AN ANALYSIS OF AGRONOMIC CHARACTERISTICS AND REACTION TO WHEAT STREAK MOSAIC VIRUS IN FOUR HARD RED WINTER WHEAT CROSSES

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L. em. Thell.) is the principal cereal grain used for food in the world and it is unlikely that the importance of this crop as a major contributor to human nutrition will decrease in the future. Thus, it becomes increasingly critical that the production of wheat be substantially increased in the future. However, many factors, including diseases, tend to limit the production of wheat each year.

Wheat streak mosaic virus (WSMV) is a serious disease in the Central Great Plains region of the United States. Losses in Kansas alone have exceeded 30 million dollars (22). The vector of WSMV is the wheat curl mite (*Aceria tulipae* Keifer). The vector can be controlled by chemicals and cultural practices, but WSMV resistant cultivars may offer the best method of control.

Resistance to WSMV exists in the genus *Agropyron*, a relative of wheat. Genes for resistance to WSMV have been transferred to wheat via chromosome engineering techniques. The source of WSMV resistance of the material in this study is derived from *Agropyron elongatum*. The transfer was accomplished by USDA cytogeneticist, Dr. E. E. Sebesta at the Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma. The translocation line developed was CI 15322 (19).

The WSMV resistant selection used in this study was derived from

CI 15322. Line 9387A was selected from the cross of CI 15322/2*Osage. Line 9387A has consistently shown a high level of resistance to WSMV in greenhouse tests and has the best agronomic traits of several thousand early generation lines examined at the Oklahoma Agricultural Experiment Station. However, there are apparently serious agronomic deficiencies associated with Line 9387A as indicated by yield data of trials conducted in Oklahoma during the past few years.

As indicated in Table I, Line 9387A ranked last among 30 entries in the 1980 Advanced Wheat Performance Trials grown at six locations. OK754615, TAM W-101, and Newton ranked first, seventh and twentieth, respectively. The average yield of Line 9387A was approximately one-half that of OK754615. Although Line 9387A is resistant to WSMV, it has a low yield potential, as indicated by these data.

The objective of this research is to determine the segregation pattern of resistance to WSMV in the F_2 generation in four crosses involving Line 9387A, to measure the field performance of the F_3 families for yield and other important agronomic characters, and to determine which yield related traits are responsible for yield depression in Line 9387A. These tests were designed to evaluate the degree of usefulness of Line 9387A in a breeding program.

TABLE I

YIELD AND RANKS FOR PARENTS AND CHECKS GROWN IN THE 1980 ADVANCED WHEAT PERFORMANCE NURSERY AT SIX LOCATIONS[1/]

Cultivar or Line	6 Station Avg. Yield (kg/ha)	(Rank)
OK754615	4157	(1)
TAM W-101	3814	(7)
Payne	3753	(11)
Vona	3578	(16)
Newton	3538	(20)
9387A	2287	(30)

[1/] Nursery consisted of 30 entries.

CHAPTER II

LITERATURE REVIEW

Virus diseases were studied before their actual identity became recognized. These diseases were thought to be uncommon or insignificant in most cereal production areas of the world until the mid-to-late 1950's. However, virus diseases of cereals are now known to exist in most regions of the world where cereals are grown (22).

Wheat Streak Mosaic Virus (WSMV) poses serious production hazards throughout the Great Plains. Millions of dollars of losses are reported annually (20). Total losses have been reported in many WSMV infected winter wheat fields in the Great Plains from Oklahoma to Montana and into southern Canada. In the Alberta, Canada area, an estimated average yield reduction of 672 kg/ha in WSMV infected wheat was reported. Data indicate that the reduction in yield was due to a reduction in the number of kernels formed and a reduction in size and weight of kernels which do form (2).

Symptoms of WSMV are characterized by yellowish-green streaking and mottling on the leaves in striated patterns followed by stunting and necrosis (2, 19, 22). Spike sterility often occurs in the few spikes which do form.

Although WSMV is a very destructive disease, it can be controlled through cultural methods such as destruction of volunteer wheat and other grasses, and by chemical control of its vector, the wheat curl mite (Aceria tulipae Keifer). The curl mite reproduces parthenogenetically which allows for a rapid increase of the mite population. Mites can transmit the virus while feeding on plant sap. Nymphal stages of Aceria tulipae are able to acquire the virus after feeding 15 minutes on infected plants. The virus persists in the nymphs after molting (22). Adult mites are unable to acquire the virus after feeding (13). Even though cultural practices and chemicals can be used for WSMV control, it is recognized that the most economical method of control is through the use of resistant cultivars.

