Resistance to Wheat Streak Mosaic Virus and its Vector, Aceria tulipae

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ABSTRACT

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Wheat-*Agropyron elongatum* lines (C.I. 15321, C.I. 15322) were resistant to both wheat streak mosaic virus (WSMV) and its vector, the wheat curl mite. A few mites developed on each line but the plants did not develop virus symptoms. Wheat lines developed from crosses with C.I. 15321, and selected for resistance to WSMV after mechanical inoculation tests, were as resistant to the mite as C.I. 15321. F_1 plants appeared to have an intermediate reaction to mites. Mites developed readily on C.I. 15092, a wheat-*A. intermedium* line but it remained resistant to WSMV. Salmon, a wheat-rye translocation line carrying a segment of rye chromosome 1R, was highly resistant to the wheat curl mite but susceptible to WSMV. The mite resistance was inherited as a dominant characteristic.

Additional key words: *Agrotriticum,* viruliferous mites.

Kansas wheat production was reduced an estimated 30 million bushels in 1974 by wheat streak mosaic virus (WSMV) (6). The vector of WSMV is the wheat curl mite, *Aceria tulipae* Keifer (8). No wheat cultivar adapted to Kansas is resistant to WSMV or its vector. A few of the Scout derivatives like Eagle and Sage have moderate tolerance to WSMV but in some years they are severely damaged.

Several WSMV resistant germplasms that contain chromosome substitutions or translocations from *Agropyron* parents have been released. C.I. 15321 and C.I. 15322, substitution and translocation lines, respectively, were released by the Agricultural Research Service of the U.S. Department of Agriculture and the Oklahoma Agricultural Experiment Station. The WSMV resistance was derived from *Agropyron elongatum* (Host) P.B. (7). C.I. 15092, a South Dakota substitution line resistant to WSMV, resulted from a wheat × *Agropyron intermedium* (L.) S.C. cross (4). Resistance of these lines to WSMV under infestations with viruliferous mites has not been reported. All previous work has been done with mechanical inoculation tests.

Wheat-*Agropyron* lines or Agrotriticum lines have been reported to carry both WSMV and mite resistance (1, 3). However, Somsen and Sill (9) reported that *A. elongatum* was susceptible to mites. Heterogeneity with respect to mite resistance must exist in *A. elongatum*. This paper reports tests on C.I. 15321, C.I. 15322, and C.I. 15092 for resistance to the wheat curl mite, and to WSMV under infestations with viruliferous mites.

Mite resistance has also been reported in wheat addition lines carrying chromosome 1R from King II and Dakold rye (2). This chromosome, when substituted or translocated into the wheat genome, should provide valuable resistance to the wheat curl mite. We evaluated several such substitution or translocation lines involving the 1R chromosome of rye for mite resistance.

MATERIALS AND METHODS

Wheat-rye substitution or translocation lines.—Seeds of 18 wheat-rye substitution or translocation lines involving chromosome 1R of rye (Table 1) and a wheat control (Eagle) were grown individually in plant growth blocks. About 10 days after wheat plants emerged, five adult mites from colonies maintained on wheat were manually transferred to each plant. Individual mites were moved from host plants using a wheat awn then dislodged on the leaf of the test plant. Only mites that were moving were used and they were observed for normal movement immediately after being transferred. The plants were kept in the greenhouse at 24 C for 10 days. All active stages of mites were counted on three to five plants per line. Counting and transferring of mites was accomplished with aid of a ×20 dissecting microscope.

