15.0	40	1745	18	917
150.0 x 5.0	23	1270	11	740
150.0 x 15.0	43	777	21	409
SE: Inter-row spacing		±110.7 (11 D.F.)		±80.4 (13 D.F.)
SE: Intra-row spacing		±47.7 (6 D.F.)		±44.2 (9 D.F.)

Insecticides

Carbofuran (1 kg a.i./ha) applied to the soil at planting protected the crop from disease for 3 weeks and had no effect upon the subsequent disease incidence, but gave a small, uneconomic increase in the yield. The incidence of bud necrosis was reduced by weekly sprays of systemic insecticides such as dimethoate (450 ml a.i./ha). However, the yield increase did not cover the cost of the insecticide applications and also such excessive use of pesticides cannot be recommended on environmental grounds. Non-phytotoxic mineral oil emulsions such as JMS oil and Sunoco 7E oil at 2% concentration, alone or in combination with dimethoate, also failed to decrease disease incidence. Insecticidal protection could be expected to be more economical if the applications were timed to coincide with the maximum immigration of the vector. However, because of the expertise and equipment required, monitoring vector numbers is impractical.

Resistance

Several germplasm lines of *Arachis hypogaea* have been screened under natural conditions where the disease incidence in standard cultivars exceeded 60%. No line was resistant or immune to the virus although some cultivars such as NC Ac2242 and NC Ac2575 have some resistance to the vector. These vector-resistant lines have either thick, leathery leaves or more phenolic compounds in the leaves than susceptible cultivars.

However, Robut 33-1, a high-yielding cultivar, although susceptible when mechanically inoculated in the laboratory, was much less infected than most other cultivars when grown in both rainy and post-rainy seasons (Table 4). The basis for this lower disease incidence in Robut 33-1 is being investigated.

Table 4. The incidence of bud necrosis in groundnut cultivars TMV2 and Robut 33-1 in rainy and post-rainy seasons on the ICRISAT farm.

Cultivar	Disease incidence* (%) at maturity				
	Rainy season† crop			Post-rainy season¶ crop	
	1978	1979	1980	1978/79	1979/80
TMV2	87	100	94	48	34
Robut 33-1	34	50	35	28	20

* = Each cultivar was grown in four 100 m^2 plots at 15 x 75 cm spacing.

† = June-October ¶ = November-April

Some wild *Arachis* spp., including *A. chacoense* (Collection Number 10602) and *A. pusilla* (Collection Number 12922), were not infected despite repeated mechanical sap inoculations in laboratory tests. Further tests using grafts and transmission by viruliferous adults of *F. schultzei* are required before it can be determined if these species are genetically resistant to TSWV.

CONCLUSIONS

Bud necrosis disease, caused by TSWV, is now one of the most important diseases of groundnut in India.

Early planting, increased plant density and use of the cultivar Robut 33-1 appear to minimize losses due to bud necrosis in Hyderabad, but need to be investigated in different regions of India before they can be generally recommended. Eliminating primary sources of infection does not appear to be feasible and roguing of infected plants is unlikely to be effective in controlling virus spread, as most infection is from sources outside the crop. The effects on disease spread of inter-cropping groundnut with re now being investigated. Groundnuts planted with green gram or black gram showed a very high incidence of bud necrosis and these plants are not recommended for inter-cropping because they are seriously affected by TSWV.

The most effective method of controlling TSWV would be to grow resistant cultivars. However, attempts to locate sources of high resistance in *A. hypogaea* have so far been unsuccessful. The only known source of resistance to TSWV appears to be in wild *Arachis* spp. and these are now being tested.

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