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THE REACTION OF INBRED, SINGLE, THREE-WAY AND FOUR-WAY HYBRID CORNS TO WHEAT STREAK MOSAIC VIRUS AND KERNEL RED STREAK

BY

JOSEFINO B. TUNAC

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Plant Pathology, South Dakota
State University

1968

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THE REACTION OF INBRED, SINGLE,THREE-WAY AND FOUR-WAY HYBRID CORNS TO WHEAT STREAK MOSAIC VIRUS AND KERNEL RED STREAK

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser — Date

Head, Plant Pathology Department — Date

266171

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INTRODUCTION

Wheat streak mosaic is a widespread and important disease of wheat, Triticum aestivum (L.), in the United States (1,5,6,9,10,13,20, 29,30,51,59,60,61,63) and Canada (7,52,54). Evidence of its presence in Rumania and Jordan has been reported (55,56). A disease of wheat in the USSR may also be caused by wheat streak mosaic virus (WSMV) (39,40). The virus vector is Aceria tulipae (K.), an eriophyid mite, commonly referred to as the wheat curl mite (2,51).

Slykhuis (53) reported that wheat was the favored host of the wheat curl mite. Orlob (35) also reported that corn seedlings, Zea mays (L.), were favorable hosts for the mites. Nault et al. (31) added that inbred lines were more preferred as hosts by the mites than were hybrids. Connin (12) suggested that corn was a possible oversummering reservoir for both the virus and the vector. In Ohio (32,64), mites were found in abundance on silks and husks on commercial corn hybrids.

The discovery of abundant mites under the husks of corn ears led some workers (32) to believe that mite feeding was the cause of a disease referred to as kernel red streak (KRS). The same disease on corn was reported from northern Indiana, northwestern Ohio, southern Michigan (3,4) and Canada (62) in 1964, and in South Dakota in 1965 (C. M. Nagel, personal communication). A similar malady was reported in Bulgaria, Chile, France, Portugal, Rumania and Yugoslavia (64).

The present investigation was designed to study the reaction of different corn inbreds and hybrids to WSMV infection, to its mite vector, and the relation of mite infestation and virus infection or both to the kernel red streak disease.

REVIEW OF LITERATURE

History:

Slykhuis (49) reported WSMV in South Dakota in 1952, however, Peltier observed the disease in Nebraska in 1922 and demonstrated the susceptibility of corn to WSMV (19). McKinney (25), in 1944 infected different varieties of sweet and field corn in the greenhouse. Later, Meiners and McKinney (30) in Washington, indicated that WSMV collected from wheat in the field produced typical symptom when inoculated to corn in the greenhouse. About the same time, Sill (43) used the characteristic symptom of WSMV in corn as the basis for distinguishing WSMV from brome mosaic virus (BMV) and barley stripe mosaic virus (BSMV).

Early investigations of the disease in corn were largely incidental to experiments of WSMV on wheat and was limited to corn infected in the greenhouse. Finley in 1951 (14) first reported the occurence of the disease in corn fields in Idaho. He observed an incidence of 75-80% in a four-acre field of ear parent for the production of Golden Cross Bantam seed (15). The disease was found in a seed production field in 1951 and surveys during the following years revealed the presence of the disease in a field of commercial corn. In Nebraska (21), the disease was found to be consistently present in hybrid seed fields in 1959, '60, and '61. In Canada (37), WSMV in corn was first observed in 1964. Infection ranged from 5-10% in some locations in Essex county, Ontario. In 1965, C. M. Nagel (personal communication), reported sporadic occurences ranging from

5-10% in South Dakota.

In 1965, Williams et al. (65) reported a virus which was isolated from field corn over large areas in Ohio. He referred to this virus as 3A and believed it to be a strain of WSMV (28,66).

Symptomatology:

Finley (15) described the symptom of WSMV in corn as "numerous small chlorotic spots and/or broken streaks on the tips of the apical leaves, later the streaks elongated parallel to the veins of the leaves". McKinney (25) and Sill and Agusiobo (47) added that the chlorotic patterns tended to diffuse and disappear gradually with age of plants.

McKinney (25) observed that some plants of Golden Giant sweet corn inoculated with WSMV showed severe chlorosis in all leaves, while in other plants chlorotic patterns were strikingly evanescent and sometimes appeared only on a single leaf. He further stated that plants with severe mosaic were stunted but no necroses occurred. Paliwal et al. (37) pointed out that plants with pronounced yellowish streaks were moderately stunted while there was no stunting in plants with mild mosaic symptoms. Finley (15) found yellowing symptoms were usually accompanied by dwarfing. On the other hand, workers in Kansas (47,48) claimed that diseased corn plants were not stunted and most field corn varieties grown in the state were either immune or highly resistant to the virus; they found no naturally infected corn plants in the field.

Inbred lines were reported to be most susceptible to wheat streak mosaic. How (21) reported the disease in Nebraska on inbred pollinator plants. Finley (15) found the corn inbred test plant P-31 more susceptible to the disease than the F_1 hybrid Golden Cross Bantam. Moreover, Finley also observed wide variation in susceptibility in related inbreds and suggested that resistance could be obtained by proper selection and mating of inbreds.

The mite vector, *A. tulipae* (K.), and WSMV:

Slykhuis (51) demonstrated that *A. tulipae* (K.) vectors WSMV. Reaction of some gramineous plants to WSMV and mite increase are shown in Table 1.

Certain workers (11,44,46,53,57) observed that mites were dispersed in the field by wind and they speculated that the spread of the virus followed the same pattern. Gibson and Painter (18) and Batchelor (8) observed mites crawling on the legs and bodies of winged aphids and suggested that this might have been a means of mite dispersal in the field.

Slykhuis (53) found that the wheat curl mite was an efficient vector of WSMV. Slykhuis (53) and Orlob (35) found that corn was more readily infected by mite transmission than by mechanical means. Slykhuis (53) and Orlob (33) reported that longitudinal rolling and trapping of wheat leaves was due to the presence of mites. In corn seedlings, Sill and del Rosario (48) observed rolling and trapping of the leaves heavily infested with mites in the greenhouse. However, they did not find the same symptom on older infested plants in the greenhouse or on corn plants in the field.

Table 1. List of some gramineous plants and their reaction to WSMV and its vector, Aceria tulipae (K.)

Scientific name	Common name	Mite increase[1/]	Reaction to WSMV[2/]	Reference
1. Crop plants:				
Avena sativa	oat	0	+	23,24,53,55
Agrotricum spp.	agropyron wheat hybrid	*	+	24
Hordeum vulgare	barley	1	+	23,24,53,55
Panicum miliaceum	proso millet	0	+	23,53,55
Saccharum officinarum	sugar cane	*	+	23
Secale cereale	rye	1	+	23,24,53
Sorghum vulgare	sorghum	2	-	23
Sorghum vulgare var. sudanense	sudan grass	1	-	23
Zea mays	corn	2	+	23,24,53
2. Annual grasses:				
Aegilops crassa	----	*	+	26
A. cylindrica	jointed goatgrass	2	+	12,23,26
A. ovata	----	*	+	26
A. triuncialis	barbgoatgrass	*	+	26
A. ventricosa	----	*	+	26
Avena fatua	wild oats	0	+	23,53,55
A. byzantina	----	*	+	25
Bromus japonicus	japanese chess	0	+	23,26,53,55
B. secalinus	cheat	0	+	53,55
B. tectorum	downy chess	0	+	12,23,53,55
Cenchrus pauciflurus	sandbur	3	+	12,23
Digitaria ischaemum	smooth crabgrass	2	+	23,26
D. sanguinalis	crab grass	0	+	23,53,55
Echinochloa crus-galli	barnyard grass	1	+	12,23,53,55
Elensine indica	goose grass	0	-	23
Eragrostis cilianensis	stink grass	1	+	23,53
Euchlaena mexicana	teosinte	1	-	23
Hordeum murinum	mouse barley	*	+	26
H. gussonianum	mediterranean barley	*	+	26
Hordeum sp.	"yurasaki mochi"	*	+	26
Haynaldia villosa	----	*	+	26
Panicum capillare	witchgrass	0	+	12,23,54,55
P. dichotomiflorum	fall panicum	*	+	45
Phalaris paradoxa	----	*	+	26
Setaria lutescens	yellow foxtail	0	-	23,53
S. verticillata	bristly foxtail	1	+	23,53,55
S. viridis	green foxtail	1	+	12,26,50,53,55
S. italica	hungarian millet	1	+	23,53
Sitanion hystrix	squirrel tail	*	+	45

Scientific name	Common name	Mite increase1/	Reaction to WSMV2/	Reference
3. Perennial grasses:				
Agropyron elongatum	tall wheat grass	0	+	27
A. intermedium	intermediate wheatgrass	*	+	27
A. lasianthum	----	*	+	27
A. pungens	----	*	+	27
A. smithii	western wheat grass	1	-	23,36
A. trachycaulum	slender wheat grass	*	+	27
A. trichophorum	----	*	+	45
A. ugamicum	----	*	+	27
Alopecurus pratensis	meadow foxtail	0	-	23
Arrhenatherum elatius	tall oatgrass	1	-	23
Bouteloua curtipendula	side oats grama	0	-	23
B. gracilis	blue grama	0	-	23
B. hirsuta	grama	3	+	23,26
Bromus inermis	smooth brome	1	-	23
Buchloe dactyloides	buffalo grass	0	+	23
Dactylis glomerata	orchard grass	0	-	23,55
Elymus canadensis	Canada wild rye	2	+	12,23,26
E. condensatus	giant wild rye	*	+	26
E. giganteus	----	*	+	26
E. virginicus	Virginia wild rye	*	+	26
Eragrostis trichodes	sand love grass	*	+	12,26
Lolium multiflorum	Italian ryegrass	*	+	55
Oryzopsis hymenoides	Indian ricegrass	1	+	23,26
Panicum virgatum	switch grass	0	-	23
Phalaris arundinacea	reed canary grass	0	-	23
Poa bulbosa	bulbous blue grass	*	+	26
P. compressa	Canada blue grass	*	+	26
P. pratensis	Kentucky blue grass	1	-	56
P. stenantha	----	*	+	26
Sorghum halepense	Johnson grass	3	-	12,23
Sorghastrum nutans	Indian grass	0	-	23
Stipa robusta	sleepy grass	*	-	26

1/ 0 = no mites; 1 = poor host; 2 = fair host; 3 = good host; * = no data.

2/ (+) = susceptible; (-) = immune;

Sill and del Rosario (48) indicated that rolling and trapping of corn leaves persisted "as long as the mites stayed on the plants". They also observed that the mites "stayed mostly on the midbrib of the youngest leaf and around the edges and tips of the leaves". Later, Orlob (34) revealed that the mites "settled in the grooved sections between the veins", an area occupied by bulliform cells.

Slykhuis (53) reported that mites were scarce or absent on wheat plants nearing maturity. He stated that mature wheat plants were not suitable hosts for the mite. Kantack and Knutson (22) found few mites on the leaves of winter wheat plants as the heads emerged, but they discovered heavy populations in the greenheads until the soft dough stage. Gibson (16) and Gibson and Painter (17) reported no mites in the fully ripened heads.

The same mite population pattern seems to occur in corn. In commercial corn fields in Kansas, Sill and del Rosario (48) seldom found mites; while Orlob (35) found no mites on field grown corn in South Dakota. However, Nault and Briones (31) recently reported the presence of mites on the green husks, silks, and kernels of corn collected from the field.

Kernel red streak (KRS):

Kernel red streak was reported to have been caused by the feeding of the wheat curl mite (32).

Williams (64) stated that KRS was due to the deposition or formation of red-purple pigment in irregular streaks within the pericarp. The streaks extended from the base toward the crown of the kernel and occasionally almost complete reddening occurred.

The KRS disease was first reported in 1963 over relatively wide areas of field corn in northeastern Indiana, northwestern Ohio, and southern Michigan (3,4). It was observed in field grown corn in Ontario, Canada in 1964 (62), and in experimental three-way hybrids in South Dakota in 1965 at Presho, and in 1966 at Highmore.

The true etiology of KRS seems unclear. Some investigators (28,37, 65,66) suspected that WSMV was related to KRS. Nault _et al_. (32), indicated that the feeding of the wheat curl mite on the kernel was the primary cause of KRS, but they discussed also the possible role of WSMV "or any factor which places the corn plant under stress, such as a virus" in the KRS syndrome. For example, they indicated that the frequency of streaked kernels from plants infected with WSMV or maize dwarf mosaic virus (MDMV) was greater than that of non-infected plants. But plants infected with both WSMV and MDMV produced more streaked kernels than plants infected with either virus alone.

Regardless of the true etiology of KRS, Wall and Mortimore (62) and Williams (64) observed differences in the intensity and expression of KRS among inbreds and hybrids. They believed that a genetic factor was involved and suggested breeding for a control measure.

MATERIALS AND METHODS

A severe strain of WSMV was used that originally came from infected winter wheat plants grown at the South Central Research Farm, South Dakota. Throughout this study, the virus was maintained in winter wheat, Nebred C.I. 10094. Nebred wheat also was used to assay for the presence of the virus in inoculated corn plants.

Inoculum for mechanical transmission was obtained from sap of infected wheat plants that were grown in eight-inch pots in the greenhouse. At the 2-3 leaf stage, the seedlings were inoculated with WSMV. A sand blasting gun[1/] operated by an air pump delivering 50-60 psi, was used to inoculate the wheat seedlings. The inoculum was mixed with about 2% 400-mesh carborundum and placed in the tank of the sand blasting gun. The tank was continuously shaken during the inoculation process to insure uniform suspension of the carborundum.

Fourteen days after inoculation the youngest leaves showing severe mosaic symptoms were harvested and used in the preparation of additional inoculum. Some of these leaves were stored for not more than a week in the refrigerator before the sap was extracted. A Hobart juice extractor[2/] located in a cold room was used to extract the sap. Inoculum for all mechanical transmission, unless otherwise specified, consisted of crude sap at a 2:5 dilution (2 parts 0.1 M phosphate buffer, pH 7, to 5 parts infected wheat sap).

1/ Port-a-Blast, Lindberg Products Co., Lakeport, Calif.

2/ Hobart Model 4612, The Hobart Mfg. Co., Troy, Ohio.

The eriophyid mite, Aceria tulipae (K.), used was a subculture of the populations used by Orlob (35). Wheat seedlings in the 2-3 leaf stages were infested with viruliferous mites and the mites were maintained on this host in the greenhouse. Rolling and trapping of the leaves usually were evident a week after infestation, however, mites for transmission experiments usually were taken from plants infested for at least a month. Planting and infesting of wheat plants with mites was done periodically to assure a steady supply of viruliferous mites.

When non-viruliferous mites were needed, eggs were placed on wheat seedlings to hatch and colonize. The non-viruliferous mites were kept in a separate greenhouse.

A collection of different corn lines consisting of inbreds[1/], single, three-way, and four-way crosses, and some commercial hybrids adapted to South Dakota were used. Seeds were germinated in moistened paper towels, then 3-4 seedlings were transplanted to eight-inch pots filled with soil.

The corn seedlings were mechanically inoculated by first dusting the leaves with 400-mesh carborundum and then gently rubbed with the inoculum between the forefinger and the thumb. All the leaves were rinsed with water immediately after inoculation.

In using the mite vector, corn seedlings were inoculated by placing 1-inch sections of diseased wheat leaves infested with mites in the whorl of the corn plants. Rolled leaves of infected wheat plants were examined

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1/ C. M. Nagel's collection herein designated as PP lines, Plant Pathology Department, South Dakota State University.

under the microscope at 27X and the leaves containing abundant populations of mites were cut into 1-inch sections.

Other specific methods used are described in appropriate sections of the results.

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RESULTS

Transmission studies with WSMV:

Different varieties of inoculated wheat plants contained varying concentrations of WSMV depending upon the age at which they were inoculated and harvested and temperature at which they were grown (M. K. Brakke, personal communication). In existing greenhouse conditions, about 70-75^{o}F, infected Nebred wheat plants were grown and harvested as described. Sap was extracted and the dilution for optimum infection was determined by a dilution end point test. Serial two-fold dilutions were used.

Table 2 showed the percent infection in corn and wheat in each corresponding dilution. By probit analysis, the median infective dose (ID_{50}) was in the order of 1/256 dilution. The last dilution where infectivity was observed was 1/1024.

The percent infection with sap from infected corn seedlings was compared with the efficiency for wheat sap by inoculations of 52 inbreds, 3 single crosses, 20 three-way crosses, 2 four-way crosses, and 2 commerical hybrids. The plant extracts for inocula were obtained in the following manner: corn inbred 214 and wheat were grown at random in a greenhouse soil bench and inoculated with WSMV in their 2-3 leaf stages by the blasting method. Fourteen days later, the youngest leaves which showed severe mosaic were harvested from each set of plants and the sap of each set was extracted.

