# Maize Streak Virus: I. Host Range and Vulnerability of Maize Germ Plasm

VERNON D. DAMSTEEGT, Research Plant Pathologist, Plant Disease Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Frederick, MD 21701

**ABSTRACT**

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One hundred thirty-eight grass accessions, 529 maize hybrids, inbreds, exotic lines, and sweet corn cultivars, several *Sorghum, Tripsacum,* and *Zea* species, and major cereal crop cultivars were tested for susceptibility to maize streak virus disease in both seedling and six- to eight-leaf stages. Fifty-four grass species were symptomatic hosts (verified by back-assays to corn) including 14 annual and 31 perennial hosts not reported previously. All maize lines were susceptible in the seedling stage except Revolution and J-2705, which were highly resistant after the four-leaf stage. Two *Tripsacum* species and several *Tripsacum* plant introductions, nursery selections, and exotic *Tripsacum* collections were susceptible. Although most *Zea mays* accessions were susceptible, a few collections of *Z. mays* subsp. *parviglumis* var. *huehuetenangensis* from Guatemala were resistant. Cultivars of commonly grown cereal crops varied in susceptibility. Several grass species in the genera *Aegilops, Andropogon, Avena, Bothriochloa, Digitaria, Echinochloa, Eleusine, Hyparrhenia, Panicum, Schizachrium, Sorghastrum, Sorghum, Trichachne, Trichloris,* and *Zea* supported abundant oviposition and nymphal development of the vector *Cicadulina mbila*.

Additional key words: containment, epidemiology, vectors

Maize streak virus (MSV), transmitted by six species of *Cicadulina*, causes a serious disease in maize, sugarcane, pearl millet (*Pennisetum*), wheat, and wild grasses in parts of Africa and India (3,7,12). It is a major production constraint in African lowlands and mid-altitude growing areas (2,7), becoming progressively less severe as altitude increases. It has never been reported from North America or the Western Hemisphere.

The disease was first described as "mealie variegation" by Fuller in 1901 (6), and its viral cause and mode of transmission were determined by Storey (13,14). Of the six species of *Cicadulina* transmitting MSV, *C. mbila* Naude is the most common and ubiquitous vector (11). None of the recognized natural vector species has been reported from the Western Hemisphere.

MSV exists as a group of related viral strains that has become host-adapted in several gramineous species and all share maize as a common susceptible host. The virus has a broad host range in the Gramineae (7,8,10,12). Very few sources of resistance or tolerance exist in cultivated maize (3–5,12,15).

This report summarizes studies with MSV conducted under controlled conditions within pathogen containment facilities in Frederick, MD, to determine: 1) the reactions of a portion of the world collections of *Tripsacum, Sorghum,* and *Zea* to maize streak, 2) the vulnerability of maize germ plasm to MSV infection, and 3) the potential epidemiological role of cereal crops and native and adventive annual and perennial wild grasses.

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## MATERIALS AND METHODS

The maize streak virus (form A) isolate and its vector, *C. mbila*, were obtained from M. C. Walters, Potchefstroom, South Africa, with the approval of the Animal and Plant Health Inspection Service (APHIS) and the Maryland Department of Agriculture. The virus in infected maize leaf pieces and the vector were hand-carried directly to our containment laboratory (16). All studies were conducted within containment facilities with insects derived from this original introduction. All experiments were conducted within a sealed fiberglass facility with supplemental lighting supplied by high-output cool-white fluorescent tubes (16-hr day length) within a temperature range of 20–30 C. All research was conducted between 15 October and 1 April of each year.

Maize seed of 337 widely grown field corn hybrids, 124 inbreds (including 22 of the 25 most widely used inbreds) (1), 56 experimental and/or exotic lines, 9 sweet corn cultivars, and 3 African selections with reported resistance were obtained from 14 commercial corn seed companies, state experiment stations, and the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). One hundred thirty-eight native and adventive grass accessions were obtained from USDA Regional Plant Introduction stations, state experiment stations, and commercial seed companies. Authenticity of species or line designation was determined by the seed suppliers. The world collections of *Tripsacum* spp., *Sorghum* spp., and *Zea* spp. were obtained from Regional Plant Introduction stations, CIMMYT, and D. H. Timothy's *Tripsacum* nursery at North Carolina State University.