Donald (4) noted that there are two types of breeding philosophies in most programs today. One is "breeding for yield per se". The other is "defect elimination", e.g., the incorporation of disease resistance into a susceptible genotype. This philosophy of defect elimination would apply to breeding for resistance to WSMV.

Plant breeders are continually searching for sources of useful germplasm to be used in breeding programs. In many cases genes for disease and insect resistance are not found in cultivated types, but are found in related wild plants. This is the case with wheat in which several genera related to wheat provide important sources of pest resistance that may be used by plant breeders (6, 8). Genes for resistance to many wheat pests have been identified in its relatives, i.e., Secale cereale L., Triticum umbellulatum, T. tauschii, and several species of Agropyron. Alien germplasm is potentially very beneficial to wheat breeding programs (8).

Desirable genes may be transferred to hexaploid wheat from related species in several ways: introgression, crossing over by homoeologous pairing or induced translocations. Regardless of the method of transfer, genes for resistance may exhibit varying transmission rates through gametes, which can be modified by the background genotype (7). Utilizing these methods, workers have been able to transfer potentially useful genes from diploid *Triticum* species and the related genera *Aegilops*, *Haynaldia*, *Agropyron*, and *Secale* to common wheat. Examples of gene transfer involve resistance to leaf and stem rusts and WSMV (16). In many cases resistance genes are linked to genes carrying deleterious characters. Difficulties in breaking linkages between deleterious and beneficial characters varies with the genetic background in which the alien chromatin is introduced (8).

Breeders have frequently encountered difficulties in transferring resistance genes because of incompatibilities between the species involved or because of sterility in the hybrid (16). Several chromosomes of *Secale*, *Agropyron* and *Aegilops* have been shown to be homoeologous with specific wheat chromosomes (5, 8).

Evidence is mounting that indicates that the chromosomes of the wheat relatives fall into the same homoeologous groupings that exist in cultivated wheats (1, 8). The homoeologous chromosomes do not ordinarily pair with each other, although structurally and functionally similar (1). The diploid-like meiotic behavior of hexaploid wheat is due to the genetic activity of the Ph gene on the long arm of chromosome 5 B (1, 5, 6). The homoeologous chromosomes of the three genomes of common wheat will pair if the Ph gene is removed or suppressed by altering the genetic envrionment (5, 6).

According to Cauderon (3) *Agropyron elongatum* (10x) was the first *Agropyron* to be successfully crossed with hexaploid and tetraploid wheats and one of the first two *Agropyron* hybrids to be used in wheat breeding programs.

Schmidt et al. (18) studied the possible use of wheat X Agropyron crosses as sources of resistance to WSMV. They observed a wide range of reaction types to the virus among the hybrids. There were indications that the immune reaction of A. elongatum (Host) Beauv. was controlled by a complex genetic mechanism, which would make it difficult to transfer a satisfactory level of resistance to wheat (18). They found that the grass-like wheat X A. elongatum hybrids were generally immune, the intermediate types were variable for WSMV reaction, and the wheat-like types were usually susceptible. Resistant wheat-like plants were thought to have resulted from the translocation of a small segment of the Agropyron chromosome carrying gene(s) for resistance to a wheat chromosome.

Sebesta and Bellingham (19) also studied wheat X Agropyron hybrids for resistance to WSMV. They concluded that the WSMV resistance of P_3-19, a 44-chromosome wheat X Agropyron derivative, was controlled by genes on more than one chromosome. This agrees in part to the findings of Swarup et al. (24) who concluded that the genes controlling resistance were carried on at least one short chromosome and on two or more long Agropyron chromosomes. It was assumed that the extra chromosomes were also Agropyron, though no proof was available. However, McKinney and Sando (12) showed that Agropyron elongatum and its hybrids with wheat exhibited high resistance to WSMV, therefore the assumption that the extra chromosomes may be Agropyron were likely to be valid. Certain Agropyron hybrids, mainly those with A. elongatum, expressed a high level of resistance or immunity to WSMV (24). McKinney and Sando (12) also found a high level of resistance in 17 species of Agropyron. None of the species expressed mosaic symptoms but a few showed local lesions. No systemic virus was detected in any of those species. In crosses involving *Agropyron* species and commercial wheat cultivars, 16 of the 25 selections showing the highest level of resistance carried genes from *Agropyron elongatum* (12).