A statistical comparison of data gave a t value of 1.16 which indicated that there was no significant difference in efficiency between corn and wheat sap (Table 3).

Additional corn plants of the same lines were inoculated to compare

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Table 2. Dilution end point of WSMV using susceptible corn inbred PP214 and C. I. 10094 Nebred wheat as assay plants.

Dilution	Percent infection 1/ Corn	Percent infection 1/ Wheat
crude sap 2/	17/18	38/38
1/2	17/17	45/45
1/4	14/15	41/41
1/8	15/15	46/46
1/16	19/19	37/37
1/32	15/17	53/55
1/64	14/16	45/52
1/128	14/17	28/46
1/256	8/14	19/34
1/512	4/16	11/40
1/1024	1/17	2/44
1/2048	0/14	0/44

1/ Numerator, number of infected plants; denominator, number of inoculated plants.

2/ From C.I. 10094 Nebred wheat inoculated with the severe strain of WSMV at the 2-3 leaf stage and harvested 14 days later.

the efficiency of WSMV transmission by mites and by mechanical means. All plants were maintained at the same temperature but plants inoculated differently were kept in separate greenhouses.

A statistical comparison of data shown in Table 3 gave a t value of 7.69 for mite vs. mechanical using corn sap; and a t value of 7.39 for mite vs. mechanical using wheat sap. Both t values are highly significant indicating that mites in colonies was a better method of transmission than mechanical (Table A.1).

A susceptible inbred PP014, a moderately susceptible three-way cross PP090 x 56A x B8, and a resistant inbred PP228 were inoculated

Table 3. The efficiency of mite transmission of WSMV compared with mechanical transmission with sap from infected corn or wheat.

Method of transmission[1/]	Mean infection (%)
Mite	72.95
Mechanical: corn sap	59.32
Mechanical: wheat sap	61.60

1/ t values: Mite vs. corn sap = 7.69**, mite vs. wheat sap = 7.39**; corn sap vs. wheat sap = 1.16

at different ages with the virus. Mechanical and mite transmissions were made at 1, 2, 3, and 6 weeks from the time the plants germinated. The plants were kept growing vigorously in eight-inch pots. Plants mechanically inoculated were placed in a separate greenhouse.

As shown in Table 4, the inbred PP014 was readily infected with WSMV by both methods of transmission even in the 6th week. In the three-way cross PP090 x SD56 x B8, susceptibility tended to decrease with time. An F value of 6.30 was obtained which is highly significant. The F value between mite and mechanical transmission was 1.14 which indicated no significant difference between these two methods.

Inbred PP228 was not infected at any time.

The efficiency of a single mite to initiate infection was evaluated. Ten corn inbreds and 20 three-way crosses were used in this study. The corn seeds were planted in clay pots, and at the 2-3 leaf stage the corn seedlings were removed from the pots. The soil was washed from the roots and a single mite was transferred to each seedling.

Table 4. Percent WSMV infection obtained in selected corn lines inoculated at different ages by mechanical method and by mites.

Method of inoculation	Age in weeks	Percent infection[1/] Inbred PP014	Three-way PP090x56AxB8	Inbred PP228
Mite vector	1	100	66.67	0
	2	100	58.33	0
	3	100	58.33	0
	6	91.67	12.50	0
Mechanical	1	100	58.33	0
	2	100	49.99	0
	3	100	33.33	0
	6	91.67	8.33	0

1/ Average percent infection of four replicates; 3 plants per replicate.

A transfer needle with an eye-brow hair glued at the tip was used for handling mites. Tightly rolled leaves from infected wheat with abundant mites were cut into pieces and placed in a petri dish. About 5 ml of water was placed in the cover of the petri dish and the bottom half was set in the cover. The water between the two halves of the dish provided a barrier preventing the escape of the mites. The leaf sections in the petri dish were placed under a 30-power stereo microscope and illuminated by a Bausch & Lomb fluorescent illuminator equipped with two 5 w fluorescent bulbs. After at least 30 minutes, the mites began to crawl out of the leaf sections and congregated along the rim of the petri dish facing the light. An active second nymph was transferred to each corn seedling.

The seedlings containing 1 mite each were placed in plastic petri dishes (5.5-inch diameter) lined with moist paper towels to maintain optimum humidity. Two to three seedlings were carefully placed in each petri dish to insure no overlapping of leaves between plants. This reduced the tendency of mites to crawl from one seedling to the other.

After 24 hours, the seedlings were transplanted to four-inch pots, 2 plants per pot.

The same procedure was followed with the wheat control.

The average infection in all corn inoculated with single mites was 13.82% compared to 75% in wheat (Table A.2).

Mite colonization:

To determine the reaction of the different corn lines to mite infestation, experiments were designed using 55 PP inbreds, 3 single crosses, 20 three-way crosses, 2 four-way crosses and 2 commercial hybrids.

In the whorl of each corn seedling was placed two 1-inch sections of diseased wheat leaves abundant with mites. A week later, rolling and trapping of the young corn leaves were observed which indicated the presence of mites. The number of mites were counted on 1-inch sections cut from the tip of the youngest rolled leaf of each corn plant. To facilitate counting, the leaf sections were placed in petri dishes appropriately labeled with regard to the plant number and corn line. These petri dishes were placed in a freezer for 24-48 hours. When thawed, the rolled leaf sections could be easily opened to expose the dead mites which were counted under a stereo microscope.

When there was no trapping or rolling, leaf samples were still cut from the tip of the youngest leaf and processed as described above.

Cutting of leaf sections and counting of mites were started a week after introducing the mites into the whorl of the corn seedling. This routine was followed every week for 6 consecutive weeks.

As shown in Table 5, the average weekly change in mite population tended to decrease as the plants aged. In inbred lines PP152, PP229, PP245, PP269, and PP228, three-way PP236x56AxB8, and commercial hybrid Pioneer 388 MF, the decline in population was rapid and by the fourth week no mites were found. However, inbred PP236 contained a high population of mites at all times (Table A.3).

Wheat curl mites induced rolling and trapping of leaves in their host plants (Figure 1). Rolling and trapping of corn leaves were most distinct one week after mites were introduced. By the second week, or as the plants matured, the plants tended to escape trapping (Figure 2). Where there was no leaf trapping or tightly rolled leaves, mites usually were found in the rolled margins near the tip of the youngest leaves.

In some lines with severe mite infestation, the rolled leaf never unfolded which caused a permanent trapping of emerging leaves. In trapped leaves, sometimes numerous watersoaked spots tended to coalesce and caused eventual death of the unfolding leaves (Figure 3). Corn inbred lines which were inherently weak and had poor vigor in the seedling stage were more susceptible to such mite damage. Some inbred lines recovered from rolling and trapping but the slow recovery usually caused stunting.

Figure 1. Typical leaf roll and trap symptoms on corn seedlings infested with the wheat curl mite, Aceria tulipae (k.).

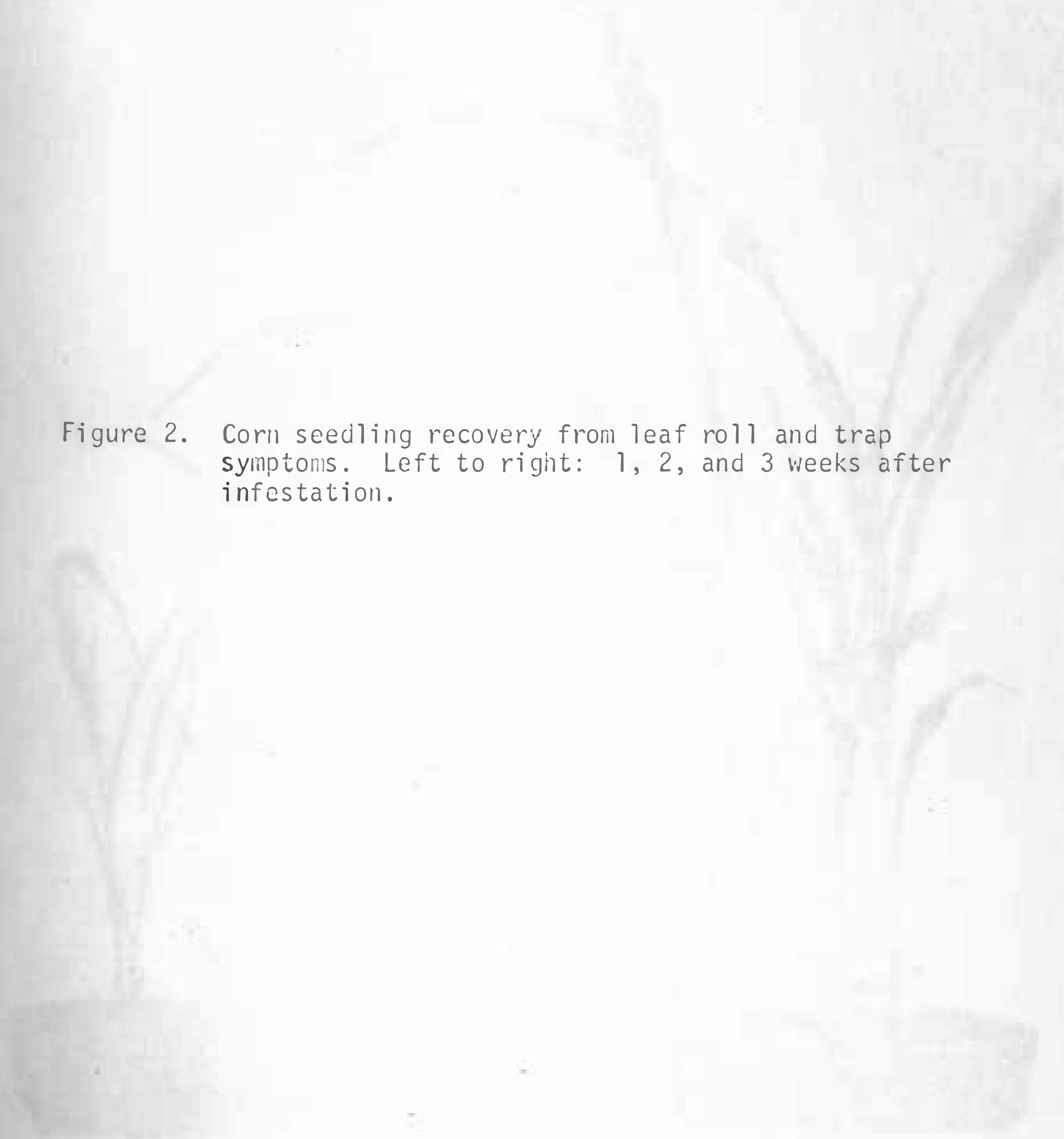


Figure 2. Corn seedling recovery from leaf roll and trap symptoms. Left to right: 1, 2, and 3 weeks after infestation.

Figure 3. Corn seedlings which show necrosis of unfolding leaves caused by severe infestation of Aceria tulipae (K.).

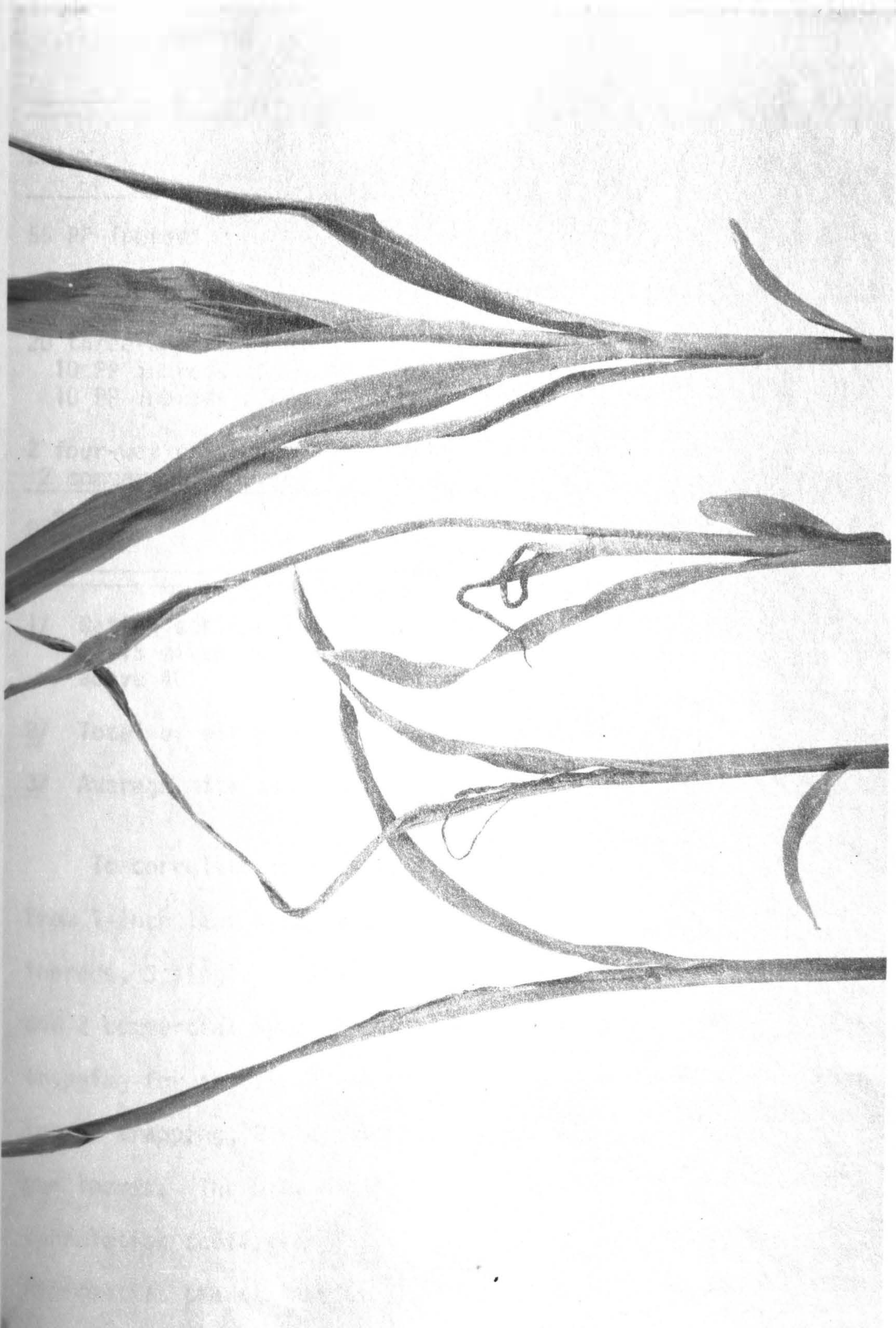


Table 5. The weekly change of mite population on corn inbreds and hybrids in the greenhouse.

Entry	Average weekly mite count 1/					
	1st	2nd	3rd	4th	5th	6th
55 PP inbreds	6.71	5.87	4.91	2.38	1.90	1.39
3 single crosses	6.94	6.06	5.14	1.37	0.79	0.55
20 three-way crosses:						
10 PP inbreds xSD26xB8	6.89	6.04	5.54	2.51	1.51	1.14
10 PP inbreds x56AxB8	6.40	4.63	2.74	1.12	0.54	0.39
2 four-way crosses	6.68	6.11	3.52	0.44	0.13	0
2 commercial hybrids	6.20	5.50	2.80	0.87	0.43	0.63
82 2/	6.63 3/	5.70	4.10	1.45	0.88	0.68

1/ Rating scale 0-7: 0 = no mites; 1 = 1-5 mites; 2 = 6-10 mites 3 = 11-15 mites; 4 = 16-20 mites; 5 = 21-30 mites; 6 = 31-40 mites 7 = above 40.

2/ Total of all lines in test; 12 plants per line.

3/ Average mite count of all lines tested.

To correlate leaf trapping with mite population, mites were counted from 1-inch leaf sections cut from the tip of the youngest leaf. Ten inbreds, 3 single crosses, 20 three-way crosses, 2 four-way crosses, and 2 commercial hybrids were used in this study. Leaf rolling and trapping for the first and the second week were rated 1-3: 1 = no rolling or trapping, 2 = medium leaf trapping, 3 = tightly rolled and trapped leaves. The mite population was counted each week. (Table A.4). The correlation coefficients are listed in Table 6, but only 0.65 was significant at the 5% level. This suggested that the number of mites was related to the degree of leaf rolling and trapping in inbred lines. In the hybrids, mite population were high but they did not necessarily cause leaf trapping or tightly rolled leaves.