Test plants were started in 10-cm clay pots within the containment area. Test plants were inoculated at the seedling stage (one to three leaves) and when plants were at least 4 wk old (six- to eight-leaf stage). Seedlings were caged individually with two or three viruliferous adults of *C. mbila* in 5-cm cellulose butyrate tubes for an inoculation access period (IAP) of 24–48 hr. The leafhoppers and cages were then removed and the plants allowed to grow for 21–28 days. The six- to eight-leaf plants were caged with three to five viruliferous leafhoppers for 48–72 hr, after which the insects and cages were removed and the plants allowed to grow for 28 days.

Test plants from the grass host range were tested for MSV by back-inoculation to corn seedlings (DeKalb XL45) to confirm symptom hosts and identify symptomless carriers. Healthy "active" (genetically capable of transmitting MSV) individuals of *C. mbila* were placed on test plants for an acquisition access period (AAP) of 24 to 48 hr followed by an IAP of 24–48 hr on DeKalb XL45 seedlings. Five or more leafhoppers were used for each assay.

The incubation period, percentage infection, and host response to infection were recorded for all maize genotypes. Presence of symptoms and percentage infection data were tabulated for all other test plants. The suitability of the wild grass species and cereal cultivars as possible food and rearing hosts of *C. mbila* was determined by the feeding behavior of adult leafhoppers, the amount of ovipositing during the IAP, and subsequent nymphal development.

## RESULTS AND DISCUSSION

All field corn hybrids, inbreds, exotic lines, and sweet corn cultivars were susceptible to MSV infection when inoculated in the seedling stage (Table 1). There was some variability in the percentage of infection and degree of stunting, streaking, and leaf deformation among maize cultivars; however, all lines except four were rated susceptible. Plant reactions obtained from inoculations in the six- to eight-leaf stage followed the same pattern as the seedling tests.

One experimental hybrid was not palatable to *C. mbila* and most test plants escaped inoculation, but if inoculated, the plant reaction was rated susceptible. Two South African selections, J 2705 and Vaal Harts Komposiet, were susceptible as seedlings, but most plants of Vaal Harts Komposiet and all plants of J 2705 remained healthy at the six- to eight-leaf stage despite repeated inoculative feeding by viruliferous leafhoppers. The most resistant line, Revolution, was mildly susceptible at the one- to two-leaf stage, although symptoms consisted only of scattered broad short streaks on fewer than 50% of the inoculated plants. Attempted inoculations made after the four-leaf stage produced no infection (Table 1).

Twenty-two of the 25 most widely used maize inbreds (1) were among the 124 inbreds inoculated on two separate occasions and all were very susceptible in both growth stages. Two perennial *Zea* species, *Z. perennis* (Hitchc.) Reeves & Mangelsd. (tetraploid) and *Z. diploperennis* Iltis, Doebley, & Guzman (diploid), were immune to infection. *Z. diploperennis* has been shown to possess resistance to several pathogens (9) and is being used as a nonrecurrent parent in breeding experiments (W. R. Findley, *personal communication*). Within *Z. mays* subsp. *parviglumis* var. *huehuetenangensis* Iltis & Doebley, PI 343233, 355921, 355922, and 355923 from Guatemala were resistant to infection, with few plants infected, and PI 343232 was never infected (Table 2).

Two *Tripsacum* species, several *Tripsacum* introductions, and *Tripsacum* nursery lines from the world *Tripsacum* collection were susceptible to infection (Table 3). None of the collections of *T. dactyloides* L. (eastern gamagrass) became infected.