Raj, as cited by Shaalan et al. (21), investigated some advanced-generation wheat X *Agropyron* lines for WSMV resistance and reported that resistance was controlled by two recessive factors in F_2 seedling tests. Specific genetic ratios were difficult to detect in these lines. Chi-square analysis of the F_2 segregation data indicated that the segregation of the three reaction types, i.e., local lesion, local lesion turning systemic, and systemic, were inconsistent in three replications tested and did not appear to be based on any specific genetic ratios. The segregation patterns appeared to be random events (24).

Lay et al. (9) noted that it was apparent that wheat grasses (*Agropyron* spp.) and *Secale* offered the most promise for sources of resistance to WSMV.

Germplasm line CI 15322, a WSMV resistant selection from the cross P_3-19 X Wichita, was released by the USDA-ARS and the Oklahoma Agricultural Experiment Station. It is resistant to the WSMV vector, the wheat curl mite, as well as to the virus itself (11, 19). This feature makes it a potentially valuable source of germplasm.

So far, there are no released cultivars possessing resistance to WSMV, although some have tolerance to the virus (14). Due to the complex nature of the hybrids of wheat and *Agropyron elongatum*, developing a WSMV resistant line of wheat with commercially acceptable characteristics will undoubtedly be difficult. Only by evaluating many selections for disease reaction and agronomic characters will this goal be attained.

Presently several sources of WSMV resistant germplasm are in use at the Oklahoma Agricultural Experiment Station. In addition to CI 15322, the sources include CI 15321, a probable substitution line derived from *A. elongatum*; SDTRB 279304A-1, a South Dakota translocation line which derives its resistance from CI 15092, an *Agropyron intermedium* derivative (25); B-6-37-1 (CI 17766), a Kansas line derived from CI 15092 by the homoeologous pairing technique (10); and several selections from a WSMV resistant composite (23).

CHAPTER III

MATERIALS AND METHODS

Four wheat crosses, each involving a common parent which is resistant to wheat streak mosaic virus (WSMV), were used in this study. The common parent, Line 9387A (OK80530) is a selection from CI 15322/2*Osage developed at the Oklahoma Agricultural Experiment Station. Resistance to WSMV in Line 9387A is derived from CI 15322. CI 15322 is a WSMV resistant translocation line selected from the cross P_3-19 X Wichita developed at the Oklahoma Agricultural Experiment Station. The gene(s) for WSMV resistance are carried on a segment of *Agropyron elongatum* chromosome which have been translocated to a wheat chromosome.

The other parents used in the crosses were OK754615, TAM W-101, Vona, and Centurk 78.

OK754615 is a hard red winter wheat selection from the cross Early Sturdy/Nicoma made at the Oklahoma Agricultural Experiment Station. It is an early maturing semidwarf line with good milling and baking properties (23).

TAM W-101 is a hard red winter wheat developed at the Texas Agricultural Experiment Station. Its pedigree is Norin 16/3/Nebraska 60//Mediterranean/Hope/4/Bison (15). TAM W-101 is a medium maturing semidwarf cultivar with good milling and baking properties. It is widely grown in the state.

Vona is a hard red winter wheat developed at the Colorado

Agricultural Experiment Station in 1976. Its pedigree is II 21183/ CO 652363//Lancer/Ks 62136 (26). Vona is an early maturing, semidwarf cultivar with good milling and baking properties.

Centurk 78 is a hard red winter wheat selected from Centurk at the Nebraska Agricultural Experiment Station. It has the pedigree Kenya 58/ 2/Newthatch/3/Hope/2*Turkey/4/Cheyenne/5/Parker. It is medium early, mid-tall, and has excellent milling and baking properties (17).

Crosses were made in the greenhouse at Stillwater in the spring of 1979. Approximately two thousand F_2 seedlings of each cross were used to study the segregation patterns of WSMV resistance. Twenty-five seeds per row were planted in flats on September 29, 1980 and grown in a greenhouse. One row each of a WSMV resistant line, P_3-19, and a susceptible cultivar, Danne, were planted in each flat as checks with eight rows of F_2 material. The 2000 F_2 plants per cross plus checks were inoculated with WSMV at the two-to-three leaf stage on October 16, 1980.

Inoculum was prepared earlier from infected plants grown in a greenhouse bed. Leaf tissue (1500 g) from these infected plants was ground in a blender containing 1500 ml water. The mixture was then strained and 50 g of celite abrasive were added to the liquid. The plants were inoculated using the spray technique.

Appearance of symptoms on susceptible plants began eight days post-inoculation. Symptoms appeared as yellowish-green chlorotic streaks on newly developed leaves. No attempt was made to distinguish between the three reaction types described by Swarup et al. (24). Plants were scored as either resistant or susceptible. Susceptible plants were counted and removed from the flats. Symptoms were read on six occassions with susceptible plants being recorded and discarded each time.