Eight inbred lines, 2 single crosses, 16 three-way crosses, 2 four-way crosses, and 2 commercial hybrids infected with WSMV and infested with mites were selected for determining the correlation coefficients between mite population and percent infection (Table A.5). The r values in Table 7 were obtained from data which excluded all lines with 100% or 0% infection. None of the r values is significant which indicated that the number of mites was not correlated with infection.

Table 6. Correlation of mite population with change in leaf rolling and trapping in inbred and hybrid corn plants during a two-week period.

Entry	r value
10[1/] PP inbreds	0.65*
3 single crosses	0.32
20 three-way crosses:	
10 PP inbreds xSD26xB8	0.34
10 PP inbreds x56AxB8	0.13
2 four-way crosses	-0.24
2 commercial hybrids[2/]	0

1/ Number of lines per entry; 12 plants per line.

2/ Sokota 388 MF and Pioneer Ts-50.

* Significant at the 5% level.

Table 7. Correlation of mite population with percent WSMV infection in corn inbreds and hybrids.

Entry	r value
8[1/] PP inbreds	-0.45
2 single crosses	0.05
16 three-way crosses:	
6 PP inbreds x SD26xB8	-0.07
10 PP inbreds x 56AxB8	0.05
2 four-way crosses	-0.09
2 commercial hybrids[2/]	0.29

1/ Number of lines in each entry; 12 plants per line.

2/ Sokota 388 MF and Pioneer Ts-50.

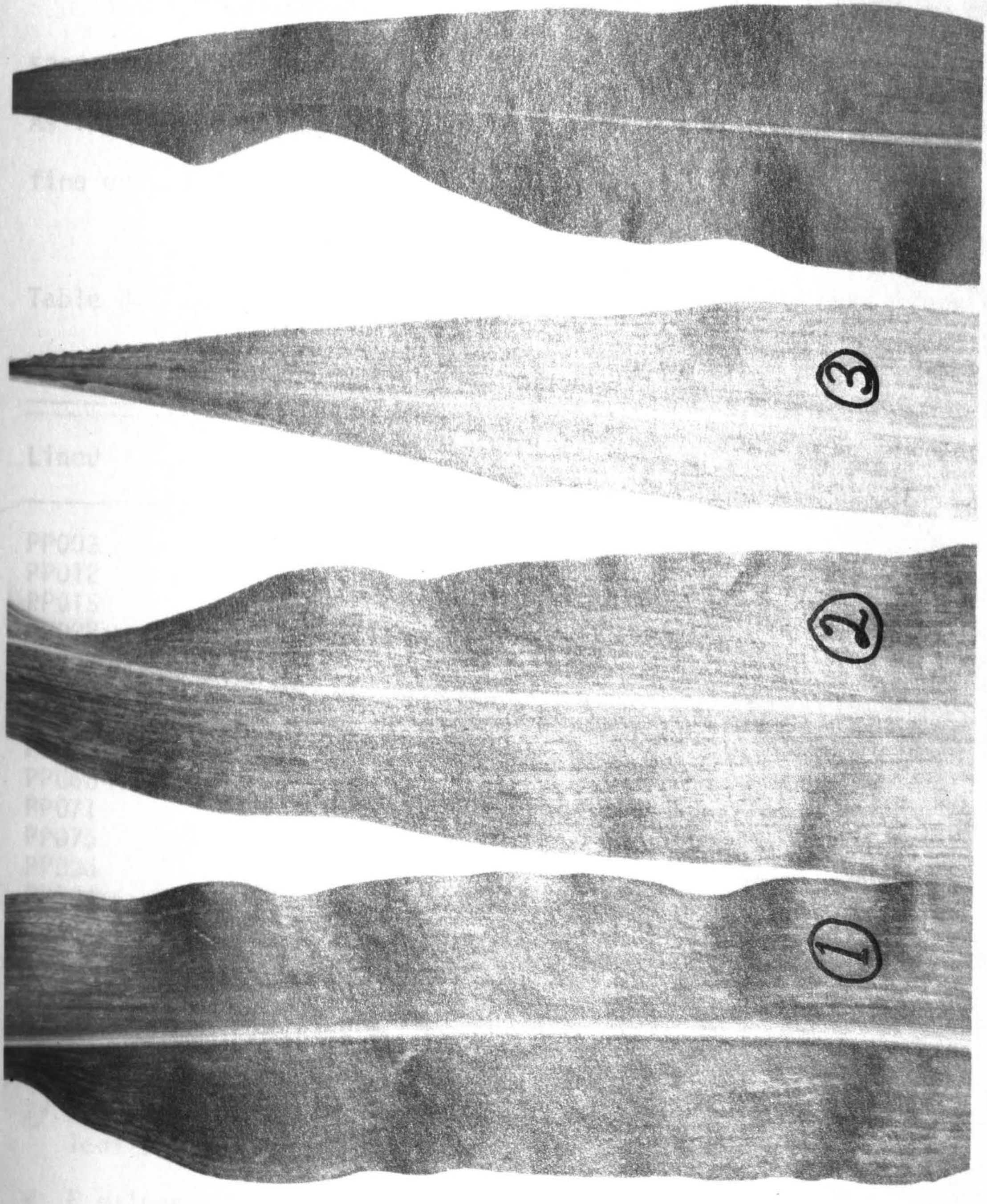
Symptomatology of WSMV on corn:

a. Fading of leaf symptoms

Preliminary observations indicated that mosaic pattern in the leaves of infected corn faded as the plants aged (Figure 4). Among 180 infected PP corn inbreds grown in greenhouse soil benches, fourteen lines (3 plants per line) which showed typically severe leaf symptoms in the seedling stage were tagged for weekly observations. Subjective ratings from 1-4 were given these plants each week until maturity. Complete fertilizer was applied every two weeks to maintain optimum growth. In winter, fluorescent lights were placed about a foot above the plants and lighted from 6:00 PM to 1:00 AM.

The data in Table 8 showed that in most lines, mosaic pattern tended to change with time. However, in inbreds PP012, PP071 and PP075, the

Figure 4. Symptoms of WSMV on (1) lower, (2) middle, and (3) top leaves of a corn plant which show a reduction in the mosaic pattern intensity as the leaf matures. Right leaf, healthy.


3
2
1

same symptom rating remained throughout the observation period.

b. Symptom expression

The typical symptom observed was characterized by diffuse chlorotic spots which usually started at the base of the youngest infected leaf. As the disease advanced, such spots coalesced and a mosaic pattern of fine or coarse streaks developed (Figure 5).

Table 8. Symptomatology in randomly selected inbred corn lines infected with WSMV in the greenhouse.

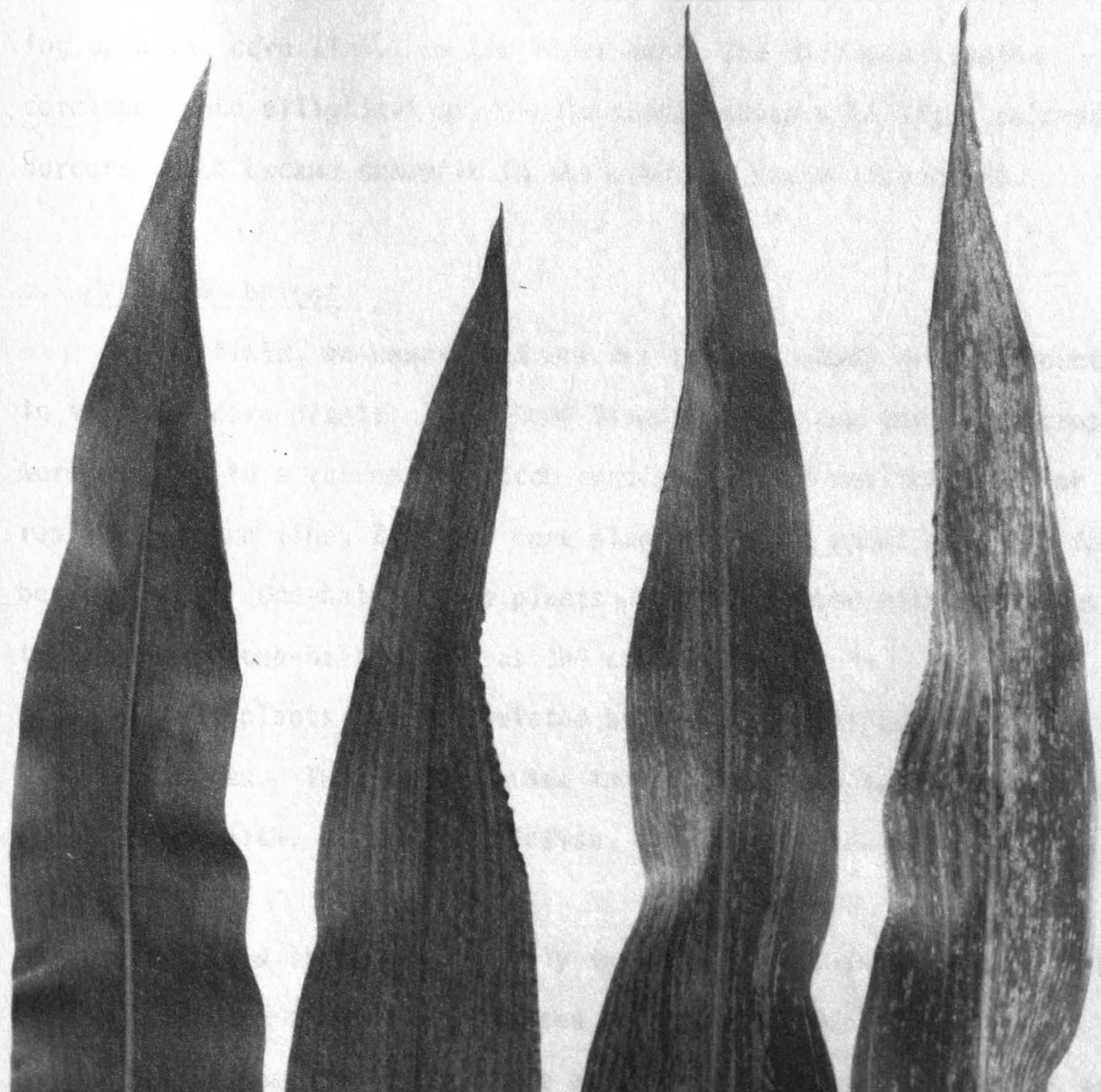
Line@	Average leaf symptom rating 1/			
	March 27	April 3	April 10 2/	April 17
PP003	4.0	2.3	2.0	2.0
PP012	4.0	4.0	4.0	4.0
PP015	4.0	3.6	3.3	3.0
PP022	4.0	2.3	2.0	2.0
PP039	4.0	2.3	2.0	1.6
PP043	4.0	2.6	1.6	1.3
PP050	4.0	1.3	1.0	1.0
PP059	4.0	3.0	2.6	1.6
PP068	4.0	3.6	2.6	1.6
PP071	4.0	4.0	4.0	4.0
PP075	4.0	4.0	4.0	4.0
PP096	4.0	2.0	1.3	1.0
PP104	4.0	2.0	1.3	1.0
PP122	4.0	2.3	1.3	1.0

1/ Rating scale: 1 = very faint, 2 = faint, 3 = moderate, 4 = severe mosaic.

2/ Appearance of tassel, (plants were inoculated Feb. 3, 1967 at the 2-3 leaf stage).

@ F values: among weeks = 30.6**; within lines = 7.1** (** means significant at the 1% level).

Figure 5. Range of WSMV symptoms on corn leaves. Left, healthy.



The streaks remained faint or developed into more severe streaks depending upon the corn line. On the other hand, the diffused symptom developed into elliptical or spindle shaped spots with light colored borders which became necrotic in the advanced stage (Figure 6).

c. Effect on height

In the field, an experiment was designed to study growth reduction in infected corn plants. PP inbred lines, single and three-way crosses were planted in a randomized block consisting of 3 replicates. For each replicated corn line, 20 seeds were planted 1 foot apart with 3.5 feet between rows. One-half of the plants were inoculated with the virus and the remaining one-half served as the control.

The test plants were inoculated by the finger wiping method in the 3-4 leaf stages. The inoculum used in the field was kept cold by placing it in an ice bath. After inoculation, the leaves were sprayed with water.

Most inbred lines were readily infected by mechanical inoculations but the single and three-way crosses remained uninfected.

A height measurement was made about a month after inoculation and another was made at plant maturity. The average heights of infected and control plants were compared.

There was a general reduction in height in infected plants (Figure 7), although some of the lines were not obviously dwarfed (see Table A.6). Table 9 presented the mean height of infected and healthy inbreds. The t value for the difference in height prior to tasseling was significant

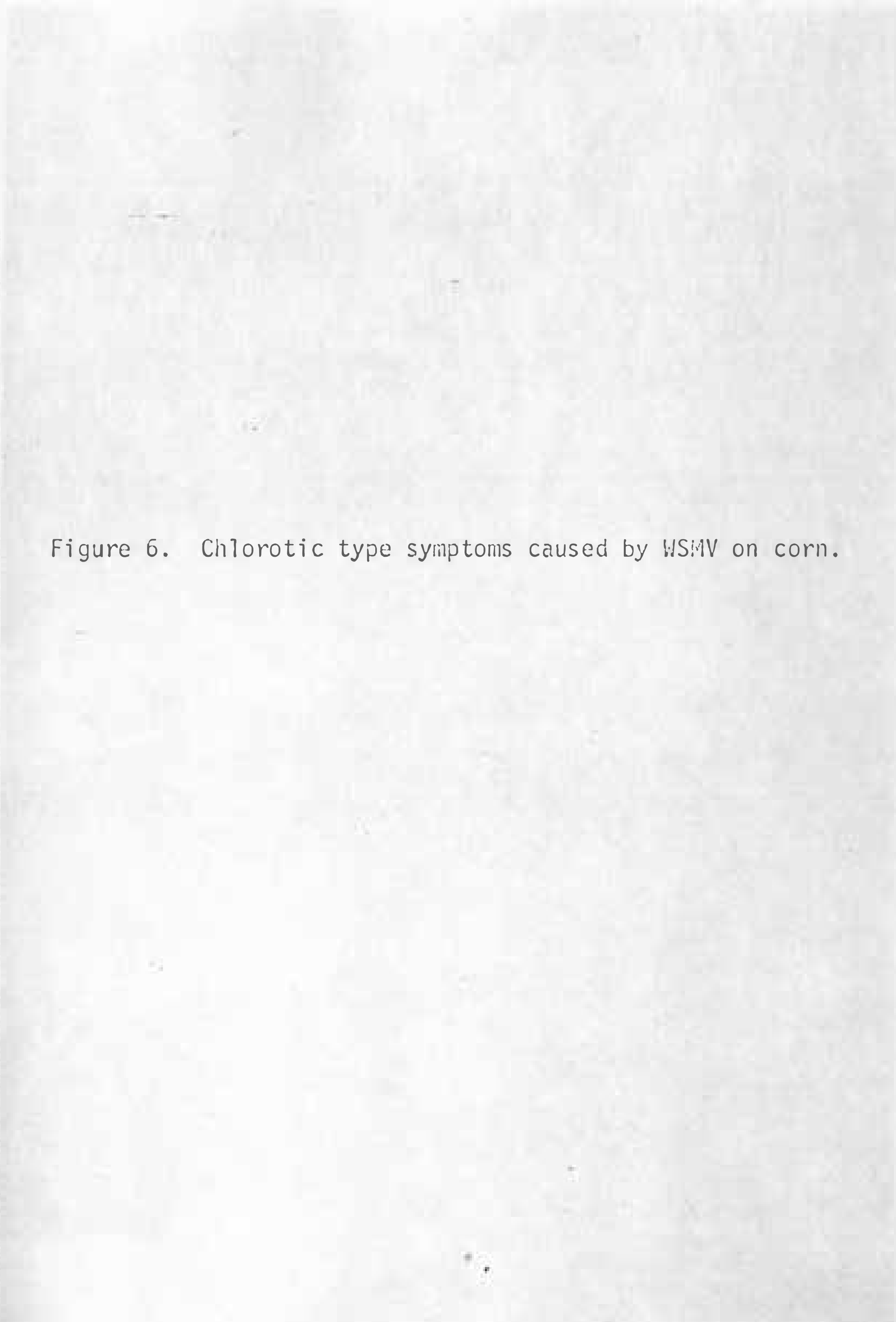
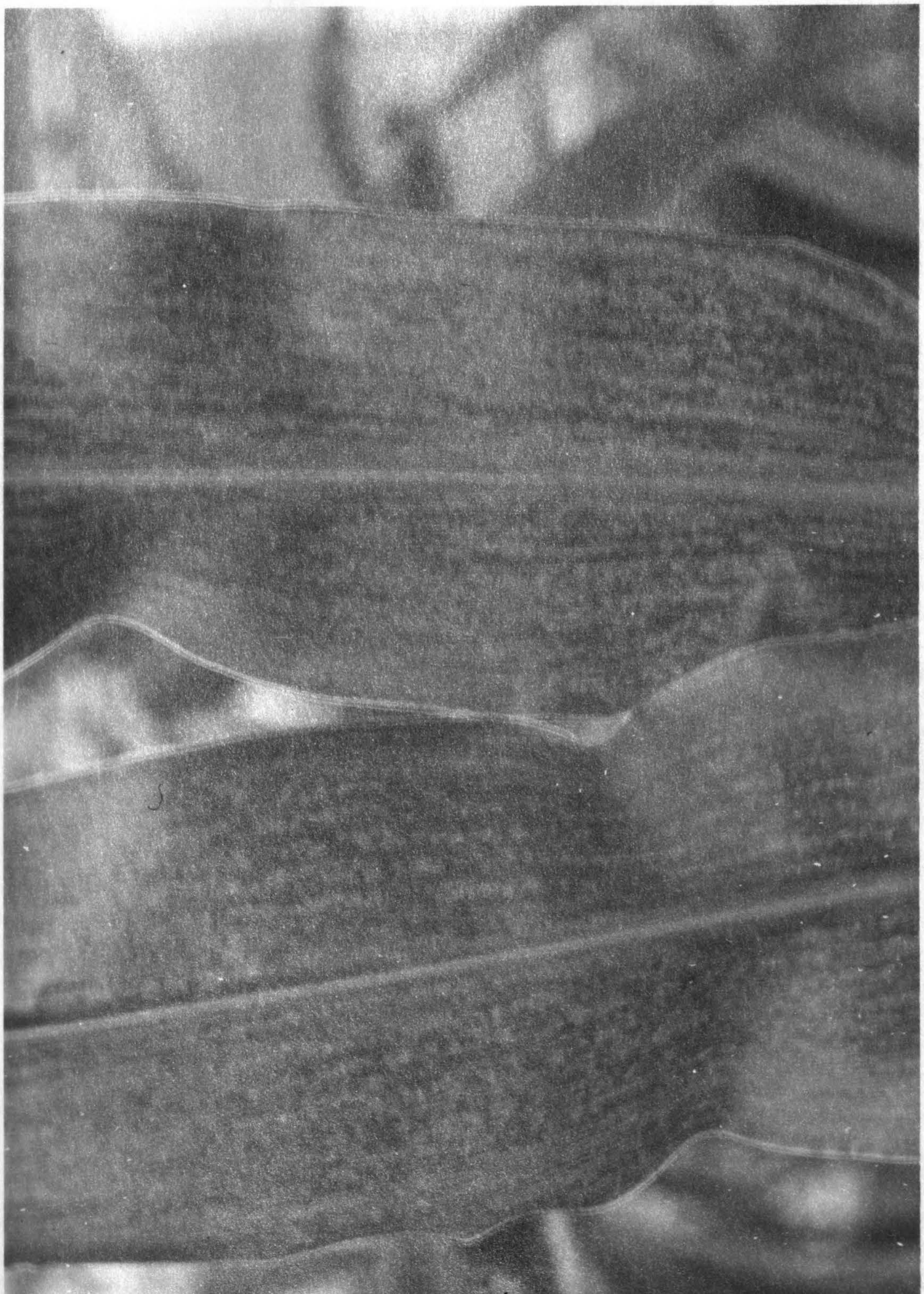


