한국식물보호학회지 : 제20권 제 3 호
Korean J. Pl. Prot. 20(3) : 177~180 (1981)

Strains of soybean mosaic virus with emphasis on the mechanism of aphid transmissibility

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Soybean[*Glycine max*.(L.) Merr.] diseases caused by soybean mosaic virus(SMV) are one of the major constraints in efforts to increase production of leading soybean cultivars and to achieve self-sufficiency in soybean production in Korea. A program of study was initiated to solve the most serious problem in soybean production, soybean virus diseases, through an "AID Loan Agreement for the Crop Improvement Research Project" established between the governments of the United States of America and the Republic of Korea, and in cooperation with the International Soybean Program (INTSOY), University of Illinois, Urbana Champaign, IL., and Office of Rural Development, Suweon, Korea. The research reported here was sponsored under the provisions of this project and is a contribution towards control of the problem (3, 4).

SMV is a member of the potato virus Y (potyvirus) group which includes a large number of agriculturally important plant viruses(2, 13). SMV particles are flexuous rods of about 750nm in length. Galvez(14) reported SMV particle widths of 15~18nm while Quantz (30) reported widths of 12~13nm. SMV virions contain single stranded RNA which comprises 5.3% of the particle; the RNA has a molecular weight of 3.25×10^6 and the coat protein with a molecular weight of 28,300 (20).

SMV is transmitted through seeds of soybeans susceptible to SMV. Seedborne SMV is the primary inoculum source for field spread since no other host species are known to carry the virus over winter in nature. The experimental host range of SMV includes only thirty species in the Leguminosae other than soybeans and wild soybeans (1, 2, 12, 13, 27, 29, 30, 37) and three *Chenopodium* species; *C. album* (14, 19), *C. amaranticolor* (19, 30), and *C. quinoa* (30).

SMV is transmitted in a nonpersistent manner by at least thirty-one species of aphids (21); the most efficient vectors were *Aphis craccivora* Koch, *Macrosiphum euphorbiae* Thomas, and *Myzus persicae* Sulz. (18, 21). In the epidemiology of SMV, the number of aphids, species of aphids, and timing of maximal aphid populations, as well as the amounts of seedborne virus, are important.

Seven SMV strains were described by Cho and Goodman(7) based on differential reactions of six SMV-resistant soybean cultivars (Table 1). Cho and Goodman (7) tested over one hundred SMV isolates obtained from seed from USDA soybean germplasm collections. A virulent SMV strain, Blister, first described by Ross (34) and used in inheritance studies of soybeans for SMV resistance by Kiihl and Hartwig (26), however, was aphid nontransmissible. Because of the possible importance of the spread of virulent SMV strains by

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Table 1. Classification of soybean mosic virus (SMV) strains based on reactions of soybean cultivars (3, 7)

Soybean cultivars	Reactions of soybean cultivars to SMV strains						
	G1	G2	G3	G4[1/]	G5	G6	G7
Rampage	M[2/]	M	M	M	M	M	M
Clark	M	M	M	M	M	M	M
Davis	—	—	—	M	M	M	M
York	—	—	—	N	M	M	M
Marshall	—	N	N	—	—	N	N
Ogden	—	—	N	—	—	—	N
Kwanggyo	—	—	—	—	N	N	N
Buffalo	—	—	—	—	—	—	N

2/ Results reported by Cho and Goodman(7) were revised(4).

2/ Symbols for symptoms : — =symptomless ; M= mosic symptoms ; N=necrosis.

aphids in the field, I decided to determine the aphid transmissibility of the seven SMV strains and the spread of SMV strains in the field.

In my results, all seven SMV strains proved aphid transmissible. However, I found that an isolate of SMV strain G5 became aphid nontransmissible during the course of maintaining SMV strains after about 30 successive mechanical sap inoculations. Such a loss of aphid transmissibility has been reported previously in isolates and strains of members of the potyvirus group (28).