Wheat-Agropyron substitution and translocation lines.—Wheat-*Agropyron* substitution and translocation lines (Table 2) and a wheat control (Centurk) were planted in half rows of a greenhouse flat. Two half rows of each line were planted randomly in the flat. Three days later the test plants were placed in the greenhouse at 24 C next to a flat of WSMV-infected Parker wheat, heavily infested with wheat curl mites. A fan was directed across the infested flat blowing mites onto the test plants. The test plants were rotated one-quarter turn twice daily. After 5 days, the infested test plants were moved to a plant

growth chamber (Warren/Sherer Model CEL 38-15) at 24 C with a 12-hour photoperiod of both fluorescent and incandescent light (5,400 lux). Mite and WSMV symptoms were recorded 21 days after initial exposure to mites. Five plants were randomly selected from each row, and the mites on each plant were counted. After 28 days, mites were counted on 10 additional plants randomly selected from each row. To verify the presence of WSMV, we macerated plants in 0.2 ml of 0.2 M potassium phosphate buffer pH 6.9, Carborundum added, and inoculated 10-day-old Parker seedlings with the extract by the finger-thumb inoculation method (5). These plants were kept in the greenhouse at 24 C for 7 to 8 days before virus symptoms were noted.

Ten seeds each of the wheat-*Agropyron* lines (Table 3), wheat-rye translocation line (Salmon), a wheat control (Eagle), and the F_1 from the following crosses: C.I. 15321 × Eagle, C.I. 15322 × Eagle, and Salmon × Sage, were planted individually in plant growth blocks. Two days after plants emerged, five adult mites from cultures maintained on WSMV-infected wheat were manually transferred to each plant. Plants were maintained in a plant growth chamber with the same environmental conditions as previously mentioned. Mites on five plants from each line were counted 13 days after infestation, then five adult mites were transferred, when possible, from each plant to Parker wheat to determine if the mites could still transmit the virus (a test for viruliferous mites). Test plants also were tested for WSMV by inoculating Parker wheat with a leaf extract of each plant. Mites were counted on the remaining five plants of each line 20 days after infestation. The plants also were tested for WSMV and for viruliferous mites.

Two wheat-*Agropyron* lines, C.I. 15321 and C.I. 15322, and two susceptible wheat cultivars, Eagle and Homestead, were planted in 50-meter rows in the field on 12 May 1975. On 19 May wheat clippings heavily infested with mites were evenly distributed along the four rows. On 5 June 20 plants were randomly selected from each row, and wheat curl mites on each plant were counted.

RESULTS

Wheat-rye substitution and translocation lines.—All but one of the wheat-rye lines tested were susceptible to the wheat curl mite (Table 1). Salmon, a translocation line, did not support any increases in mite numbers. Mites may prefer several lines (Zorba, Weihenstephen 1007-53, Weique, and Feldkrone) to the wheat control.

Wheat-Agropyron and wheat-rye substitution or translocation lines.—When many mites were blown onto test plants (Table 2), Centurk and C.I. 15092 (a WSMV-resistant wheat-*A. intermedium* substitution line) were susceptible (based on mite symptoms and numbers) but C.I. 15092 had significantly fewer mites than Centurk at 28 days. All wheat-*A. elongatum* lines (C.I. 15322, translocation; C.I. 15321, substitution; 3391-2, 3391-3, 3508-4, breeding) appeared resistant and supported significantly fewer mites than Centurk or C.I. 15092 at 28 days. WSMV was not recovered from any of the wheat-*Agropyron* lines.

When five mites were manually transferred to each individual plant, Eagle and C.I. 15092 appeared highly susceptible to mites (Table 3). WSMV and viruliferous mites were found on Eagle at both dates. WSMV was never recovered from C.I. 15092. Viruliferous mites were on C.I. 15092 at 13 days, but none was recovered at 20 days; however, only one successful transfer of mites was made from C.I. 15092 at 20 days.

The wheat-*A. elongatum* lines had significantly lower mite populations than Eagle or C.I. 15092 at both dates (Table 3). WSMV was not recovered from these plants, but viruliferous mites were found four times at 13 days, when 19 successful transfers were made to WSMV-susceptible plants. Viruliferous mites were not found at 20 days. F_1 plants from the cross C.I. 15321 × Eagle had fewer mites than Eagle at 13 days and the same number of mites as C.I. 15321. At 20 days, F_1 plants had fewer mites than Eagle, and significantly more mites than C.I. 15321. The F_1 plants of the cross C.I. 15322 × Eagle did not differ from C.I. 15322 in mites at either date, but had fewer than Eagle on both dates. WSMV was recovered from two F_1 plants (C.I. 15321 × Eagle) at 13 days. WSMV was not found in the remaining F_1 plants at 20 days. Viruliferous mites were on the F_1 plants at 13 days, but not at 20 days. Viruliferous mites were not found at either date on the F_1 of C.I. 15322 × Eagle.