Figure 6. Chlorotic type symptoms caused by WSMV on corn.



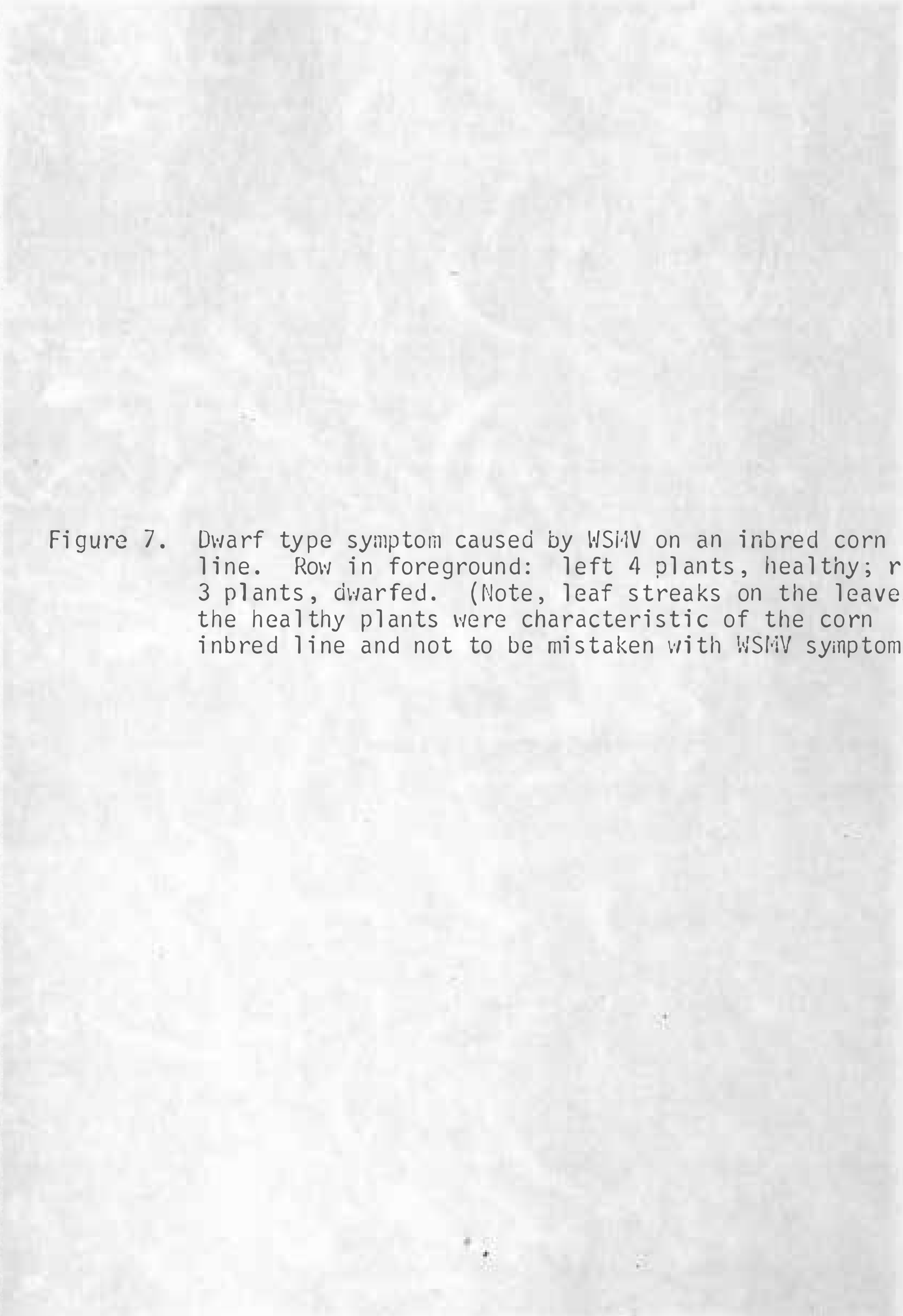
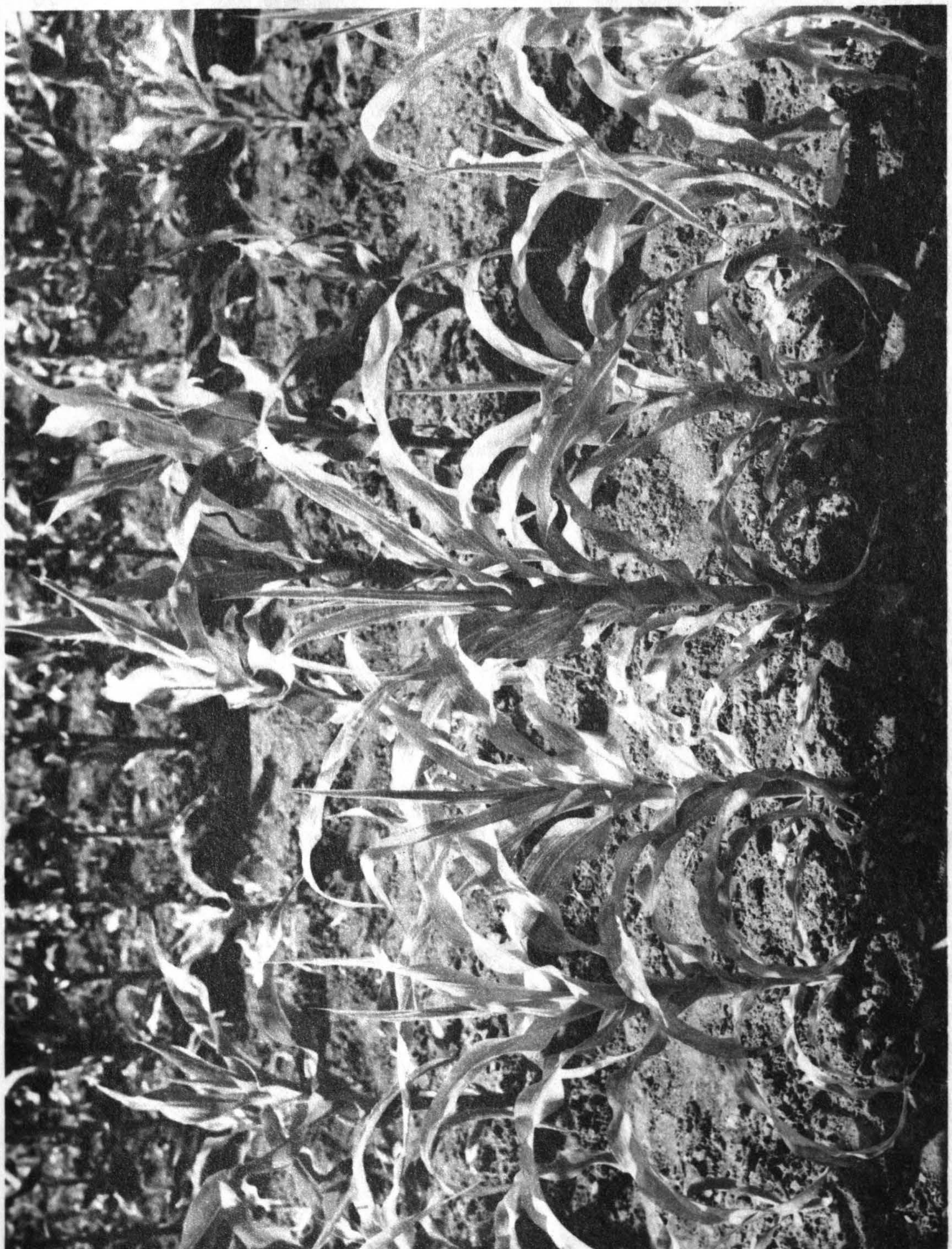


Figure 7. Dwarf type symptom caused by WSMV on an inbred corn line. Row in foreground: left 4 plants, healthy; right 3 plants, dwarfed. (Note, leaf streaks on the leaves of the healthy plants were characteristic of the corn inbred line and not to be mistaken with WSMV symptoms).



at the 5% level and significant at the 1% level at plant maturity, which indicated that the WSMV infected plants were shorter than the control.

d. Effect on yield

The mature ears were handpicked, husked and wet weights recorded. The yields from infected and healthy plants were compared. Table 9 showed a highly significant reduction in ear weight for infected inbreds. Figure 8 showed the difference in ear length in WSMV infected inbreds.

Table 9. Effect of WSMV on height and yield of 100 corn inbreds inoculated mechanically in field experiments.

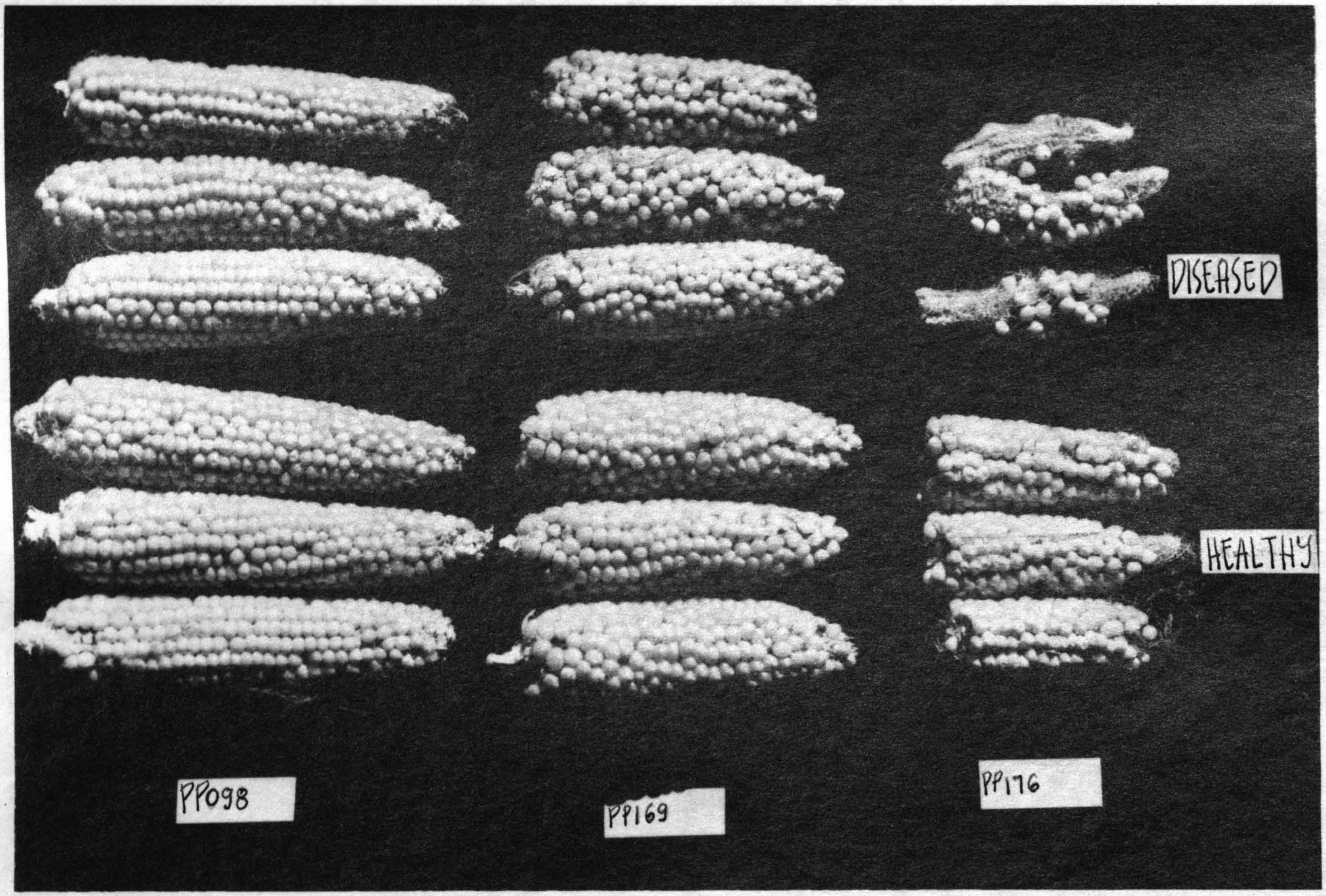
Date of measurement	Means 1/		
	Infected	Healthy	t values
Height in inches:			
a. July 20, 1967 (prior to tasseling)	24.24	25.77	2.21*
b. August 30, 1967 (at maturity)	41.63	45.37	12.34**
Yield in grams:			
Sept. 30, 1967 (gross yield)	99.44	128.82	12.04**

1/ Three replicates of 2-10 plants in a randomized block. Inoculated June 21, 1967.

* Significant at the 5% level.

** Significant at the 1% level.

Figure 8. Three susceptible inbred corn lines which show reduction in ear size due to the WSMV.


DISEASED
HEALTHY
PP098
PP169
PP176

The severity of leaf symptom was highly correlated with the reduction in height and yield of infected inbreds. Symptoms at tasseling were related 1-5: 1 = very faint mosaic, 2 = faint, 3 = moderate, 4 = severe, 5 = very severe, yellow leaves. The computed r values were significant at the 1% level: 0.39 for severity of symptom vs. height, and 0.57 for severity of symptom vs. yield. This suggested that severity of symptom was correlated with shorter height and inferior ear size in infected inbreds.