Resistant plants were transplanted to new flats on November 25, 1980. Vernalization at outside temperature was initiated December 4, 1980. These resistant plants were saved for use at the Oklahoma Agricultural Experiment Station breeding program.

As the temperature in the greenhouse increased, more susceptible plants appeared. These were recorded and discarded. Genetic ratios of susceptible:resistant plants were examined using a computer Chi-square program.

In addition to the genetic study conducted in the greenhouse, a field study of F_3 families of the same four crosses was conducted at the Agricultural Experiment Station, Oklahoma State University, Stillwater. Seed for the F_3 test was obtained from F_2 bulks grown in the field at Stillwater in 1980. These F_2 bulks had not been previously selected for reaction to WSMV. The F_3 families were grown in the absence of the virus.

A total of 100 mature spikes was selected from each cross. Spikes were taken from plants exhibiting satisfactory agronomic characters. From these 100 spikes, 76 spikes with 25 seeds or more were selected for planting in the field.

Twenty-five seeds from each of the 76 selected spikes (families) were divided into five replications, each containing five seeds per hill. These seeds, in addition to seeds from the respective parents plus three check cultivars, were planted in hill plots using a jab-planter on October 29, 1980 on a Udic Paleustolls soil type at the Stillwater station. A 9 X 9 Lattice Square design was used for this experiment. There were 81 hill plots per replication. Hills were spaced 30.5 cm apart within and between rows. All test hills were bordered.

Supplemental water was applied on eight occasions due to the dry season. Malathion was applied to control greenbugs. No preplant fertilization was applied, however, on March 5, 1981 a top dressing of 112 kg/ha ammonium nitrate was applied. Weeds were controlled manually.

The field study was harvested during the period May 30 to June 13, 1981 by pulling and bagging all the plants in each hill plot. The best spike was saved separately to determine the number of spikelets/spike and kernels/spike. The remaining spikes were threshed in a small Vogel thresher. Yield and yield component measurements for each field plot were recorded.

Twenty-five seed from each entry (family) of replications one and two were used for a greenhouse virus test. Due to limitations of space and inoculum, only two replications of each cross could be tested. The 25 seeds of each of the 81 entries per cross, along with the resistant check, P_3-19, were planted in a single row in a flat on September 28, 1981. Plants were inoculated on October 13, 1981. The inoculation procedures were the same as previously described for the F_2 generation. the objective of this virus test was to determine the percentage of WSMV resistant plants in each family. Readings were taken on seven occasions, with the final reading occurring on December 17, 1981.

Characters Evaluated, F_3 Field Study

Heading date, height, the number of tillers/hill, and grain yield, number of kernels/spike, number of spikelets X 2, average kernel weight, and percent spike fertility were measured for each hill plot in the field study.

Heading Date

A visual estimate was made when 50% of the spikes in each hill plot were fully extruded above the flag leaf. The date when this occurred was then recorded. This character was expressed as the number of days after March 31.

Height

This trait was measured as the average distance in centimeters from the crown (soil line) to the upper story heads of each hill plot.

Tiller Number

Tiller number/plot was recorded as the number of fertile spikes per hill plot prior to threshing.

Grain Yield

Grain yield was measured as the weight of treshed grain from each plot, in addition to the weight of the grain from the single spike selected for other measurements. It was recorded as grams/hill.

Number of Spikelets X 2

This character was determined by counting the number of spikelets/spike on the single best spike from each hill plot excluding the basal and terminal spikelets, then multipled by two.

Kernels/Spike

The single, selected spike was threshed and the seed were counted to determine the number of kernels/spike.

Kernel Weight

The weight of the kernels of selected spike measured to the nearest 0.01 gram was divided by the number of seeds produced on the selected spike. This character was expressed as grams per 1000 kernels.

Fertility Index

This character was calculated as follows: number of kernels per spike ÷ (number of spikelets per spike X 2) X 100%. By this method it is possible to obtain fertility values greater than 100% if tertiary or quaternary florets set seed.

Statistical Analyses

Chi-square values were calculated for the F_2 generation of each cross from the greenhouse WSMV test based on the ratio of the number of susceptible:resistant plants. These ratios were tested against 32 known ratios available in the computer program at Oklahoma State University (Table II) to determine the inheritance patterns of WSMV.

Although the field study was originally designed for a 9 X 9 Lattice Square, it was analyzed finally as a randomized incomplete block design for convenience. The decision was based on the similarity of the error mean squares after analyzing some of the data by both methods.