Salmon, a WSMV-susceptible wheat-rye translocation line, had the fewest mites per plant of all lines tested (Table 3). F_1 plants of Salmon × Sage also were resistant. WSMV was recovered from both of these lines both dates. Viruliferous mites were found on Salmon and its F_1 at 13 days. The F_1 had viruliferous mites at 20 days, but no successful mite transfers were made from Salmon at 20 days.

The wheat-*A. elongatum* lines (C.I. 15321, C.I. 15322) and two susceptible wheats (Eagle, Homestead) were spring planted and infested with mites by scattering mite-

TABLE 1. Numbers of wheat curl mites infesting wheat cultivars containing translocations or substitutions of the 1R chromosome from rye

Cultivar	Translocation (T) or substitution (S)	Average no. of mites per plant
Eagle (wheat control)	...	68
Zorba	S	104
Weihenstephen 1007/53	S	100
Weique	S	95
Feldkrone	T	88
Weique	T	82
Riebesel 47/51	S	67
Wentzel	S	66
Benno	T	65
Salzmunde 14/44	S	64
Neuzucht	S	58
Linos	T	58
Odilo	T	55
Aurora	S	47
Hamlet	T	47
Urban	T	44
Kavkas	T	41
Orlando	S	39
Salmon	T	2

TABLE 2. Wheat curl mite symptoms, number of plants with wheat streak mosaic virus (WSMV), and number of mites on wheat and wheat-*Agropyron* seedlings inoculated by blowing mites from heavily infested WSMV infected plants for 5 days

Cultivar or line	Translocation (T) or substitution (S)	Mite symptoms			Plants with WSMV	Average no. of mites per plant	
		Normal	Curled	Curled and trapped	(no./total)	21 days[a]	28 days[b]
Centurk	...	0	36	6	39/42	187	1,679
C.I. 15092	S	0	15	9	0/24	127	898
C.I. 15321	S	38	1	0	0/39	15	117
C.I. 15322	T	17	7	0	0/24	44	277
3391-2	S	27	2	0	0/29	23	188
3391-3	S	21	6	0	0/27	51	175
3508-4	S	16	7	3	0/26	99	281

[a]LSD ($P = 0.05$) = 113.
[b]LSD ($P = 0.05$) = 593.

TABLE 3. Number of mites per plant, number of plants with wheat streak mosaic virus (WSMV), and number of plants with viruliferous mites 13 and 20 days after infestation. Five mites originally were manually transferred to each plant

Wheat cultivar or line	13 days after infestation			20 days after infestation		
	Mites (no. per plant)[a]	Plants with WSMV (no./total)	No. of plants with viruliferous mites[c]: No. of successful mite transfers	Mites per plant[b]	Plants with WSMV (no./total)	No. of plants with viruliferous mites[c]: No. of successful mite transfers
Eagle	48.2	4/5	3/3	422.0	4/5	3/3
C.I. 15092	83.5	0/5	3/4	366.0	0/5	0/1
C.I. 15322	10.8	0/5	1/4	43.4	0/5	...
C.I. 15321	4.8	0/5	0/4	24.2	0/5	...
3391-2	11.0	0/5	2/3	35.2	0/5	0/2
3391-3	12.3	0/5	0/3	17.8	0/5	0/1
3508-4	17.0	0/5	1/5	36.0	0/5	0/3
C.I. 15322 × Eagle F_1	17.5	0/5	0/4	98.0	0/5	0/4
C.I. 15321 × Eagle F_1	17.5	2/5	2/4	121.0	0/5	0/2
Salmon	3.0	3/5	1/2	1.2	2/5	...
Salmon × Sage F_1	12.3	2/5	2/2	4.4	1/5	1/1