In the greenhouse and in the field, inoculated corn plants that showed no leaf symptom were considered resistant or immune. Sap was extracted from the leaves of such plants and used to inoculate wheat to determine whether infected symptomless plants were present among the corn lines.

Corn lines which was inoculated with WSMV and did not show leaf symptoms did not produce infection when their sap was assayed on wheat.

In corn plants that showed leaf symptoms, sap was extracted separately from the silk, cob, husk and kernel of immature ears. The relative infectivities of different extracts were assayed on wheat.

Inoculations made from sap extracted from various parts of diseased corn resulted in the following percentage when inoculated to wheat: silk, 63%; cob, 95%, husk, 54%; and kernel, 16%.

Kernel red streak:

Kernel red streak has been reported to be associated with WSMV or its mite vector, and was observed in some inbred lines in this study. Ten seeds of each inbred line selected for further observation were planted 6 inches apart in greenhouse soil benches, then infested with viruliferous mites at the 2-3 leaf stage.

Some of the selected PP lines were immune to WSMV but they were suitable hosts for the mite. The mite-infested plants were allowed to produce ears. At maturity, the ears were inspected for mites under a stereo microscope and 98% of the ears were infested. A random sample of mite infested ears from WSMV immune and diseased corn plants was placed in pots of wheat seedlings. In every case rolling and trapping occurred in most of the wheat seedlings, however, virus infection was variable and ranged from 10-100%. This suggested that a mixed population of viruliferous and non-viruliferous mites was present in the ears.

The frequency of ears with KRS was higher in plants infected with WSMV than in non-infected plants (Table 10).

The ears were visually examined and rated for the percent of kernels showing intense streaking. A rating scale 0-5 was used: 0 = no streaked kernels, 1 = 1-10%, 2 = 10-20%, 3 = 20-25%, 4 = 50-80%,

Table 10. Percent of ears with KRS on plants inoculated with WSMV in the greenhouse.

Treatment	Percent ears with KRS[1]
Non-infected	25.00
Infected	44.11

[1] 133 inbred lines consisting of 3-6 plants per line. Mites were found in the ears at harvest time.

5 = 80-100%. The ears also were examined at 27X and the estimated mite population was rated 0-5: 0 = no mites, 1 = 1-10, 2 = 10-50, 3 = 50-100, 4 = 100-200, 5 = above 200. A correlation coefficient was determined for mite population vs. percent of kernels with intense KRS in the ears of WSMV infected and healthy plants.

Correlation coefficients of 0.22 for ears from WSMV infected plants and 0.24 from healthy plants were obtained by the square root transformation method. However, only 0.24 was significant at the 1% level which indicated that the percent of kernels with intense KRS in the ears of healthy plants was correlated with the number of mites. In WSMV infected plants, the percent of streaked kernels was not significantly correlated with mite population (Table A.7.).

In the laboratory, mites introduced in the silk of an excised green ear survived and even multiplied until the entire ear was dry. The basal portion of the excised ear was placed in water then kept in a jar lined with moist paper to reduce drying. Abundant mites on the husks, silks and kernels were noted periodically under the micropscope.

To study mite colonization and KRS development in the field, 2 replicates of 15 seeds per inbred line, and three-way crosses were planted. Where possible, viruliferous mites were placed in the whorl of five plants in the 3-4 leaf stage. Five plants were infested with viruliferous mites by inserting mite-infested wheat sections in emerging silks. Following this procedure, the ears were immediately pollinated and covered with pollination bags to prevent spread of mites to other plants. The 5 remaining plants served as controls.

In plants where mites were introduced into the whorl of the seedlings, no mites were found from random samples one week later.

Table 11 showed the average frequency of ears with KRS in the different treatments. There was a higher frequency of ears which showed KRS when the plants were infested with viruliferous mites on the silk (Table A.8).

The effect of either virus or mites in initiating KRS was studied with the corn inbred PP124 which was susceptible to WSMV and KRS. Five sets of 20 seeds each were planted in soil benches in separate

Table 11. Percent of ears with KRS from inbred and hybrid corn plants grown in the field.

Treatment	% ears showing KRS
Infected with WSMV (no mites introduced to the silk).	3.17
Healthy, but viruliferous mites introduced to the silk.	27.11
Control (healthy, no mites introduced to the silk)	3.70

greenhouses. In one treatment, plants were mechanically inoculated with WSMV in the 2-3 leaf stage. In the second treatment non-viruliferous mites were placed on the emerging silks. In the third treatment, the plants were mechanically inoculated with WSMV in the seedling stage and at silking time viruliferous mites were placed on the emerging silks.

Plants in the fourth treatment were healthy but viruliferous mites were introduced on the emerging silks. No mites were introduced on the healthy control.

In all the treatments where mites were introduced to the silks, abundant mites were observed on the husks, kernels, and silks, when the ears were picked. At least 6 ears were picked from every treatment. The individual kernels from these ears were examined under a stereo microscope and rated from 0-5 for percent and intensity of red streaks: 0 = no streaks at 27X; 1 = 1-10% streaks, very faint color at 27X; 2 = 10-20% streaks, light color intensity; 3 = 20-50% streaks, light to moderate color intensity; 4 = 50-80% streaks, moderate to severe color intensity; 5 = 80-100% streaks, severe color intensity.

Kernel red streaks were observed in all of the ears where mites were introduced in the emerging silks (Table 12). However, intensity of the streaks was significantly less in the ears infested with non-viruliferous mites than in those infested with viruliferous mites. There was no significant difference in the intensity of streaks between the ears of WSMV infected plants and the ears infested with viruliferous mites of originally WSMV free plants.

Table 12 showed that viruliferous mites placed on the silk of WSMV infected or non-infected plants produced 100% streaked kernels in all the ears. The average percent of kernels with KRS from the ears of WSMV free plants with non-viruliferous mites was 79.43. When mites were absent in the ears, no KRS developed (Figure 9).

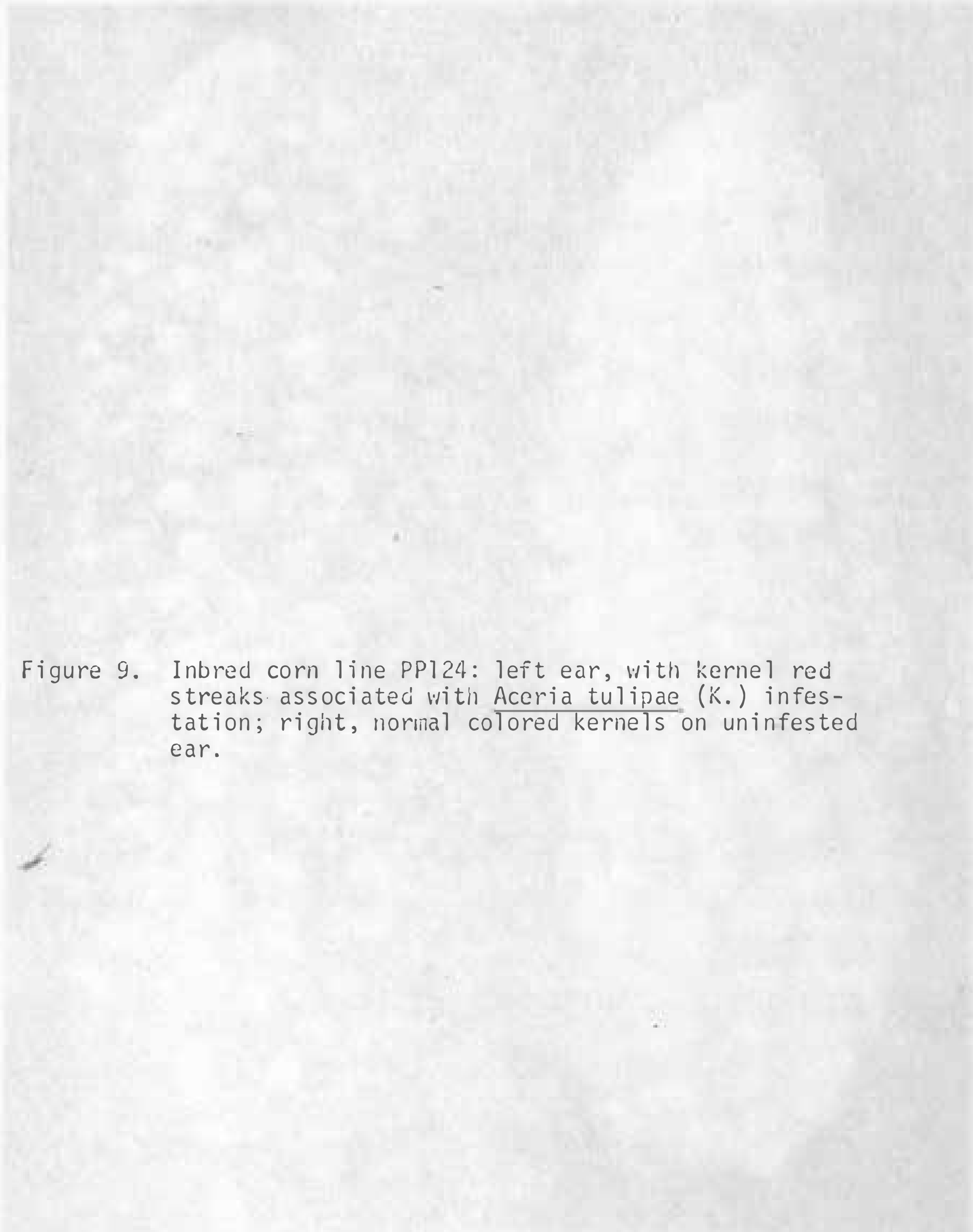


Figure 9. Inbred corn line PP124: left ear, with kernel red streaks associated with <u>Aceria tulipae</u> (K.) infestation; right, normal colored kernels on uninfested ear.

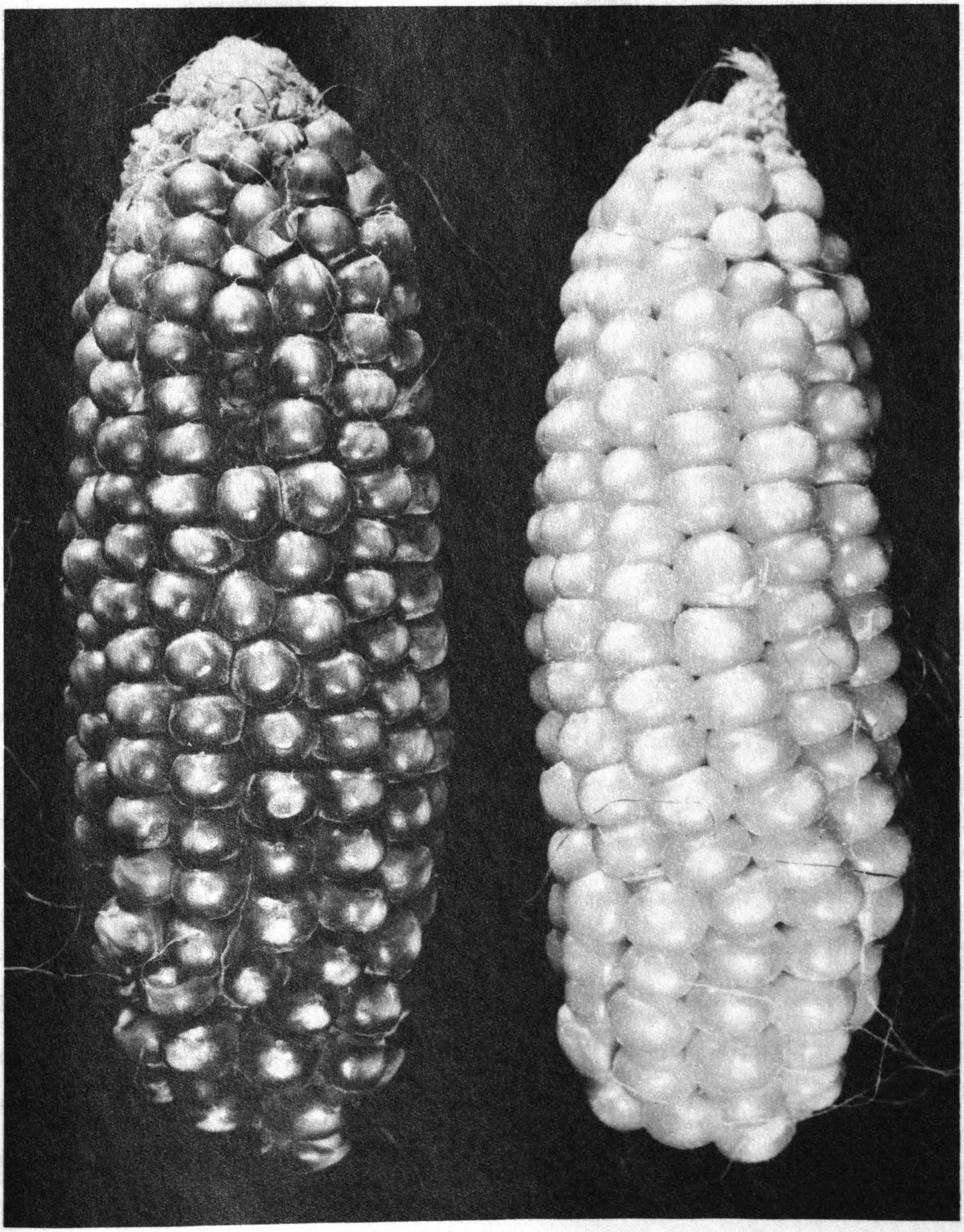


Table 12. Symptomatology of KRS on kernels of inbred corn line PP124.

Treatment 1/	Percent kernel with KRS	Intensity of streaks 2/
1. viruliferous mites placed on the emerging silks of WSMV infected plants	100	3.61
2. virulfierous mites placed on emerging silks of WSMV free plants	100	3.39
3. non-viruliferous mites placed on the emerging silks of WSMV free plants.	79.43	1.50
4. WSMV infected plants (no mites)	0	0
5. WSMV free plants (control, no mites)	0	0

1/ t values for intensity of streaks: 1. vs. 2. = 0.67; 1. vs. 3. = 7.15**; 2. vs. 3. = 7.05** (** means significant at the 1% level).

2/ Average intensity of kernels from 6 ears at a 0-5 rating scale.

Kernels from the ears of WSMV infected plants with or without KRS were assayed for WSMV on wheat. Both sets of kernels produced infection: 17.54% for kernels with KRS, and 16.66% for kernels without KRS. Kernels from ears of WSMV free plants which were infested with viruliferous mites on the emerging silk produced 17.39% infection when assayed on wheat.

Inbred line PP124 planted in 3 replicates in the field and infected with WSMV by mechanical inoculation did not show KRS in the ears. No KRS was observed in the control.

In other experiments in the field, red discoloration of kernels was observed in certain inbred lines (Table A.6). Such discoloration was found frequently in kernels with smut infection, bird damage or natural exposures by other factors. Kernel discoloration apparently could be induced in certain lines by several such factors. The presence or absence of WSMV did not change the frequency of red discoloration in such lines.

In Table A.9, results from the artificial inoculations with viruliferous mites in the greenhouse of 241 inbreds and 25 hybrids were shown. Most hybrids were infected but the percent infection was low.

DISCUSSION

Wheat streak mosaic virus is arthropod-borne and also transmitted mechanically. However, efficiency of mechanical transmission seemed to vary with the age or the length of time following inoculations of the plants from which the inoculum was obtained. Preliminary inoculations in corn showed that sap obtained from wheat infected with the virus for one month gave less infection than sap obtained from wheat seedlings infected for 14 days. M. K. Brakke (personal communication) indicated that younger infected wheat plants contained a higher concentration of viruses than older infected plants. This might have accounted for the increased infection when inoculum from younger wheat seedlings was used. Inocula obtained from corn and wheat seedlings were used. Inocula obtained from corn and wheat seedlings which were infected for the same length of time with WSMV produced comparably the same percent infection in corn plants. This suggested that concentrations of virus in these two hosts were the same.

The use of infected younger host plants as source of inoculum increased the efficiency of mechanical transmission, but the level of infection was still less than that obtained with the mite vector. Orlob (35) and Slykhuis (53) also found that mite vector was more efficient than mechanical method in transmitting WSMV. Paliwal and Slykhuis (38) reported high concentrations of WSMV in the alimentary tract of the mite. The efficiency of the mite vector seemed to lie in the protection of the WSMV by the mite's alimentary system and the manner in which the virus was deposited during feeding. In mechanical transmission, WSMV was suspended in a liquid which subjected it to physical and chemical agents that could have considerably reduced infectivity.

