Aphid Transmission of Strawberry Mottle Virus from *Chenopodium quinoa* to *Fragaria vesca*

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ABSTRACT

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A severe isolate (HJ) of strawberry mottle virus (SMV) was sap-inoculated to *Chenopodium quinoa* from *Fragaria vesca* and then returned to *F. vesca* by aphid (*Chaetosiphon fragaefolii*) inoculation to produce typical symptoms of strawberry mottle disease. Isometric, viruslike particles approximately 30 nm in diameter were seen in cells in both inoculated host plants but not in noninoculated plants. This is the first report of successful inoculation from infected *C. quinoa* to produce strawberry mottle disease in *F. vesca*.

RESUMEN

La aislación severa HJ del virus del moteado de la fresa, SMV, fue transmitida mecanicámente desde *Fragaria vesca* a *Chenopodium quinoa*, y luego por medio de áfidos (*Chaetosiphon fragaefolii*) desde *C. quinoa* a *F. vesca*, reproduciéndose los síntomas característicos de moteado. Partículas similares a virus, de treinta nanometros de diámetro se observaron en las células de plantas inoculadas de ambos huéspedes y no en las no-inoculadas. Esta es la primera transmisión positiva del moteado de la fresa desde *C. quinoa* a *F. vesca*.

Strawberry mottle virus (SMV), transmitted semipersistently by *Chaetosiphon fragaefolii* (Ckll.) and several other aphid species, has been mechanically transmitted from *Fragaria* to *Chenopodium* and several other herbaceous hosts but has not been successfully inoculated back to *Fragaria* (1,2,4). We attempted to repeat and expand this work using the severe HJ isolate of SMV (4). We reported our results in an abstract (6).

MATERIALS AND METHODS

Leaves of *F. vesca* var. *semperflorens* (Duch.) Ser. 'Alpine' seedlings showing severe mottling symptoms after aphid (*C. fragaefolii*) inoculation with SMV-HJ were harvested and ground in a mortar and pestle (1:5, w/v) in Frazier's buffer (4). The resulting plant sap, mixed with Celite, was mechanically inoculated onto leaves of young *Chenopodium quinoa* Willd. plants. The mottling symptoms that subsequently developed on *C. quinoa* leaves were similar to those shown in illustrations published elsewhere (3).

We attempted to transmit SMV from *C. quinoa* to *F. vesca* 'UC-4' (3) and Alpine by means of *C. fragaefolii*. After fasting for 8 hr, aphids in batches of 40–50 were confined on young, noninoculated leaves of SMV-inoculated *C. quinoa* showing faint systemic mottling. After 16 hr, aphids were transferred (10 per plant) to young UC-4 plants and to Alpine seedlings for 2 days or longer before being killed by exposure to the insecticide dichlorvos (Vapona). A group of *C. fragaefolii* aphids directly from our insectary was maintained on a parallel set of Alpine plants as controls. All test plants were observed for symptom production for several months. The UC-4 and Alpine plants with SMV symptoms inoculated from *C. quinoa* SMV sources were then used to inoculate other UC-4, Alpine, and *C. quinoa* plants by use of *C. fragaefolii* and leaflet grafts.

For ultrathin section electron microscopy, pieces cut from midribs of *C. quinoa* and UC-4 were inoculated with SMV from *C. quinoa*, fixed, dehydrated, embedded in Spurr's medium, sectioned, and stained with lead citrate and uranyl acetate according to published procedures (5). All electron microscopy was done with a Philips 300 electron microscope at 60 kV.

RESULTS AND DISCUSSION

Two weeks after aphid inoculation from SMV-inoculated *C. quinoa* plants, two of 28 SMV-inoculated plants (one UC-4 and one Alpine) showed symptoms typical of the HJ severe isolate of SMV (Fig. 1), whereas none of the 15 control Alpine plants showed such symptoms. SMV was readily transmitted from these two plants by aphid or by leaflet graft to other UC-4 and Alpine plants and by mechanical inoculation to *C. quinoa*. Symptoms typical of the SMV-HJ isolate developed in all three inoculated hosts (eight of 10 UC-4, eight of nine Alpine, and 19 of 22 *C. quinoa*). This is the first