Twenty-four *Sorghum bicolor* (L.) Moench accessions and four additional *Sorghum* species from the world collection were tested by force-feeding viruliferous leafhoppers on test seedlings in small cages and/or by natural preference feeding in a large cage. Six *S. bicolor* accessions developed symptoms of maize streak (Table 4). Among the *S. bicolor* accessions, the grain sorghum Tx412 was susceptible but the sweet sorghum cultivar Rio was immune.

All cereal crops tested were susceptible to MSV infection. Barley, rye, and wheat developed streak symptoms similar to those in maize but symptoms in rice were narrow discontinuous streaks similar to those caused by rice hoja blanca virus infection. Two barley cultivars, Erie and Rapidan, showed 8% infection, rye cultivar Balbo had 16% infection, oat cultivar Clintland 60 had 47% infection, wheat cultivars Baart and Red Coat averaged 60% infection, and rice cultivars CI 8970, Colusa, Nato and Zenith averaged 63% infection. The two wheat cultivars exhibited extreme stunting, leaf curling, and streaking. All rice cultivars

**Table 1.** Response of maize germ plasm to infection by maize streak virus in the seedling and six- to eight-leaf stages (1975–1981)

| Host type | Number of entries | Seedling stage[a] | | | Six- to eight-leaf stage[b] | |
|---|---|---|---|---|---|---|
| | | Incubation period[c] | Infection (%) | Reduction in height[d] | Incubation period | Infection (%) |
| Commercial field corn hybrids (14 companies) | 337 | 4.0 | 95 | 41 | 12.8 | 84 |
| Inbreds | 124 | 3.6 | 96 | 46 | 10.3 | 90 |
| Exotic lines[e] | 56 | 4.1 | 92 | 34 | 10.8 | 96 |
| Sweet corn cultivars | 9 | 3.5 | 99 | 48 | 9 | 98 |
| Vaal Harts[f] | 2 | 3.2 | 100 | 23 | ...[g] | 50 |
| Revolution[h] | 1 | 4.2 | 82 | 30 | 0 | 0 |

[a] Seedlings inoculated in one- to two-leaf stage (6–10 days after planting).
[b] Six- to eight-leaf stage ranged from 28 to 35 days after planting.
[c] Average number of days from inoculation to first visible symptom.
[d] Percent reduction in height compared with healthy uninoculated controls in each test.
[e] Lines or selections made outside the United States.
[f] Vaal Harts lines were selected for field resistance in South Africa (J 2705 and Vaal Harts Komposiet).
[g] No data.
[h] Revolution selected as a highly resistant open-pollinated line in endemic area (Reunion).

**Table 2.** Response of *Zea* species and collections to inoculation with maize streak virus

| Taxonomy | MSV reaction |
|---|---|
| *Zea mays* | |
| subsp. *mays* | 529/529[a] |
| subsp. *mexicana* (Schrad.) Iltis | |
| Central Plateau (race) | 7/9[b] |
| Chalco (race) | 11/11[b] |
| subsp. *parviglumis* | |
| var. *parviglumis* | 19/20[b] |
| var. *huehuetenangensis*[c] | 8/58[b] |
| *Z. luxurians* (Durieu & Ascherson) Bird | 12/13[b] |
| *Z. perennis* (Hitchc.) Reeves & Mangelsd. | 0/14[b] |
| *Z. diploperennis* Iltis, Doebley, & Guzman | 0/12[b] |

[a] Numerator is number of entries with susceptible plants and denominator is number of entries inoculated—two varieties were resistant by the four- to six-leaf stage. Each entry is represented by a minimum of 10 inoculated plants, range 10–[illegible]0 plants each.
[b] Numerator is number of plants with symptoms and denominator is number of plants inoculated. Test plants comprised of several plant introduction numbers.
[c] Several collections of subspecies *parviglumis* var. *huehuetenangensis* from Guatemala were highly resistant or immune to infection, PI 343232, 343233, 355921, 355922, and 355923.