A single mite was found to be sufficient to initiate infection in susceptible corn and wheat seedlings. However, percent infection was higher in wheat. In all infected wheat seedlings, leaf rolling and trapping developed which indicated that the mite multiplied. No leaf rolling or trapping was observed in corn and no mites were recovered. Since the single mites were obtained from naturally infested wheat, the lower percentage of infection in corn could be the failure of the mite to adapt and feed on corn. Rosario and Sill (42) found physiologic strains of the mite vector based upon the ability of the mite to adapt to different hosts. Sometimes adaptations to new hosts were difficult and slow (41). The percent infection by a single mite in corn seedlings might have been increased by using mites naturally colonizing corn.

In the field, it was found that WSMV caused an important disease in some inbred lines and severely reduced yield. However, in some infected lines, there was no apparent reduction in height or yield. The disease was less important in hybrids. Hybrids were rarely infected in the field and symptoms were generally less severe. Swarup <u>et al.</u> (58) indicated that the location of genes for resistance to WSMV in Agrotricum hybrids was the same for the agronomic characteristics. Such phenomena may be similar in hybrid corn. In inbred lines, the genes for resistance seemed to be dominant since percent infection was generally either high or none.

It has been characteristic of systemic infections by most viruses that the successively emerging leaves continued to show symptoms. This pattern existed in WSMV infected corn plants, but the symptoms tended to fade as the leaf matured. Therefore in mature plants, the mosaic pattern was absent in some or all the leaves. McKinney (25) described this phenomenon as evanescence. In some inbred lines however, mosaic symptoms remained severe in all the leaves at any stage of development.

Another symptom expressed in some hybrids was the production of streaks in only one or two leaves. McKinney (25) observed the same condition. Therefore, in the field it was difficult to distinguish all infected plants by means of symptom expression alone. This was demonstrated by randomly collected leaf samples from plants with no visible symptoms of WSMV at maturity from fields of Pioneer 349, Pioneer 3218, and some unidentified experimental three-way crosses at the South Central Research Farm. Some of these leaves produced infection when assayed on wheat. This preliminary result suggests the desirability of assaying commercial field corn as to the prevalence of the virus.

Plants in which the symptoms have disappeared may be placed in the category of symptomless carriers. However, results indicated that there were no true symptomless carriers that failed to show leaf symptom at some phase of their growth. Inoculated plants which did not show any leaf symptom always produced negative results when assayed on wheat. Such plants were considered immune.

From the time Slykhuis (51) found that the wheat curl mite was the vector of WSMV, the virus and the mite vector have been inseparable in subsequent reports of the disease. Interestingly, the mites often injured the host in addition to and independent of the effect of WSMV. In corn, a heavy infestation of mites caused leaf rolling and trapping in the seedling stage. Direct feeding of the mites in young corn resulted in water soaked spots in the rolled leaf. The spots became visible as minute chlorotic spots when the leaf unrolled. Such chlorotic spots were irregularly distributed over the leaf. In contrast, the spots caused by WSMV infection tended to follow a regular pattern and were characterized by definite borders.

Inbred lines were more susceptible to leaf rolling and trapping than hybrids. Hybrids often outgrew such effects and hence never became stunted. In the field, both inbred and hybrid seedlings were probably more sturdy and might have accounted for the absence of leaf rolling and trapping.

Orlob (34) reported that mites fed on the bulliform cells of grass leaves and caused the leaves to roll. The rolled leaves consequently offered a favorable place for mite colonization. Heavy mite populations caused leaf rolling in young corn, but most corn seedlings recovered from rolling as they matured. Mature cells seemed to be a less desirable feeding site for the mites. It was observed that the mites tended to move to the next youngest leaf and colonized in the rolled margins near the tip. In mature corn where the leaf margins ceased to roll, it was not known whether or not at this time the mites have left the plants. However, the presence of heavy mite populations in the ears of greenhouse grown plants suggested that some mites could have survived in the leaf whorl.

Visual inspection of the mite infested ears from WSMV susceptible and immune plants in the greenhouse revealed the presence of KRS. This indicated that mites were involved in the KRS etiology. Since the percent of ears with kernels with intense streaking was higher in WSMV infected plants, it is believed that viruliferous mites were primarily involved in the development of the KRS syndrome. The random presence of KRS in the ears of WSMV immune plants could be accounted for by the movement of mites from the ears of WSMV infected plants. It should be pointed out here that the final generations of mites in the ears of WSMV infected plants were possibly viruliferous. The final generations of mites in the ears of WSMV immune plants should have been non-viruliferous since Slykhuis (53) found that there was no transovarial passage of the virus. An assay of the ears revealed a mixed population of mites which could be accounted for by the movement or transfer of mites among the ears of the plants grown in close proximity in the greenhouse. The highly significant r value between the percent of streaked kernels and the number of mites in the ears of WSMV immune plants could be interpreted as a correlation of the number of viruliferous mites that have moved to such ears and the percent of streaked kernels.

In another experiment, results showed that viruliferous or non-viruliferous mites introduced to the emerging silk produced KRS, but infestations of viruliferous mites resulted in more intense KRS. Non-viruliferous mites produced very faint streaks on the kernels of healthy corn. Nault _et al_. (32) suspected a toxicogenic effect of mite feeding on the kernels. The more intense streaks produced by viruliferous mites suggested a synergistic action between the mite and the virus. For such synergism to take place the virus must be inside the mite's body. In support of this view, intensification of streaking in the ears infested with viruliferous mites occurred regardless of whether the plant was WSMV infected or healthy. In the absence of mites, no KRS was produced in WSMV infected plants.

Some corn lines were susceptible to KRS and resistant to WSMV, and others were susceptible to WSMV but did not necessarily develop KRS (Table A.7). This indicated that resistance to KRS could be independent of the resistance to WSMV. Williams (64) reported that some inbreds and hybrids showed different degrees of KRS resistance.

Mite feeding produced KRS that was characterized by faint or heavy red streaks on the sides of the kernel pericarp. The streaks started at the base and extended towards the dent end. Usually, the streaks tended to run parallel, but in severe cases, the whole side of the kernel became red. The intensity of the streaks decreased from the base toward the top of the kernel and the red color seldom extended into the dent.

In the field, another type of red kernel discoloration was observed. This red discoloration was lighter in intensity and tended to be diffused in contrast to the true KRS produced by mite feeding. This diffused discoloration appeared to be predominantly confined to the dent end of the kernel; while the true KRS started at the base and extended toward the dent. Kernels which showed the diffuse type of discoloration were found mostly in the exposed tips of ears. Discolored kernels were generally found in corn lines where kernel exposure was due to smut infection, bird damage and other factors. In field grown plants with viruliferous mites introduced to the silk, the true KRS syndrome was observed.

In 1967, kernel discoloration which resembled true KRS was observed in the field in some ears of experimental three-way hybrids at the

South Central Research Farm. Mites were found in the ears. An extensive survey is suggested to establish the relationship of such discoloration to the presence of mites throughout South Dakota corn fields.

SUMMARY

A disease caused by wheat streak mosaic virus reduced plant height and yield in some very susceptible corn inbreds. Apparently, the disease was less important in hybrids; some hybrid plants were readily infected in the greenhouse but were difficult to infect in the field.

A single viruliferous mite was sufficient to transmit WSMV in wheat or corn seedlings, but numerous mites transferred on 1-inch leaf sections of WSMV infected wheat plants was more efficient. Mechanical inoculation was less efficient than mites in colonies. In mechanical transmission, the sap from WSMV infected corn seedlings was equally as effective as the sap from infected wheat seedlings of the same age. The median infective dose (ID_{50}) was approximately 1/256 dilution. In inoculations made at different ages of the corn plant, percent infection decreased with age in three-way PP090 x 56A x B8; while percent infection was high even at the 6 week stage for susceptible inbred PP014.

Some corn inbreds were immune to WSMV while others were susceptible. In susceptible lines, different symptom expressions were observed. The symptoms seemed to be characteristic of each line. While the symptom of some lines tended to disappear with age, other lines showed severe leaf symptoms at all stages of development.

Kernels, silks, husks and cobs of infected corn plants were assayed for WSMV.

Mite infestation in corn seedlings caused leaf rolling and trapping.

but usually the plants recovered. Inbreds were generally more susceptible than hybrids to leaf rolling and trapping. In seedlings of very susceptible inbreds, heavy mite infestation could cause permanent trapping of the leaves and eventual death.

Corn in the seedling stage offered a favorable host for mite colonization. As the plant aged it appeared to be a less desirable host as evidenced by a decrease in mite population. At ear formation stage, mites were found in the ears of greenhouse grown plants. It seemed that some mites survived in the whorl of the corn and later moved to the ears where they rapidly multiplied.

The feeding of the mites in the kernels caused a disease called KRS. More severe KRS was associated with viruliferous mites. Non-viruliferous mites produced very faint streaks on the kernels of healthy corn plants. Infection with the virus alone failed to produce KRS. Since KRS occurred in WSMV immune plants, it was believed that resistance to KRS was independent of WSMV resistance in corn.

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APPENDIX

Table A.1. Percent infection with WSMV by means of mechanical inoculation and mite transmission to inbred and hybrid corn seedlings.

Line	Percent Infection [1/]		
	Mite	Mechanical [2/]	
		Sap from Corn [3/]	Sap from Wheat [4/]
Inbred			
PP012	100	72.72	73.33
PP014	100	100.00	100.00
PP016	58.33	30.77	64.28
PP018	100.00	44.44	55.55
PP023	100.00	66.67	70.00
PP025	100.00	100.00	100.00
PP029	87.50	80.00	61.53
PP031	60.00	76.92	75.00
PP032	90.90	76.92	75.00
PP040	100.00	100.00	88.89
PP043	100.00	42.86	33.33
PP045	91.67	55.55	50.00
PP083	100.00	91.67	76.92
PP084	100.00	84.61	83.33
PP090	100.00	100.00	100.00
PP102	100.00	92.30	100.00
PP104	100.00	90.00	100.00
PP106	100.00	91.67	85.71
PP145	100.00	75.00	100.00
PP152	100.00	100.00	100.00
PP154	88.89	81.81	90.00
PP163	100.00	71.42	100.00
PP172	57.14	100.00	50.00
PP179	100.00	50.00	45.45
PP180	100.00	46.15	50.00
PP186	100.00	66.67	72.72
PP197	100.00	38.46	38.46
PP206	100.00	66.67	66.67
PP209	100.00	92.30	100.00
PP211	100.00	88.89	77.78
PP213	100.00	85.71	100.00
PP214	100.00	100.00	100.00
PP223	100.00	80.00	100.00
PP228	0	0	0
PP229	0	0	0
PP230	0	0	0

(Continued)

Table A.1. (Cont'd)

Line	Percent Infection: Mite	Mechanical: Sap from Corn	Mechanical: Sap from Wheat
PP231	0	0	0
PP232	0	0	0
PP233	100.00	90.00	88.89
PP236	100.00	30.77	50.00
PP240	33.33	16.67	33.33
PP242	70.00	14.28	20.00
PP248	100.00	84.61	92.31
PP253	27.27	8.33	11.11
PP254	100.00	55.55	50.00
PP255	100.00	100.00	83.33
PP261	100.00	100.00	100.00
PP262	100.00	92.30	100.00
PP274	100.00	83.33	78.57
PP281	57.14	60.00	76.92
PP286	100.00	100.00	100.00
PP307	100.00	100.00	100.00
Three-way crosses:			
A.			
PP023xSD26xB8	83.33	66.67	62.23
PP029xSD26xB8	50.00	50.00	27.27
PP090xSD26xB8	100.00	66.67	75.00
PP229xSD26xB8	0	0	0
PP232xSD26xB8	14.28	0	0
PP236xSD26xB8	30.76	50.00	27.27
PP261xSD26xB8	23.33	66.67	100.00
PP274xSD26xB8	75.00	71.42	73.33
PP286xSD26xB8	88.89	58.33	72.72
PP307xSD26xB8	70.00	72.72	78.57
B.			
PP023x56AxB8	55.55	50.00	27.27
PP029x56AxB8	41.66	8.33	9.00
PP090x56AxB8	54.54	53.84	69.23
PP229x56AxB8	25.00	8.33	0
PP232x56AxB8	16.67	0	6.67
PP236x56AxB8	58.33	38.46	30.77
PP261x56AxB8	50.00	33.33	54.54
PP274x56AxB8	54.54	40.00	31.25
PP286x56AxB8	91.66	58.33	54.54
PP307x56AxB8	83.33	25.00	50.00

Table A.1. (Cont'd)

Line	Percent Infection: Mite	Mechanical: Sap from Corn	Mechanical: Sap from Wheat
Single Cross:			
SD26xB8	10.00	0	0
56AxB8	8.33	0	0
HYRFxC_{103}RF	8.33	8.33	21.40
4 way Cross:			
SD10xB8)x(SDP1xPP303)	77.77	33.33	54.54
SD26xB8)xSD20xSDP1)	66.67	72.72	66.67
Released Hybrid:			
Pioneer 388MF	22.22	7.69	0
Sokota Ts-50	70.00	53.84	54.54

1/ Average of 4 replications; 3-4 plants/replication.

2/ Susceptible corn (line 214) and susceptible wheat (Nebred) inoculated with WSMV at the 2-leaf stage, then harvested as source of inoculum 2 weeks from inoculation.

3/ & 4/ Sap was separately extracted in the Hobart juice extractor. Dilution was 2:5 (2 parts crude sap to 5 parts 0.1 phosphate buffer).

Table A.2. WSMV transmission by single mite.

Entry		% Infection[1/]
Inbred:		
	PP023	22.22
	PP029	12.50
	PP090	9.09
	PP229	0
	PP232	0
	PP236	10.00
	PP261	11.11
	PP274	33.33
	PP286	14.28
	PP307	22.22
Thru-way Crosses:		
A.	PP023xSD26xB8	10.00
	PP029xSD26xB8	0
	PP090xSD26xB8	10.00
	PP229xSD26xB8	0
	PP232xSD26xB8	0
	PP236xSd26xB8	0
	PP261xSD26xB8	11.11
	PP274xSD26xB8	0
	PP286xSD26xB8	0
	PP307xSD26xB8	8.33
B.	PP023x56AxB8	0
	PP029x56AxB8	0
	PP090x56AxB8	0
	PP229x56AxB8	0
	PP232x56AxB8	0
	PP236x56AxB8	0
	PP261x56AxB8	0
	PP274x56AxB8	10
	PP286x56AxB8	0
	PP307x56AxB8	0
	Average	13.82
Inbred wheat C.I. 10094		75.00

1/ Average of 2 reps; 4-6 plants per rep.

Table A.3. Population dynamics of the eriophyid mite, Aceria tulipae (K.) in inbred and hybrid corn seedlings in the greenhouse.