Standard analyses of variance were conducted for the F_3 families of each cross. Resistance categories were identified from a list of ranked means based on percent resistance. The boundary percentages for each category were arbitrarily set at 0-10%, >10<50%, and >50% resistant

TABLE II

RATIOS TESTED FOR CHI-SQUARE ANALYSIS
OF F_2 GENERATION

1:1	13:3	55:9	225:31
3:1	15:1	59:5	229:27
5:3	37:27	60:3	243:13
7:1	39:25	60:4	246:10
9:7	45:19	61:3	247:9
10:6	48:16	63:1	253:3
11:5	49:15	139:117	255:1
12:4	54:10	207:49	704:320

plants per family for categories 1, 2, and 3, respectively. These categories were established because there were very few families in which 100% of the plants were resistant. These categories were used to identify the resistance level of each F_3 family. The t-Test for significance between two means of the three possible two-way comparisons among resistance categories was calculated as:

$$t = \frac{\overline{Y}_1 - \overline{Y}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

$\overline{Y}_1$ = mean 1

$\overline{Y}_2$ = mean 2

s = standard deviation of 76 F_3 families

n_1 = number of families represented by $\overline{Y}_1$

n_2 = number of families represented by $\overline{Y}_2$

Among-family correlation coefficients were calculated for all possible comparisons involving percent resistance. These correlations are primarily associated with genetic differences.

CHAPTER IV

RESULTS AND DISCUSSION

Segregation of WSMV Reaction, F_2

Greenhouse Study

A Chi-square analysis was conducted for each of the four F_2 populations to determine which genetic ratios gave the best fit for WSMV reaction. These data are presented in Table III, Appendix. The total number of susceptible and resistant plants per cross were recorded and these were used for the analysis.

In Cross 1 (OK754615/9387A) a total of 1970 F_2 plants were tested, of which 269 were resistant to the virus. An observed ratio of the number of susceptible to resistant plants was calculated to be 6.3 S:1.0 R. Two ratios were found which fit the data with probabilities greater than 0.05. These ratios were 55:9 and 7:1. The 55:9 ratio gave the best fit based on probability levels. This ratio is for three genes controlling resistance and susceptibility with interactions involved.

A total of 1993 F_2 plants of Cross 2 (9387A/TAM W-101) were tested, of which 345 were found to be resistant. This cross produced the smallest ratio of susceptible to resistant plants, i.e., 4.8 S:1.0 R. A 13:3 ratio best fit the data obtained from this test. This ratio is for two genes controlling resistance and susceptibility with epistatic interactions.

Cross 3 (9387A/Vona) had only 169 resistant plants out of a total of 1974 tested. This gave an observed ratio of 10.7 S:1.0 R. A 59:5 ratio gave the best fit. This is a three gene ratio with interactions involved.

Cross 4 (3987A/Centurk 78) showed the greatest proportion of susceptible plants of the four crosses. In this cross there were 1858 susceptible plants out of a total of 1967 F_2's tested. The observed ratio was calculated to be 17.0 S:1.0 R. Five ratios were found to fit the data. These ranged from a two gene to a four gene model. The four gene model fits best, and gave an expected ratio of 243:13.

Pooled data for all four crosses involved a total of 7904 plants tested. A 7.9 S:1.0 R observed ratio was obtained. None of the 32 genetic ratios tested fit the observed data (Table III).

The genetic control of WSMV resistance and susceptibility appears to be rather complex in crosses involving 9387A. It is apparent from Table III that resistance is not a simply inherited character. The fact that resistance is carried on a translocated segment of *Agropyron elongatum* chromatin may be one explanation for the complex ratios observed. Such results may be due to complications in pairing between the segments involved, resulting in the genetic interactions observed. There may also be an unequal transmission of the translocation chromosome to the gametes as suggested by other workers (7, 24).

The background genotype appears to have an influence on the expression of resistance in the four crosses. As indicated by the observed ratios of susceptible to resistant plants, there may be some modifying genes in the adapted parents. In the cross 9387A/TAM W-101 the observed S:R ratio was 4.8:1.0 as compared to 17:1.0 in the cross 9387A/Centurk 78. TAM W-101 must be contributing some modifying genes for resistance to WSMV since there is a higher frequency of resistant plants in this cross as compared to the cross with Centurk 78.

Analyses of Variance, F_3 Families

Standard analyses of variance were conducted to detect differences among the 76 F_3 families derived from a different F_2 plant in each cross. Resistance categories were established as described in Chapter III.

Mean squares, along with coefficients of variation, for eight agronomic characters measured in the F_3 field study are presented in Table IV, Appendix. Differences among families were highly significant (0.01 probability level) for all eight characters in all four crosses.