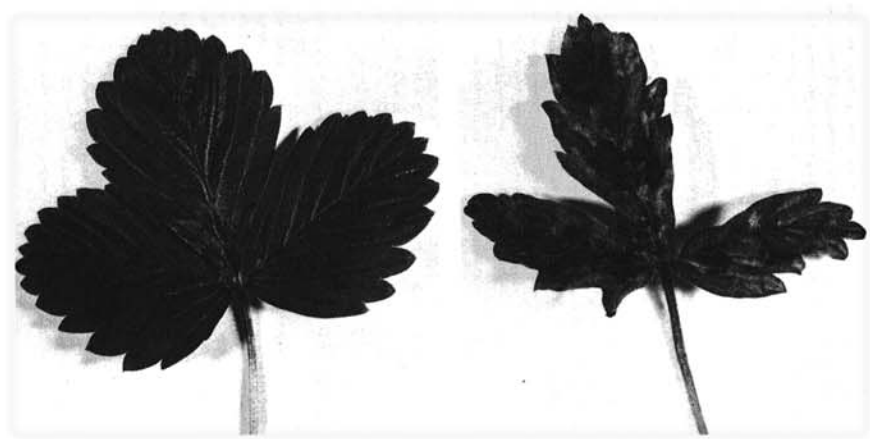

Fig. 1. (Right) Symptoms of strawberry mottle virus in *Fragaria vesca* var. *semperflorens* 'Alpine' after aphid (*Chaetosiphon fragaefolii*) inoculation from *Chenopodium quinoa* that had shown faint leaf mottling symptoms after inoculation with *C. fragaefolii* from *F. vesca* infected with the HJ isolate of strawberry mottle virus. (Left) Healthy Alpine leaf.

This work was done when the first author was on sabbatical leave at Oregon State University.

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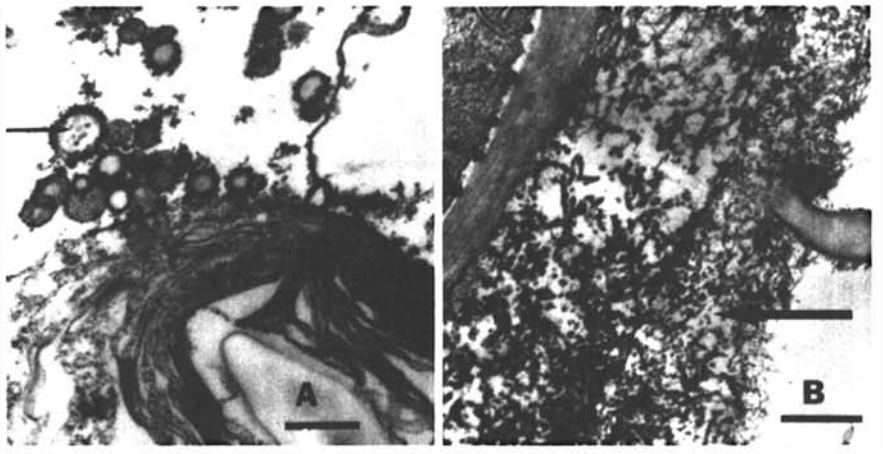

Fig. 2. Ultrathin sections of midribs from **(A)** *Fragaria vesca* 'UC-4' and **(B)** *Chenopodium quinoa*, both inoculated with the HJ isolate of strawberry mottle virus. Isometric, viruslike particles within vesicles (arrow) are present in a phloem parenchyma cell of UC-4, and similar viruslike particles (arrow) surrounded by fibrillar material occur in a xylem vessel in *C. quinoa*. Scale bars = 1,000 nm.

report, as far as we are aware, of the successful transmission of SMV from *C. quinoa* to *Fragaria* sp. to cause typical symptoms of strawberry mottle disease in the latter.

Isometric, viruslike particles (VLP) 25–30 nm in diameter were illustrated by Kitajima et al (7) in their electron microscopic study of ultrathin sections of SMV in *F. vesca* in Brazil. We found VLP approximately 30 nm in diameter ($n = 20$) occurring occasionally in cells from SMV-inoculated UC-4 and *C. quinoa*. In UC-4 midribs, the VLP occurred in phloem parenchyma cells, often in vesicles (Fig. 2A). In *C. quinoa*, VLP also occurred in association with fibrillar material within xylem vessels (Fig. 2B). No such VLP were found in comparable sections from either noninoculated host, but similar fibrillar material occurred in xylem vessels of noninoculated *C. quinoa*. To our knowledge, this is the first illustration of VLP in SMV-inoculated *C. quinoa*.

We conclude that the virus(es) associated with strawberry mottle disease in *F. vesca* is able to infect *C. quinoa*, producing faint mottling symptoms. These infected *C. quinoa* plants can then serve as sources of SMV for aphid transmission to *F. vesca*, producing typical strawberry mottle disease symptoms in the latter, from which SMV is readily transmitted by aphid or by graft to other *F. vesca* plants to produce typical symptoms. We believe the 30-nm VLP we observed in ultrathin sections of *Fragaria* and *Chenopodium* are associated with SMV infection, although satisfactory purification, inoculation, and resultant typical mottle disease in strawberry will be needed to establish this point.

ACKNOWLEDGMENTS

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