Entry	Mite Count[1/]					
	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.
A. Inbreds						
PP012	7	6	7	3.75	2	1.75
PP014	6.8	7	4.25	3.5	0	0
PP016	7	6.80	5.33	2.72	3.72	2.81
PP018	6.81	7	6.28	2	3.8	1.4
PP023	6.88	7	6.20	5.20	-	-
PP025	6.54	6.00	5.44	1.37	0	0
PP029	5	5	2.28	1.14	2	1.44
PP031	7	6	6.4	0.66	3	2.8
PP032	7	3.18	5.4	3.0	3.8	0.7
PP040	6.9	6.87	5	2.33	0.77	2.22
PP043	5.75	6.83	5.09	2.81	1	0.63
PP945	7.0	3.6	2.9	1.7	2.6	1.5
PP083	6.5	3.3	2.3	2.3	0	0
PP084	6.75	7	6.12	4.5	2.33	0
PP090	7	4.5	4.62	2.66	3.33	0.80
PP102	6.72	2.63	1.90	0.18	0	0
PP104	7	4.8	4	2.33	1	1
PP106	7	7	6.37	4.37	2.83	1.83
PP145	7	5.37	7	6.85	7	6
PP152	6	6.14	0.25	0	0	0
PP154	6.5	6.55	7	1.66	2	0
PP163	6.5	7	4	0.25	0	0
PP172	7	7	4	0.66	0	0
PP179	7	7	4.7	1.72	0.77	0
PP180	7	5.18	7	1.44	2.88	3.44
PP186	6.84	6.81	5.6	3.25	3.0	1.6
PP197	7	7	7	1.3	0	0
PP206	6.2	5.6	3	0.20	0.20	0
PP209	6.7	6	5	0.71	1.85	2.62
PP211	6.64	6.81	6	3.5	2	2.33
PP213	7	5.1	6.18	1	1.45	1.5
PP214	6.72	4.45	1.9	0.63	0	0
PP223	6	5.11	3.25	2.37	2.5	1.37
PP228	6.84	5.36	.45	0	0	0
PP229	7	7	7	4.62	3.87	3.75
PP230	6.25	5.9	3.31	0.36	0.5	0
PP231	7	7	4.14	2.28	0.71	0.71
PP232	6.85	7	5	3	0	0
PP233	6.9	5.75	6.2	2.77	3.5	0.65
PP236	7	7	7	7	7	7

Entry	Mite Control					
	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.
PP240	6.75	7	7	5.50	5.66	4.33
PP242	6.5	3.7	1.2	.1	0	0
PP245	6.3	3.72	1.9	0	0	0
PP248	6.66	7	6.19	3.9	2.33	1.14
PP253	7	7	7	5.45	4.27	6.81
PP254	7	6	6	5	4.16	2
PP255	6.12	6.33	5.28	1	0	0
PP261	7	5.75	6	6.5	4.5	5
PP262	6.45	2.5	3.2	0.1	0.7	0.1
PP269	7	7	6	0	0	0
PP274	6.81	6	6.12	3.33	0.5	0
PP281	7	6.75	6.9	2.6	2.11	1
PP286	6.09	4.8	2.0	0	0	0
PP303	7	7	6.5	4.1	4.55	4.1
PP307	7	7	6.72	2.33	1.88	1.11
B. Single Cross:						
SD26xB8	6.90	7.0	5.7	.80	0.60	0.7
56AxB8	6.92	5.58	3.41	2.0	1.63	0.45
HYRFxC_{103}RF	7.0	5.6	6.33	1.33	0.16	0.5
C. Three Way Cross:						
1)						
PP023xSD26xB8	7	6.58	5.5	2.83	1.08	1.33
PP029xSD26xB8	7	5.75	5.0	1.41	1	0.08
PP090xSD26xB8	6.91	6	6.54	2.33	1.6	1
PP229xSD26xB8	6.7	5.88	5.44	4.0	4.0	1.12
PP232xSD26xB8	6.92	7	5.64	2.41	2	2.33
PP236xSD26xB8	7	6	6.76	3.84	1	2.30
PP261xSD26xB8	7	6.83	6.90	2.66	2.25	1.4
PP274xSD26xB8	6.45	3.83	2.0	0.08	0	0
PP286xSD26xB8	7	5.77	6.44	3.44	1.55	1.33
PP307xSD26xB8	7	6.81	5.2	2.1	0.7	0.5
2)						
PP023x56AxB8	6.9	4.7	1.44	0.77	0.11	0
PP029x56AxB8	6.18	3.83	1.5	0.416	0.083	0
PP090x56AxB8	6.09	4.90	2.5	0.36	0	0
PP229x56AxB8	7	7	5.54	4.45	2.16	2.09
PP232x56AxB8	6.84	6.0	4.75	1.16	1	1.16
PP236x56AxB8	5.41	4	2.25	0	0	0
PP261x56AxB8	6.70	3.63	2.20	1.0	0.10	0
PP274x56AxB8	5.75	2.63	0.72	0.18	0	0

Table A.3. (Cont'd)

Entry	Mite Control					
	1st wk.	2nd wk.	3rd wk.	4th wk.	5th wk.	6th wk.
PP286xSD56xB8	6.66	5.75	3.83	1.75	0.83	0.5
PP307xSD56xB8	6.5	3.9	2.7	1.18	1.18	0.18
D. Four Way cross:						
(SD10xB8) (SDPLxP303)	6.54	5.81	3.72	0.54	0.18	0
(SD26xB8) (SD20xSDPL)	6.83	6.41	3.33	0.33	0.083	0
E. Commercial Hybrid:						
Pioneer 388MF	5.66	4	1.3	0	0	0
Sokota Ts-50	6.75	7	4.37	1.75	0.87	1.25

1/ Average count of 12 plants per entry.
0 = No mite
1 = 1-5 mite
2 = 6-10 mites
3 = 11-15 mites
4 = 16-20 mites
5 = 21-30 mites
6 = 31-40 mites
7 = 41 - and above

Table A.4. Change of mite population and corresponding change in the degree of leaf rolling and trapping in corn seedlings over a two-week period. (Date of infestation, August 13, 1966).

Line	Mite Count[1/]		Degree of Trapping[2/]	
	August 20, 1966	August 27, 1966	Aug 20	Aug 27
Inbred:				
PP023	6.87	7.0	3	2
PP029	4.5	3.7	2.25	1.25
PP090	7.0	4.87	3	2.25
PP229	7.0	7.0	3	2.25
PP232	6.87	7	3	1.75
PP236	7.0	7.0	3.0	3.0
PP261	7.0	5.95	3	2.0
PP274	6.5	6.0	3	3.0
PP286	6.16	4.70	2.5	1.5
PP307	7.0	7.0	3	2.25
Three-way cross:				
A.				
PP023xSD26xB8	6.91	6.58	3	1.5
PP029xSD26xB8	7.0	5.49	2	1
PP090xSD26xB8	6.91	6.08	2.75	1.25
PP229xSD26xB8	6.74	6.16	3	3
PP232xSD26xB8	6.98	7.0	3	3
PP236xSD26xB8	7.0	6.0	3	1.5
PP261xSD26xB8	7.0	6.88	2.5	1.75
PP274xSD26xB8	6.33	3.88	2	1
PP286xSD26xB8	7.0	5.76	3	1
PP307xSD26xB8	6.41	6.24	3	2
B.				
PP023x56AxB8	5.91	5.41	2	1
PP029x56AxB8	6.24	3.83	2.25	1
PP090x56AxB8	6.12	4.87	2.0	1
PP229x56AxB8	7.0	7.0	3.0	1.75
PP232x56AxB8	6.83	5.91	3	2
PP236x56AxB8	5.91	3.99	2.5	1
PP261x56AxB8	6.62	4.15	2.25	1
PP274x56AxB8	5.33	3.83	2.25	1
PP286x56AxB8	6.49	5.75	2.25	1
PP307x56AxB8	6.58	5.70	2.0	1

Table A.4. (Con't)

Line	Mite Count August 20, 1966	Mite Count August 27, 1966	Degree of Trapping Aug 20	Degree of Trapping Aug 27
Single Cross:				
SD26XB8	6.87	7.0	3	1.5
56AXB8	7.0	5.58	3	1
HYRFxC$_{103}$RF	7	6.41	3	1.25
Four-way Cross:				
SD10XB8)X (SDP1XPP303)	6.58	5.53	1.5	1
(SD26XB8)X (SD20XSDP1)	6.83	6.41	1.75	1
Commercial Hybrid:				
Pioneer 388MF	6.66	4.08	2	1
Sokota Ts-50	6.50	6.75	3	2

1/ 0 = No mite
1 = 1-5 mites
2 = 6-10 mites
3 = 11-15 mites
4 = 16-20 mites
5 = 21-30 mites
6 = 31-40 mites
7 = above 40 mites

2/ 1 = No trapping
2 = Medium
3 = tightly rolled.

Table A.5. Average population of mite on corn over a 6-week period and percent infection with WSMV.

Entry	% Infection[1/]	Relative Mite Count[2/]	Entry	% Infection	Relative Mite Count
A. Inbred:					
PP012	100	4.58	PP242	70	1.91
PP014	100	3.59	PP245	0	1.98
PP016	58.3	4.73	PP248	100	4.54
PP018	100	4.54	PP253	37.5	6.25
PP023	100	6.32	PP254	100	5.02
PP025	100	3.22	PP255	100	3.12
PP029	100	2.76	PP261	100	5.79
PP031	76.92	4.31	PP262	100	2.19
PP032	90	3.84	PP269	50	3.33
PP040	100	4.01	PP274	100	3.79
PP043	100	3.68	PP281	60	4.39
PP045	100	3.21	PP286	100	2.14
PP083	100	2.40	PP303	0	5.54
PP084	100	4.45	PP307	100	4.34
PP090	100	3.81			
PP102	100	1.90	B. single cross		
PP104	100	3.35	SD26xB8	9.09	3.61
PP106	100	4.15	56AxB8	8.33	3.19
PP145	100	6.53			
PP152	100	2.06	C. Three-way cross		
PP154	100	3.95			
PP168	100	2.95	1) PP023xSD26xB8	83.3	4.05
PP172	100	3.11	PP029xSD26xB8	50.0	3.37
PP179	100	3.53	PP090xSD26xB8	100	4.06
PP180	100	4.49	PP229xSD26B8	0	4.52
PP186	100	4.51	PP232xSD26xB8	14.28	4.38
PP197	100	3.71	PP236xSD26xB8	57.71	3.58
PP205	100	2.53	PP261xSD26xB8	100	4.50
PP209	100	3.81	PP274xSD26xB8	85.71	2.06
PP211	100	4.54	PP286xSD26xB8	100	4.25
PP213	100	3.10	PP307xSD26xB8	70	3.71
PP214	100	2.28			
PP223	100	3.43	2) PP023x56AxB8	55.5	2.32
PP228	0	1.94	PP029x56AxB8	41.66	2.00
PP229	0	5.37	PP090x56AxB8	54.54	2.25
PP230	0	3.43	PP229x56AxB8	25.00	4.70
PP231	0	3.64	PP232x56AxB8	16.66	3.48
PP232	23.07	3.64	PP236x56AxB8	58.3	1.94
PP233	100	4.29	PP261x56AxB8	54.54	2.27
PP235	100	7.00	PP274x56AxB8	54.54	1.54
PP240	25	6.04	PP286x56AxB8	58.33	3.22
			PP307x56AxB8	83.3	2.60

Table A.5. (Con't)

D. Four-way cross:		
(SD10xB8)x (SDP1xPP303)	54.54	2.79
(SD26xB8)x (SD20xSDP1)	72.72	2.83
E. Released hybrid:		
Pioneer 388MF	22.22	1.82
Sokota Ts-50	75.00	3.66

1/ Average of 4 replications; 3 plts/rep.

2/ 1 = 1-5 mites; 2 = 6-10 mites; 3 = 11-15 mites; 4 = 16-20 mites; 5 = 21-30 mites; 6 = 31-40 mites; 7 = 41 and above mites.

Table A.6. The effect of WSMV upon symptom expression, height and yield in 100 inbred corn lines grown in the field.[1/]

LINE	Symptom rating[2/]	Height in Inches: Prior to tasseling, Infected	Height in Inches: Prior to tasseling, Healthy	Height in Inches: At maturity, Infected	Height in Inches: At maturity, Healthy	Yield in Grams[3/]: Infected	Yield in Grams[3/]: Healthy
PP005	1.00	21.00	19.92	41.33	43.84	98.18	109.50
PP006	1.00	23.50	24.23	38.90	42.65	80.90	109.50
PP007	1.00	24.66	27.20	38.50	45.22	113.63	150.45
PP012	2.00	24.25	24.50	42.75	43.80	96.36	110.90
PP013	2.33	26.72	27.20	42.55	47.00	95.90	143.18
PP014	2.50	25.90	29.64	40.76	46.61	118.18	131.18
PP019	2.00	26.00	26.95	40.66	42.07	75.90	103.18
PP020	2.66	19.58	21.55	42.08	47.70	86.81	104.09
PP028	3.00	20.50	24.00	37.00	46.60	98.18	147.72
PP033	1.33	29.40	30.90	43.63	45.84	119.54	148.63
PP034*	2.00	27.54	28.95	40.00	43.30	116.81	127.27
PP035	3.66	19.40	21.26	39.07	46.68	84.09	119.09
PP049	1.50	24.60	22.23	40.50	37.14	159.09	155.00
PP070	3.00	13.25	14.60	34.00	36.83	63.63	99.09
PP082	1.00	27.20	27.33	40.00	42.55	71.36	105.00
PP083	1.00	27.50	29.70	44.75	46.50	79.54	100.00
PP084	1.50	29.84	31.15	46.30	48.92	136.36	168.63
PP085*	2.00	27.18	30.10	46.00	49.90	124.09	159.09
PP088	1.00	27.00	27.50	41.66	49.75	120.00	145.00
PP089	1.50	22.50	23.77	40.33	42.95	110.00	150.90
PP090	2.00	24.75	23.70	41.60	43.85	114.54	142.72
PP091	1.33	26.73	28.32	40.40	43.51	95.45	92.72
PP092	2.00	23.75	24.92	44.25	46.42	136.36	115.45
PP094	2.00	26.00	25.57	39.00	41.46	113.63	147.72
PP095	1.50	27.25	26.66	44.50	45.85	82.72	103.63
PP098*	1.50	31.50	32.66	45.33	49.39	131.81	168.63
PP099	1.66	26.40	27.63	46.80	45.54	113.63	153.18
PP102	1.00	30.30	33.22	43.11	46.33	127.27	129.09
PP104	1.33	26.10	25.66	40.61	52.57	92.27	121.36
PP105	3.00	23.00	26.60	46.50	48.77	113.63	113.63
PP106	2.00	32.50	30.60	49.50	55.60	136.36	143.63
PP110	3.00	26.69	28.30	38.04	39.43	98.18	132.72
PP112	4.00	16.00	16.00	33.00	37.75	22.73	96.26
PP114	4.00	17.85	23.23	33.57	40.00	86.81	88.18
PP124	1.00	30.70	28.00	44.33	45.50	189.09	193.18
PP126	2.00	17.00	19.64	42.20	41.50	81.81	98.18
PP127	2.00	18.00	22.70	36.60	39.85	140.00	175.90
PP129	2.00	15.00	14.00	36.00	36.25	79.54	100.00
PP133	2.33	16.50	19.50	38.00	44.00	39.54	74.54
PP134	2.50	20.30	22.56	40.80	47.00	56.80	100.00
PP136	3.00	20.10	21.50	41.33	45.50	121.36	136.36
PP137	1.50	17.20	20.60	40.30	43.33	100.00	125.90
PP141	2.00	13.00	10.66	36.00	37.66	68.18	102.27

Table A.6. (Con't)

PP144	4.00	13.00	14.60	34.00	35.60	53.18	54.54
PP146	3.33	16.76	22.04	32.66	42.42	60.45	96.80
PP150	2.33	20.88	22.14	40.16	45.37	63.63	84.54
PP151	2.00	21.80	21.53	42.20	45.37	100.00	136.36
PP152	3.33	17.00	22.21	37.66	41.90	57.72	102.27
PP153	2.33	17.75	21.08	39.20	47.34	78.63	115.90
PP155	3.33	18.82	22.00	38.07	43.24	85.45	106.36
PP156	2.33	17.00	19.33	35.87	40.81	73.18	100.45
PP159	2.00	22.12	26.00	44.62	46.53	96.36	108.18
PP160	1.00	21.80	26.00	36.60	46.40	90.90	136.36
PP162*	3.00	19.00	25.10	38.00	45.45	79.54	152.72
PP163	1.00	21.30	23.63	38.50	42.42	97.27	121.81
PP169	3.33	18.08	21.24	39.00	45.96	92.73	192.27
PP176	4.00	26.54	28.71	45.16	49.22	35.00	117.27
PP177	4.00	28.33	30.11	43.50	47.61	98.63	185.45
PP178	5.00	28.10	31.00	40.16	53.33	49.09	135.00
PP180	5.00	30.00	32.31	38.37	46.15	53.18	156.81
PP183	3.00	27.60	31.25	41.16	47.87	68.18	117.27
PP190	2.00	15.00	17.67	40.00	45.00	136.36	166.36
PP191	2.00	27.33	27.00	43.75	46.00	159.09	186.36
PP199	5.00	26.50	27.00	41.16	49.93	102.27	178.63
PP201	3.00	20.46	19.95	35.00	40.50	62.72	96.36
PP205	3.00	26.80	28.00	34.80	41.00	64.09	151.81
PP206	1.00	25.00	24.60	50.00	50.75	136.36	113.63
PP207	1.00	24.50	20.00	43.75	44.75	90.90	79.54
PP209	2.33	27.50	29.09	46.61	49.35	89.09	119.09
PP210	2.66	29.70	29.77	41.00	47.60	115.90	165.90
PP211	3.00	30.70	27.00	54.33	56.50	105.90	155.45
PP212	1.00	25.28	27.45	40.71	48.40	121.36	140.90
PP213	1.50	27.05	30.23	45.89	48.50	148.60	173.18
PP214	2.00	23.80	28.21	45.00	48.46	125.00	151.81
PP215	3.33	23.80	24.68	44.60	45.73	63.63	106.81
PP219	2.00	29.50	32.31	44.70	49.45	72.72	128.18
PP220	1.33	28.50	28.48	43.37	44.18	90.90	113.63
PP221	3.00	25.63	27.56	42.36	49.64	88.63	114.54
PP222	2.00	25.50	24.75	35.00	35.75	102.27	107.72
PP223	2.00	24.70	25.70	49.28	48.75	125.00	148.63
PP224	3.00	25.30	30.80	41.50	42.50	156.36	198.63
PP225*	2.66	17.91	22.90	34.00	39.39	70.00	80.90
PP233	2.00	28.20	27.00	43.60	44.50	133.63	125.00
PP234*	1.00	21.80	27.50	50.60	51.06	109.09	131.81
PP248	1.00	30.69	33.41	43.92	46.91	116.81	152.27
PP256	1.65	32.41	32.30	48.35	49.21	43.63	62.72
PP260	1.33	24.20	24.50	42.83	46.60	109.09	115.90
PP261	1.66	25.80	26.92	45.37	45.56	130.45	150.00
PP262	1.00	30.00	32.53	42.00	50.42	181.81	165.45
PP264	1.00	27.54	29.73	51.36	53.96	152.72	151.36
PP273	1.66	33.30	25.94	47.12	51.58	82.27	105.45

Table A.6. (Con't)

PP274*	1.00	25.20	28.21	40.80	45.27	147.72	143.18
PP280	2.33	27.58	29.95	38.10	40.70	80.00	115.90
PP281	3.00	27.00	26.38	44.60	44.07	83.16	136.36
PP284	1.50	30.50	30.60	50.00	49.00	105.90	131.81
PP286	2.00	25.75	24.92	44.91	46.25	68.18	98.18
PP288	1.33	25.00	25.50	43.28	40.30	121.81	133.18
PP292	1.00	25.20	29.00	41.77	45.45	118.63	143.63
PP306	2.00	31.50	26.20	33.00	37.00	113.63	132.27
PP307	2.00	24.10	25.72	47.87	51.30	90.90	146.30

1/ Average reaction of 3 reps. 2-10 plants per rep; mechanically inoculated at the 3-4 leaf stage.