In Cross 1 (OK754615/9387A) mean squares for all characters except heading date and tillers were highly significant for the resistance categories source of variation. This indicates that there were significant differences among the three categories of resistance, i.e., categories one, two, and three, for these characters. Replication mean squares were highly significant (0.01 level) for heading date, height, tillers, and yield, while the replication mean square for kernel weight was significant at the 0.05 probability level. This indicates that blocking was effective in reducing extraneous variation, thereby increasing the precision of the experiment.

In Cross 2 (9387A/TAM W-101), significant replication mean squares were found for all characters except heading date and kernels/spike. Highly significant mean squares among resistance categories were found for height, yield, spikelets X 2, kernels/spike, kernel weight, and fertility index. Mean squares for tillers were significant at the 0.05

level.

Significant replication mean squares were obtained for heading date, height, yield, kernel weight, and fertility index in Cross 3 (9387A/Vona). All characters were significant for the resistance category source of variation.

Heading date, height, tillers, yield, kernels/spike, and fertility index mean squares were significant for the replication source of variation in Cross 4 (9387A/Centurk 78). Highly significant mean squares among resistance categories were found for all characters.

Coefficients of variation for most characters in all four crosses were of acceptable magnitude except those for tillers and yield, which were considered rather high. The high C. V.'s may have been due to the nature of the small plot (hills) utilized in this study.

Comparison Among Means of Resistance Categories, F_3 Families

Means for eight characters within each resistance category for Crosses 1, 2, 3, and 4 are presented in Tables V, VI, VII, and VIII, Appendix, respectively. In addition, t-Tests for significance between the three possible two-way comparisons between resistance categories are shown.

The majority of the 76 F_3 families fell within Category 1 (0-10% resistant plants) in each of the four crosses. The range was 49 families for Cross 2 to 66 families for Cross 3. By comparison, Category 3, which showed the greatest percentage of resistant plants, is comprised of the fewest families; ten in Cross 1, nine in Cross 2, two in Cross 3, and two in Cross 4.

In comparisons among categories for heading date, only one cross showed significant differences, i.e., Cross 4. Category 2 had the earliest heading date in each of the four crosses, while Category 3 had the latest heading date.

Only in one cross, Cross 2, were significant differences for height among resistance categories found. The mean plant height was greatest in Category 1 in all four crosses.

There were no significant differences among resistance categories for tiller number in any of the four crosses.

Significant differences for yield were found between Categories 1 and 2 in three of four crosses, i.e., Crosses 2, 3, and 4. In two of the crosses, Category 1 was significantly higher than Category 3. No significant differences were found for mean yield comparisons among Categories 2 and 3 in any of the four crosses.

In all four of the crosses the mean value of spikelets X 2 decreased from Category 1 through Category 3. In three of four crosses, i.e., Crosses 2, 3, and 4, Category 1 was significantly greater than Category 2. In Crosses 1, 2, and 3, Category 1 was significantly greater than Category 3. Category 2 was significantly greater than Category 3 only in Cross 2.

Category 1 had a significantly higher mean value for kernels/spike than either Category 2 or 3 in all four crosses. No significant differences were found among Category 2 and 3 means in any of the four crosses.

In all four crosses kernel weight decreased from Category 1 through Category 3. Category 1 was significantly greater than Category 2 in Crosses 2 and 3. Category 1 was significantly greater than Category 3 in Crosses 1 and 2. No significant differences were found among Category

2 and Category 3 for kernel weight.

Significant differences for the fertility index were found in Crosses 1, 2, and 3 in comparisons among Categories 1 and 2. No significant differences were found among Categories 1 and 3, and, 2 and 3 in any of the four crosses.

Examination of the agronomic characters by resistance category indicated that WSMV resistance resulted in or was associated with consistently depressed values for kernels/spike across the four crosses. Significance varied for yield, spikelets X 2, kernel weight, and fertility. Tillering potential did not appear to be associated with WSMV resistance.

Since total grain yield is the product of the average number of tillers/unit area X the average number of kernels/spike X the average kernel weight, it appears that the depressed yield of 9387A reported in previous tests is primarily due to the reduction of kernels/spike. Some reduction can also be attributed to kernel weight. Tillering potential was apparently not affected. This suggests that the translocated segment of *Agropyron* chromosome that carries the gene(s) for WSMV resistance also carries deleterious effects for two of these three yield components.

Among-Family Correlation Coefficients

Among-family correlation coefficients were calculated for all possible comparisons involving percent resistant plants. These correlations are mostly due to the genetics of the populations. The data are presented in Table IX, Appendix.