**Table 3.** Response of *Tripsacum* species, plant introduction (PI) numbers, nursery lines, and exotic lines of *Tripsacum* to inoculation with maize streak virus

| Taxonomy | MSV reaction |
|---|---|
| *Tripsacum maizar* Hern. & Randolph | 0/7[a] |
| *T. pilosum* Scrib. & Merr. | 0/5[a] |
| *T. lanceolatum* Rutr. ex. Fourn. | 0/8[a] |
| *T. latifolium* Hitchc. | 0.8[a] |
| *T. andersonii* J. R. Gray | 2/4[b] |
| *T. bravum* J. R. Gray | 2/2[b] |
| *T. dactyloides* L. | 0/5[b] |
| K-71-4 (site 4-kato) CIMMYT Collection | 0/9[a] |
| K-67-23 (TL 73 A-J.E.) CIMMYT Collection | 0/9[a] |
| K-67-2 (BA-74G-10) CIMMYT Collection | 2/6[a] |
| PI numbers—Tripsacum Garden (297793, 314130, 325575, 326499, 326504) | 5/24[b] |
| Nursery line numbers—Tripsacum Garden (68-22-2, 68-60-2, 68-62-5, 68-65-1) | 4/12[b] |

[a] Numerator is number of plants with symptoms and denominator is number of plants exposed to viruliferous leafhoppers.
[b] Numerator is number of entries with symptoms and denominator is number of entries exposed to viruliferous leafhoppers. Each entry represented by five to 15 plants. Plant introduction and nursery line numbers listed in parentheses are susceptible.