2/ Leaf mosaic symptom rating at tasseling time:
- 1 - very faint mosaic
- 2 - faint mosaic
- 3 - moderate mosaic
- 4 - severe mosaic but no yellowing
- 5 - severe, yellow leaves.

3/ wet weight of husked ear per plant.

* Lines showing kernel discoloration due to kernel exposure.

Table A.7. Mite population and percent of kernels which showed intense KRS in the ears of WSMV infected and non-infected corn plants in the greenhouse.[1/]

Line	Leaf Symptom[2/]	Mite Population on Ear[3/]	% KRS[4/]
PP004	+	5	2.5
PP006	+	4	0
PP013	+*	4	0
PP015	+*	4	0
PP016	+	4	1
	-*	4	0
PP019	+	4	0
PP022	+	4.5	5
PP025	+*	2	3
PP028	-	4	0
PP029	+	4	4
PP030	+	5	0
PP031	-	3.5	0
PP033	+*	4	4
PP037	+	5	3
	-	4	3
PP039	+	3	2
PP042	-*	4	0
PP045	+	4	1
PP046	-*	4	0
PP047	+	4.2	2.5
	-*	5	4
PP049	+*	4	2
	-*	4	2
PP050	+*	5	0
PP051	-*	4	0
PP052	-*	4	0
PP055	-	4.5	0
PP056	+*	5	1
PP058	+	4	0
PP059	+	4	1
	-*	4	2
PP060	+	4	1.5
PP066	-	2	0
PP068	+	3	0.5
	-	4	0
PP081	-	4	0
PP085	-	4	0
PP086	+*	4	3
	-*	2	0

Table A.7. (Con't)

Line	Leaf Symptom	Mite Population on Ear	% KRS
PP088	+	3.5	0
PP090	-*	4	0
	+*	4	0
PP091	+	4	1
PP092	+*	3	2
PP093	+*	4	3
PP094	+*	4	0
	-*	3	0
PP098	+	4	2
PP102	-	3.5	0
	+*	4	2
PP104	+	4	0
PP105	-*	2	0
PP110	+	1.5	0
	-	1	0
PP118	-*	4	0
PP119	-*	4	0
PP122	-*	5	0
	+*	5	0
PP124	+	4.5	5
	-*	5	0
PP125	-*	5	0
PP126	-	3.5	0
PP129	-*	4	0
PP132	-	3.5	0
PP133	-	2.5	0
PP134	-	4	0
PP140	-*	5	0
PP142	+*	4	4
PP143	-	4	0
PP144	-	4.5	1.5
PP147	-*	4	3
PP152	-	4.67	1.67
PP154	+*	5	0
	-*	4	3
PP155	-	4	1.5
PP156	-*	5	4
PP159	-	3	1.5
PP162	-*	3	3
PP164	-*	4	0
PP165	-*	3	3
PP169	-*	3	3
PP174	-	5	0
PP175	-	5	4

Table A.7. (Con't)

Line	Leaf Symptom	Mite Population On Ear	% KRS
PP177	-	4.67	3
PP179	-*	4	2
PP182	-	2.75	0
PP184	+*	5	3
	-*	4	3
PP187	+*	4	3
	-*	4	3
PP191	-	3.33	1.67
PP192	-	4.33	2.67
PP194	-*	5	4
PP196	-*	3	0
PP197	+*	4	0
	-*	4	4
PP199	-	4	0
PP201	+	4	0
PP203	+*	5	0
	-*	5	0
PP206	-	4	0.5
PP209	+*	4	0
PP210	-	4	0
PP213	-	2	0
PP214	-	2	0
PP215	-*	4	0
PP218	+*	3	0
PP219	+*	4	0
PP220	+*	4	0
PP224	-	4	1.67
PP226	-*	2	0
PP227	-	3	0
PP228	-	1	0
PP229	-	0	0
PP231	-	0	0
PP232	-*	4	0
PP239	-*	4	0
PP245	-	3	0
PP247	-	4	0.5
PP248	-	3.33	0
PP249	-	3.5	2
PP250	-*	4	0
PP253	-	4	0
PP256	-*	4	0
PP257	-	5	0
PP262	-	4	0

Table A.7. (Con't)

Line	Leaf Symptom	Mite Population On Ear	% KRS
PP263	-*	3	0
PP264	-	4	0
PP268	-	4	0
PP273	-	1.33	0
PP275	-*	4	2
PP276	-*	3	0
PP278	-	4	0
PP280	-	3.33	0.67
PP282	-*	2	0
PP284	-	4	0
PP290	-	4	0
PP292	-	4	0
PP298	-	4	0.67
PP305	-	4	0.67
SD5	-	4	0.67
SD7	-	4	0
SD26	-	4	1
SD45	-*	4	0
SD509	-	4	0
56A	-	4	0
M14	-	4	1
Pa362	-	3	0
W117	-	4	0

1/ Average of 2-6 plants per line unless otherwise specified.

2/ (+) = with leaf symptom, (-) = without leaf symptom, not infected with WSMV.

3/ Rating, 0-5: 0 = no mites; 1 = 1-10; 2 = 10-50; 3 = 50-100; 4 = 100-200; 5 = above 200 mites.

4/ Percent of kernels showing intense red streaks. Rating, 0-5: 0 = no streaked kernel; 1 = 1-10%; 2 = 10-20%; 3 = 20-50%; 4 = 50-80%; 5 = 80-100%.

* = only one plant.

Table A.8. Incidence of ears which showed KRS in the field.

Line	Percent of ears showing KRS: With Leaf Symptom	Viruliferous mites introduced to the silk	Control
Inbred:			
PP090	0	0	0
PP261	0	60	0
PP274	16.6	75	18.7
PP236	0	-	0
PP286	0	-	0
PP029	-	0	0
PP023	0	-	7.69
PP229	-	50	8.33
PP307	0	-	0
PP232	-	-	10.5
Three-way cross:			
A.			
PP029xSD26xB8	-	-	0
PP232xSD26xB8	-	-	0
PP236xSD26xB8	0	-	0
PP261xSD26xB8	20	-	4.54
PP274xSD26xB8	0	-	0
PP090xSD26xB8	0	-	4.76
PP286xSD26xB8	0	50	0
PP023xSD26xB8	0	0	0
PP229xSD26xB8	-	33.33	12.50
PP307xSD26xB8	0	-	0
B.			
PP261x56AxB8	0	66.66	0
PP229x56AxB8	-	33.33	21.50
PP090x56AxB8	0	0	0
PP232x56AxB8	-	-	0
PP274x56AxB8	0	-	9.52
PP236x56AxB8	-	-	4.54
PP029x56AxB8	0	0	0
PP286x56AxB8	0	16.66	0
PP023x56AxB8	0	16.66	0
PP307x56AxB8	-	0	0

1/ Average of 8-12 ears.

Table A.9. List of infected and non-infected corn lines which were inoculated with WSMV by means of the mite vector.

Line	Infection	Reaction to WSMV[1/]	Line	Infection	Reaction to WSMV[1/]
Inbreds:					
PP001	0/7[2/]	R	PP045	4/4	S
PP002	6/6	S	PP046	4/6	MS
PP003	5/5	S	PP047	9/9	S
PP004	6/6	S	PP048	3/3	S
PP005	4/4	S	PP049	5/7	MS
PP006	5/5	S	PP050	2/2	S
PP007	8/8	S	PP051	0/8	R
PP008	3/4	MS	PP052	0/6	R
PP010	6/6	S	PP055	1/5	MR
PP011	9/9	S	PP056	2/2	S
PP012	5/5	S	PP058	2/2	S
PP013	7/9	MS	PP059	3/4	MS
PP014	4/4	S	PP060	4/4	S
PP015	7/7	S	PP062	4/4	S
PP016	6/8	MS	PP064	5/5	S
PP017	6/6	S	PP065	4/4	S
PP018	9/9	S	PP066	7/7	S
PP019	7/7	S	PP068	6/9	MS
PP020	3/4	MS	PP070	2/2	S
PP022	7/7	S	PP071	4/4	S
PP023	6/6	S	PP072	2/2	S
PP024	4/4	S	PP073	4/5	MS
PP025	6/6	S	PP074	2/3	MS
PP026	5/5	S	PP075	5/5	S
PP027	7/7	S	PP078	2/2	S
PP028	7/10	MS	PP081	2/5	MR
PP029	6/6	S	PP082	4/4	S
PP030	5/5	S	PP083	6/6	S
PP031	4/5	MS	PP084	9/9	S
PP032	7/7	S	PP085	7/8	MS
PP033	6/6	S	PP086	6/6	S
PP034	6/6	S	PP087	6/6	S
PP035	7/7	S	PP088	7/7	S
PP036	4/7	MS	PP089	4/4	S
PP037	9/9	S	PP090	8/8	S
PP038	3/3	S	PP091	10/10	MS
PP039	8/8	S	PP092	3/3	S
PP040	9/9	S	PP093	3/3	S
PP042	2/4	MS	PP094	4/5	MS
PP043	6/6	S	PP095	4/4	S
PP044	1/1	S	PP096	3/4	MS

Table A.9. (Cont'd)

Line	Infection	Reaction to WSMV	Line	Infection	Reaction to WSMV
PP098	7/7	S	PP163	3/3	S
PP099	4/4	S	PP164	2/2	S
PP102	5/8	MS	PP167	9/10	MS
PP104	9/9	S	PP168	5/5	S
PP105	3/3	S	PP169	8/8	S
PP106	8/8	S	PP171	0/4	R
PP109	2/2	S	PP172	3/3	S
PP110	5/6	MS	PP173	0/3	R
PP113	1/1	S	PP174	0/4	R
PP114	7/7	S	PP175	2/2	S
PP119	0/7	R	PP176	8/9	MS
PP122	5/7	MS	PP177	3/6	MR
PP124	5/5	S	PP178	4/5	MS
PP125	4/6	MS	PP179	3/3	S
PP126	10/10	S	PP180	9/9	S
PP127	5/7	MS	PP181	0/5	R
PP129	6/7	MS	PP182	0/7	R
PP130	1/11	MR	PP183	3/3	S
PP132	0/2	R	PP184	0/6	R
PP133	7/8	MS	PP186	10/10	S
PP134	4/6	MS	PP189	2/5	MR
PP135	2/11	MR	PP190	5/5	S
PP136	3/3	S	PP191	3/7	MR
PP137	4/5	MS	PP192	4/7	MS
PP140	6/6	S	PP193	6/7	MS
PP141	3/3	S	PP195	4/10	MR
PP142	4/4	S	PP196	5/7	MS
PP143	2/3	MS	PP197	9/9	S
PP144	4/7	MS	PP198	0/4	R
PP145	8/8	S	PP199	5/9	MS
PP146	5/5	S	PP201	3/3	S
PP148	2/2	S	PP203	3/5	MS
PP150	7/7	S	PP204	7/7	S
PP151	7/8	MS	PP205	7/7	S
PP152	7/7	S	PP206	5/5	S
PP153	8/8	S	PP207	4/4	S
PP154	8/8	S	PP209	9/9	S
PP155	4/4	S	PP210	4/4	S
PP156	5/6	MS	PP211	9/9	S
PP157	4/4	S	PP212	4/4	S
PP158	2/2	S	PP213	8/9	MS
PP159	5/6	MS	PP214	5/6	MS
PP160	6/6	S	PP215	4/6	MS
PP161	2/2	S	PP218	2/2	S
PP162	4/5	MS	PP219	7/7	S

Table A.9. (Cont'd)

	Infection	Reaction to WSMV
PP220	4/5	MS
PP221	4/4	S
PP222	2/3	MS
PP223	9/9	S
PP224	6/7	MS
PP225	4/5	MS
PP226	2/3	MS
PP227	2/7	MR
PP228	0/10	R
PP229	0/8	R
PP230	0/11	R
PP231	3/12	MR
PP232	1/10	MR
PP233	9/9	S
PP234	0/4	R
PP236	8/8	S
PP237	0/3	R
PP238	0/1	R
PP239	0/2	R
PP240	0/8	R
PP241	0/5	R
PP242	7/10	MS
PP244	0/4	R
PP245	0/5	R
PP246	0/1	R
PP247	0/10	R
PP248	10/10	S
PP249	4/7	MS
PP250	0/6	R
PP251	0/8	R
PP253	0/10	R
PP254	8/8	S
PP255	7/7	S
PP256	5/5	S
PP259	2/2	S
PP260	4/5	MS
PP261	8/8	S
PP262	10/10	S
PP263	6/8	MS.
PP264	4/4	S
PP265	3/5	MS
PP268	3/4	MS
PP269	3/3	S
PP270	2/2	S
PP272	4/8	MS
PP273	3/4	MS

	Line	Infection	Reaction to WSMV
	PP274	8/8	S
	PP275	4/7	MS
	PP276	4/5	MS
	PP278	4/7	MS
	PP28[illegible]	7/7	MS
	PP281	8/10	MS
	PP282	2/3	MS
	PP283	4/4	S
	PP284	4/7	MS
	PP286	9/9	S
	PP288	3/3	S
	PP290	0/2	R
	PP292	4/4	S
	PP295	5/6	MS
	PP297	0/2	R
	PP298	0/9	R
	PP299	0/2	R
	PP301	0/2	R
	PP302	0/5	R
	PP303	0/10	R
	PP305	7/7	S
	PP306	3/3	S
	PP307	10/10	S
	2-way hybrids		
	SD26xB8	1/6	MR
	56AxB8	1/6	MR
	3-way hybrids		
A.	PP023xSD26xB8	5/6	MS
	PP029xSD26xB8	3/6	MS
	PP090xSD26xB8	6/6	S
	PP229xSD26xB8	0/6	R
	PP232xSD26xB8	1/7	MR
	PP236xSD26xB8	7/7	S
	PP261xSD26xB8	6/6	S
	PP276xSD26xB8	4/6	MS
	PP286xSD26xB8	4/4	S
	PP307xSD26xB8	4/4	S
B.	PP023x56AxB8	3/6	MS
	PP029x56AxB8	2/6	MR
	PP090x56AxB8.	3/5	MS
	PP229x56AxB8	1/6	MR
	PP232x56AxB8	1/7	MR
	PP236x56AxB8	4/6	MS

Table A.9. (Cont'd)

Line	Infection	Reaction to WSMV	Line	Infection	Reaction to WSMV
Commercial Hybrids:			PP261x56AxB8	2/4	MS
			PP274x56AxB8	1/5	MR
Pioneer 388MF	1/5	MR	PP286x56AxB8	2/6	MR
Sokota Ts-50	4/5	MS	PP307x56AxB8	5/7	MS

1/ S = susceptible, 100% infection; MS = moderately susceptible, 50-99% infection; MR = moderately resistant, 1-49% infection; R = resistant, 0 infection.

2/ Numerator, number of infected plant; denominator, total number of inoculated plants.