Heading date was not significantly correlated with percent resistant plants in any of the four crosses.

Height was significantly correlated with percent resistant plants in only one cross, i.e., Cross 2. This value was -0.279*.

Tiller number was not significantly correlated with percent resistant plants in any of the four crosses.

Yield was significantly correlated with percent resistant plants in Crosses 1, 2, and 3. A nonsignificant correlation coefficient was found in Cross 4. These values ranged from -0.207 to -0.571**.

Highly significant negative correlations were found involving spikelets X 2 and percent resistant plants in all four crosses. These correlation coefficients were intermediate in magnitude and ranged from -0.319** to -0.531**.

Highly significant negative correlations were found in all four crosses involving kernels/spike and percent resistance. Coefficients ranged from -0.370** to -0.567**.

Significant negative correlations involving kernel weight and percent resistant plants were found for all four crosses. Coefficients in Crosses 1, 2, and 3 were significant at the 0.01 level, while Cross 4 was significant at the 0.05 level. Values ranged from -0.252* to -0.528**.

Significant negative correlations were found for comparisons involving the fertility index and percent resistant plants. Values ranged from -0.244* to -0.338**.

It appears that WSMV resistance is this material will result in a reduction of yield as evidenced by the correlations involving spikelets X 2, kernels/spike, kernel weight and yield. Although significant negative correlation coefficients were found, none of these were of high magnitude. This suggests that improvements in yield and yield components could be combined with resistance to WSMV in these crosses.

Ranked Means of F_3 Families

Tables X through XIII, Appendix, present the top thirty F_3 families ranked on mean yields for Crosses 1, 2, 3, and 4, respectively. Data for the respective parents and checks are presented for comparison. This ranking was done to identify the families with high yield potential and to examine corresponding values for percent WSMV resistant plants.

Mean yields of the 30 F_3 families ranked by yield in Cross 1 (Table X) ranged from 30.2 grams to 19.9 grams. All 30 families exceeded the test mean yield and also the mean yield of Line 9387A. Entry 25 had the fifth highest yield (28.2 g) and the highest percentage of resistant plants (15.8%).

One of the check cultivars, Newton, had 29.9% resistant plants. This result is suspicious since the percentage of resistant plants of Newton in Tables XI, XII, and XIII, are 9.1%, 0.0%, and 0.0%, respectively. This high percentage of resistant plants may be due to escape or possibly due to delayed symptom expression.

Mean yields of the 30 F_3 families in Cross 2 (Table XI) ranged from 32.6 grams to 22.4 grams. All 30 families exceeded the test mean yield, the mean yield of 9387A, and that of the three check cultivars, Payne, Osage, and Newton. Three entries, 40, 16, and 49, had WSMV resistant percentages of 29.3, 26.2 and 19.6, respectively.

Mean yields of the 30 F_3 families in Cross 3 (Table XII) ranged from 27.8 grams to 18.7 grams. All 30 families exceeded the test mean yield and the mean yield of Line 9387A. The highest percentage of WSMV resistant plants was 9.1 shown by entries 20 and 14.

Mean yields of the 30 F_3 families in Cross 4 (Table XIII) ranged from 27.2 grams to 17.6 grams. All 30 exceeded the test mean yield and the mean yield of Line 9387A.

Crosses 1 and 2 had the highest yielding families and the highest percentage of resistant plants per family. Across the four crosses the highest yields were 30.2 g, 32.6 g, 27.8 g, and 27.2 g, for Crosses 1, 2, 3, and 4, respectively. The highest percentages of resistant plants were 93.8, 100, 68.3, and 59.6, for Crosses 1, 2, 3, and 4, respectively. Mean yields and mean percentages of resistance were the highest in Crosses 1 and 2.

CHAPTER V

SUMMARY AND CONCLUSIONS

Four hard red winter wheat crosses involving Line 9387A (CI 15322/2*Osage), a WSMV resistant translocation line were studied at the Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma in 1980 and 1981. CI 15322, a WSMV resistant germplasm line derives its resistance from a translocated segment of *Agropyron elongatum*. The other parents were OK754615, TAM W-101, Vona, and Centurk 78.

Approximately 2000 F_2 seedlings of each of the four crosses were inoculated with the virus in the fall of 1980 in an attempt to determine the segregation patterns of the resistance-susceptibility reaction.