**Table 4.** Wild Gramineae susceptible to maize streak virus and preferred hosts for *Cicadulina mbila*

| Subfamily Tribe[a] | Growth habit[b] | Symptomatic hosts | Plants infected/inoculated | *C. mbila* hosts[c] |
|---|---|---|---|---|
| Andropogonoideae | | | | |
| Andropogoneae | P | *Andropogon gerardi* Vitman[d] | 1/6 | *Andropogon gerardi, A. hallii* |
| | A | *Bothriochloa alta* (Hitchc.) Henn.* | 6/12 | *Bothriochloa alta* |
| | P | *Cymbopogon distans* (Nees) W. Wats.* | 5/5 | *Hyparrhenia rufa* |
| | P | *C. schoenanthus* (L.) Spreng.* | 5/5 | *Schizachrium scoparium* |
| | A | *Heteropogon contortus* (L.) Beauv. | | *Sorghastrum nutans* |
| | | ex Roem. & Schult.* | 2/25 | *Sorghum halepense* (L.) Pers. |
| | P | *Hyparrhenia rufa* (Nees) Stapf | 1/6 | |
| | P | *Schizachrium scoparium** | 14/50 | |
| | P | *Sorghastrum nutans* (L.) Nash* | 3/6 | *Zea luxurians* |
| | A | *Sorghum bicolor* | 71/260 | |
| | | (*S. miliiforme*)[e] (5/32) | | |
| | | (*S. nervosum*)[e] (2/20) | | |
| | | (*S. plumosum*)[e] (2/44) | | |
| | | (*S. versicolor*)[e] | (13/26) | |
| | | (S. *verticilliflorum*)[e] | (4/52) | |
| | | (*S. vulgare*)[e] (45/86) | | |
| Chloridoideae | | | | |
| Chlorideae | P | *Bouteloua curtipendula* (Michx.) Torr.* | 18/61 | *Eleusine coracana* |
| | P | *Chloris argentina* (Hack.) Lillo & Parodi* | 10/23 | *Trichloris crinita* |
| | P | *C. cucullata* Bisch.* | 4/24 | *T. pluriflora* |
| | P | *C. gayana* Kunth (3 accessions)* | 8/50 | |
| | A | *C. radiata* (L.) Swartz.* | 4/33 | |
| | P | *C. submutica* H.B.K.* | 1/12 | |
| | A | *C. virgata* Sw. | 2/2 | |
| | P | *Cynodon dactylon* (L.) Pers.* | | |
| | | (1 of 3 accessions) | 1/8 | |
| | A | *Eleusine coracana* (L.) Gaertn. | 6/25 | |
| | A | *E. indica* (L.) Gaertn. | 22/25 | |
| | P | *Leptochloa virgata* (L.) Beauv.* | 6/19 | |
| | A | *Schedonnardus paniculatus* (Nutts.) Trel. | 2/50 | |
| | P | *Trichloris crinita* (Lag.) Parodi* | 19/21 | |
| | P | *T. pluriflora* Fourn.* | 12/16 | |
| Festucoideae | | | | |
| Aveneae | P | *Agrostis gigantea* Roth.* | 1/85 | *Aegilops cylindrica* |
| | P | *Alopecurus pratensis* L.* | 1/56 | *A. triaristata* |
| | A | *Avena fatua* L.* | 18/28 | *A. triuncialis* |
| | P | *Calamagrostis canadensis* (Michx.) Beauv.* | 1/12 | *Avena fatua* |
| | P | *Holcus lanatus* L.* | 3/10 | |
| Festuceae | P | *Lolium perenne* L. (2 accessions)* | 6/74 | |
| | A | *L. multiflorum* Lam. (2 accessions)* | 25/32 | |
| | P | *Vaseyochloa multinervosa* (Vasey) Hitchc.* | 3/4 | |
| Glycerieae | P | *Glyceria fluitans* (L.) R. Br.* | 1/2 | |
| Hordeae | A | *Aegilops cylindrica* Host* | 3/9 | |
| | A | *A. triaristata* Willd.* | 10/10 | |
| | A | *A. triuncialis* L.* | 5/17 | |
| | A | *A. umbellulata* Zhuki* | 3/9 | |
| | P | *Agropyron repens* (L.) Beauv.* | 5/55 | |
| | P | *A. sibiricum* (Willd.) Beauv.* | 2/66 | |
| Panicoideae | | | | |
| Paniceae | P | *Brachiaria erusaeformis* | 19/21 | *Digitaria decumbens* Stent |
| | | (J. E. Smith) Griseb.* | | *D. milanjiana* |
| | P | *Digitaria longiflora* (Retz.) Pers.* | 4/27 | *D. sanguinalis* |
| | P | *D. milanjiana* (Rendle) Stapf* | 1/4 | *Echinochloa crusgalli* (L. Beauv.) |
| | A | *D. sanguinalis* (L.) Scop.* | 17/17 | |
| | P | *Echinochloa polystachya* (H.B.K.) Hitchc.* | 3/5 | *Panicum hallii* |
| | P | *Panicum bergii* Arech.* | 11/17 | *P. texanum* |
| | P | *P. hallii* Vasey* | 7/12 | *Trichachne californica* |
| | A | *P. texanum* Buckl.* | 20/30 | |
| | P | *P. virgatum* L.* | 7/26 | |
| | P | *Paspalum almum* Chase* | 3/4 | |
| | P | *P. notatum* Fluegge | 11/32 | |
| | P | *Pennisetum clandestinum* Hochst. et Chiov. | 3/13 | |
| | A | *Setaria faberi* Herrm.* | 7/9 | |
| | A | *S. italica* (L.) Beauv.* | 8/11 | |
| | A | *Setaria viridis* (L.) Beauv.* | 17/23 | |
| | P | *Trichachne californica* (Benth.) Chase* | 2/4 | |

[a] Taxonomic system by A. S. Hitchcock (*Manual of the Grasses of the United States*, USDA Misc. Publ. 200, 2nd ed., 1951) and Edward E. Terrell (*A Checklist of Names for 3,000 Vascular Plants of Economic Importance*, Agric. Handb. 505, 1977).
[b] P = perennial growth habit; A = annual growth habit.
[c] Preferred grass host for food, oviposition, and nymphal development.
[d] * = New, previously unreported host.
[e] Six former *Sorghum* species now listed in synonymy under *S. bicolor*.

were susceptible; however, *C. mbila* does not prefer rice. The oat cultivar and wild oat accessions showed a mild, diffuse chlorotic mosaic and no streaking. Both oat types reacted strongly to *C. mbila* feeding, with extensive veinal enlargement and growth deformation.