[a]LSD ($P = 0.05$) = 26.1.
[b]LSD ($P = 0.05$) = 86.7.
[c]If mites were not successfully transferred from the test plants to a susceptible host, the plant was not included. Successful mite transfer was determined by the presence of active mites on the susceptible host 10 days after transfer.

infested leaf clippings along the rows. Two weeks later Eagle, Homestead, C.I. 15321, and C.I. 15322 averaged 24.8, 19.6, 3.0, and 2.9 mites per plant, respectively. Eagle and Homestead varied from 0 to 100 mites per plant, while C.I. 15321 and C.I. 15322 varied from 0 to 12 mites per plant.

DISCUSSION

The wheat-*A. elongatum* lines, C.I. 15321 and C.I. 15322, were resistant to the wheat curl mite and WSMV when infested with viruliferous mites. F_1 plants of these lines appeared to be intermediate in response to the mites. The three breeding lines (F_4 generation) also were resistant to both WSMV and the wheat curl mite. The gene(s) for mite resistance is (are) either closely linked to the gene(s) controlling WSMV resistance, or both characters are controlled by the same gene(s) coming from *A. elongatum*.

It appeared the mites that developed on wheat-*Agropyron* lines did not acquire WSMV. No viruliferous mites were found on these lines 20 days after infestation. The original five mites carrying WSMV could have been present 13 days after infestation, which would explain the viruliferous mites found then. Wheat curl mites can transmit the virus during any stage of development except the egg stage (8), but it can acquire the virus only as a nymph (9). Therefore, the mites that developed on the wheat-*A. elongatum* lines probably were unable to acquire the virus because the host also was resistant to virus development.

The wheat-*A. intermedium* line, C.I. 15092, was

susceptible to the wheat curl mite. Though many mites developed on this line, it remained free of WSMV. Viruliferous mites were found three times in four successful transfers from this line at 13 days. That seems high when compared with four times in 19 transfers from wheat-*A. elongatum* lines. The virus might exist in localized areas of C.I. 15092, which could allow a few developing mites to acquire it. WSMV was never detected in these plants, so its concentration must be very low. More data are needed on viruliferous mites at later dates after infestation before conclusions are drawn. We made only one successful transfer of mites from C.I. 15092 at 20 days, and WSMV did not develop as a result of that transfer. Thus, we may have the same situation with C.I. 15092 as we have with the wheat-*A. elongatum* lines. That is, the original five mites that infested the plants could still have been present and carrying the virus.

Mite resistance in wheat-rye translocations and substitutions involving rye chromosome 1R may be rare, since of 18 lines tested only Salmon was resistant. The resistance from rye appears to be higher and probably is different than that from *Agropyron*. However, because Salmon is susceptible to WSMV, its use in breeding programs may be limited to broadening the base for mite resistance. A broader base for mite resistance may be needed as wheat curl mite populations appear highly variable and may adapt to resistant hosts. Lines with mite resistance from both rye and *Agropyron* are being developed for evaluation. Studies are needed on the mechanisms of mite resistance from different sources, and its relation to virus transmission in the field.

Few mites were required to produce the leaf curling symptom. Tests for mite resistance based on leaf curling symptoms alone could result in discarding many resistant plants. Counting mites on each plant is a more reliable test.

Infesting individual plants manually with a known number of mites reduced variation in our experiments. Blowing many mites onto test plants probably would be acceptable when working with many plants as when screening lines for mite resistance. On the other hand, using many mites may give a better indication of the variability and adaptability of mite populations.

C.I. 15321 and C.I. 15322 seem to be the most promising sources of resistance to use in breeding programs to control WSMV. As WSMV resistance and mite resistance are associated in both lines, one needs to select only for WSMV resistance; mite resistance should be obtained simultaneously. The fact that C.I. 15322 is a translocation line makes it the most desirable line because it should carry fewer undesirable characters from the *Agropyron* parent. Resistance to the vector in combination with WSMV resistance should reduce development of resistance-breaking strains of virus by lowering transmission rates.

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