The mechanism of transmissibility of viruses by aphids has been extensively investigated over the past 40 years. It has been shown that the transmission of viruses by aphids in the potyvirus group requires the involvement of a factor called helper component (15, 16). Therefore, the absence of helper component was suggested to be responsible for the case of aphid nontransmissibility of viruses in the potyvirus group (28). Govier *et al.* (17) were able to partially purify the helper component from tobacco plants infected with potato virus Y (PVY) but not from healthy tobacco plants. Purified PVY was not transmissible by membrane feeding technique unless the helper component was also provided (16, 17).

The first evidence for the role of helper component in aphid transmission of viruses was from experiments demonstrating that an aphid nontransmissible virus could be transmitted from sequential acquisition tests (23); a virus originally not transmissible by aphids was transmitted when aphids were allowed to probe first on plants infected with an aphid transmissible virus (PVY or potato virus A(PVA)), and then on plants infected with an aphid nontransmissible virus such as potato virus C (PVC) and potato aucuba mosaic virus (PAMV). Transmission of PVC or PAMV did not occur when acquisition access was in the reverse order.

That a virus originally not transmissible by aphids could be transmitted was first observed in studies with mixed infections of PVA and PAMV by Clinch *et al.* (9) and confirmed by Kassanis (22). These results were explained by the results of tests demonstrating the role of helper component (24).

With regard to aphid transmissibility among isolates of barley yellow dwarf virus (BYDV), a classical persistent virus, there is a high degree of specificity between BYDV isolates and aphid species(32). For example, the RPV isolate is transmitted by *Rhopalosiphum padi* L. but not by *Macrosiphum avenae* Fab. whereas the MAV isolate is transmitted by *M. avenae* but not by *R. padi* (31). However, *R. padi* was able to transmit the MAV isolate from plants doubly infected with MAV and RPV isolates; heterologous encapsidation was suggested to be the mechanism for this phenomenon. In cases of persistent viruses, aphid transmission of the nontransmissible virus by an aphid species does not occur by sequential acquisition tests (32).

In my experiments, the aphid nontransmissible isolate of strain G5 (NG5) was transmitted from plants doubly infected with an aphid transmissible SMV strain but not from sequential acquisition tests. This appears to be the first time such a phenomenon has been observed among members of potyvirus group.

SMV causes two distinct diseases of soybeans depending upon combinations of soybean genotype and virus strain (7). The mosaic disease was first reported in Connecticut in the USA in 1915 by

Clinton (10) and is known to occur wherever soybeans are cultivated and disease surveys have been conducted (2, 8, 12, 36). The second disease, characterized by a severe systemic necrotic reaction, was first described in 1924 (25). In Illinois, the necrotic disease was first observed in the soybean cultivar Ogden by Conover (11). Development of necrosis in SMV-infected heterozygous F_1 plants was noticed by Koshimizu and Iizuka (27). However, Han and Murayama (19) found that virulent SMV strains could cause necrotic reactions in soybeans such as Norin No. 2 and Ou No. 3 which possess resistance to less virulent SMV strains. The concept that necrotic reactions occurred in soybeans which possess resistance to less virulent SMV strains after infection with virulent SMV strains was verified by the work of Cho and Goodman (7).

The soybean accession PI 96983 was identified as a source of resistance to SMV by previous workers (33) and became widely used by soybean breeders as a source of SMV resistance (26, 35). However, the most virulent SMV strain G7 caused a severe necrotic disease in PI 96983 (7). Therefore, one of my resarch goals was to search for new sources of resistance by evaluation of soybeans reported to be resistant to SMV by previous workers (26, 27, 33, 35) with the seven SMV strains classified by Cho and Goodman (7). Six Suweon soybean lines were found to be immune to all seven SMV strains. The discovery suggests that development of soybeans resistant to both mosaic and necrotic diseases can be achieved by breeding based on an understanding the genetic interaction between SMV strains and soybean genotypes (4).

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