Fifty-four of 138 grass accessions in the subfamilies Andropogonoideae, Chlorodoideae, Festucoideae, and Panicoideae produced positive symptoms and positive bioassays (Table 4). Several species showed mild symptoms and had very low percentages of infection. Most of the grass accessions were chosen for study because of their perennial growth habit (overwintering hosts), their widespread importance as a weed or pasture species, or as a representative of a given tribe or subfamily in a generic host range study (17). Symptoms varied on different accessions, some being much more susceptible to MSV than others. Symptoms on *Agropyron repens* consisted of a diffuse mosaic similar to symptoms produced on *Avena* sp. Less than 5% seedling infection of *Agropyron repens, A. sibiricum, Agrostis gigantea, Alopecurus pratensis*, and *Schedonnardus paniculatus* and less than 10% infection of *Calamagrostis canadensis, Chloris submutica*, and *Heteropogon contortus* indicates a low level of susceptibility to MSV. Extremely low infection levels could also indicate heterogeneity in the seed sample. Vector feeding preferences, oviposition, and nymphal development varied greatly among grasses (Table 4). Among the 54 grasses with positive symptoms, 14 annuals and 31 perennials previously had not been reported as hosts of MSV (Table 4).

The following plants were not susceptible to MSV infection: *Andropogon hallii, Bothriochloa barbinodis, Eremochloa ophiuroides, Sorghum bicolor* (18 accessions), *S. halepense, S. miliaceum*, and *S. propinguum* of the tribe Andropogoneae; *Agrostis canina, A. palustris, A. stolonifera, A. tenuis, Alopecurus aequalis, Arrhenatherum elatius*, and *Phleum pratense* of the tribe Aveneae; *Bouteloua gracilis, B. hirsuta, Chloris canterai, C. distichophylla*, and *Cynodon dactylon* (two accessions) of the tribe Chlorideae; *Dactyloctenium gigantea* of the tribe Eragrostideae; *Bromus carinatus, B. erectus, B. inermis, Dactylis glomerata, Festuca ovina, F. rubra, Poa compressa, P. nemoralis, P. pratensis*, and *P. trivialis* of the tribe Festuceae; *Agropyron cristatum, Elymus canadensis*, and *Hordeum jubatum* of the tribe Hordeae; *Coix lachryma-jobi* (two accessions) and *Tripsacum dactyloides* (three accessions) of the tribe Maydeae; *Leersia hexandra* of the tribe Oryzeae; *Cenchrus ciliaris, Digitaria decumbens, D. valida, Echinochloa crusgalli, Panicum coloratum, P. makarikariense, Paspalum dilatatum, P. urvillei* (two accessions), *Pennisetum americanum, P. macrorum, P. purpureum*, and *Stenotaphrum secundatum* (four accessions) of the tribe Paniceae; and *Phalaris arundinacea* of the tribe Phalarideae.

Abundant oviposition and nymphal development by *C. mbila* occurred in 25 different plant species of which 22 were wild grasses or wild *Zea* species and the remaining three were maize, wheat, and teosinte. The most abundant populations of *C. mbila* occurred on annuals or warm climate perennials. Two species, *Schizachrium scoparium* (Michx.) Nash and *Sorghum halepense*, were excellent insect hosts, the former is susceptible to MSV and the latter is immune.

These studies have extended the host range of MSV-A within the Gramineae by 45 species. *C. mbila* preferred selected Andropogonoids, Festucoids, and Panicoids. Susceptible members of these groups could serve as food and developmental hosts for the vector and as nonmaize virus hosts.


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