In addition to this test, a field study of 76 F_3 families and the two respective parents of each cross was conducted at the Experiment Station in Stillwater during the 1980-81 crop season. A 9 X 9 Lattice Square design with five replications was used. Eight agronomic characters were evaluated. These were heading date, height, tillers, yield, the number of spikelets/spike, kernels/spike, kernel weight, and spike fertility. The progeny of these F_3 families were tested for WSMV reaction in the fall of 1981 to determine the percentage of WSMV resistant plants in each family. Resistance categories were established to identify the level of WSMV resistance in each family since very few families were 100% resistant.

The segregation pattern for WSMV resistance in crosses involving

Line 9387A appeared to be complex. No simple genetic ratio fit the data obtained. Gene interactions appeared to be involved in each cross. A 55:9 ratio, a three gene model, gave the best fit in Cross 1 (OK754615/9387A). A 13:3 ratio, a two gene model, gave the best fit in Cross 2 (9387A/TAM W-101). A 59:5 ratio, a three gene model, best fit Cross 3 (9387A/Vona). A 243:13 ratio, a four gene model, best fit Cross 4 (9387A/Centurk 78). These complex genetic ratios are most likely due to the unequal transmission of the chromosome containing the *Agropyron* chromatin through the gametes, as described by Knott (7). The possible presence of modifying genes may have influenced the segregation patterns observed, as evidenced by Crosses 1 and 4. Cross 1 had an observed susceptible:resistant ratio of 4.8 S:1.0 R, while Cross 2 had an observed ratio of 17.0 S:1.0 R.

Based on the analysis of variance, the mean squares for families were highly significant (0.01 level) for all eight characters in all four crosses. Differences among the resistance category source of variation varied in the four crosses.

The majority of the 76 F_3 families fell within Category 1 (0-10% resistant) in each of the four crosses. Category 3, greater than 50% resistant, was comprised of the fewest families.

Significant differences were found for yield among Categories 1 (0-10% resistant plants) and Category 2 (>10<50% resistant plants) in Crosses 2, 3, and 4. Category 1 was significantly greater than Category 3 (>50% resistant plants) in Crosses 1 and 2.

There were no significant differences among resistance categories for tiller number in any of the four crosses.

Category 1 had a significantly greater mean value for kernels/spike than either Category 2 or 3 in all four crosses.

Significant differences for kernel weight were found in Crosses 2 and 3 in comparisons of Categories 1 and 2. Category 1 was significantly greater than Category 3 in Crosses 1 and 2.

Highly significant, negative correlation coefficients were found between yield and percent resistant plants in Crosses 1, 2, and 3. Correlations ranged from -0.207 to -0.571**.

Kernels/spike was negatively correlated with percent resistant plants in all four crosses. These correlations were highly significant and ranged from -0.370** to -0.567**.

Negative correlations involving kernel weight and percent resistant plants were found in all four crosses. Crosses 1, 2, and 3 were significant at the 0.01 level, while Cross 4 was significant at the 0.05 level.

Although these characters were negatively correlated with percent WSMV resistant plants, the magnitude was not high. This suggests it is possible to recover WSMV resistant plants with acceptable agronomic characters.

Based on these results, the yield depression in Line 9387A observed in the F_3 field study appeared to be primarily the result of a reduced number of kernels/spike and to some extent a reduced kernel weight. Tillering potential did not appear to be influencing yield.

Ten potentially promising families were identified on the basis of mean yield and a percentage of resistant plants of five percent or greater (Table XIV, Appendix). These families were 25, 16, and 72 in Cross 1; 51, 57, 40, and 16 in Cross 2; 69 and 20 in Cross 3; and 4 in

Cross 4. These families may provide useful sources of WSMV resistance without sacrificing yield to any great degree.

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APPENDIX

TABLE III

CHI-SQUARE ANALYSIS OF THE F_2 GENERATION OF FOUR WINTER WHEAT CROSSES SEGREGATING FOR RESISTANCE TO WSMV

Cross No.	Pedigree	Number of Plants			Observed Ratio S:R	Calculated Ratios with Nonsignificant (P>.05) Chi-Square Values[1/]				
		Total	Suscept.	Resist.						
1	OK754615/9387A	1970	1701	269	6.3:1.0	55:9	7:1			
2	9387A/TAM W-101	1993	1648	345	4.8:1.0	13:3				
3	9387A/Vona	1974	1805	169	10.7:1.0	59:5				
4	9387A/Centurk 78	1967	1858	109	17.0:1.0	243:13	61:3	60:4	60:3	15:1
Total		7904	7012	892	7.9:1.0	All Chi-Square values were significant at P<.05				

[1/]A total of 32 ratios tested.

TABLE IV

MEAN SQUARES FOR EIGHT CHARACTERS FROM THE ANALYSIS OF VARIANCE OF 76 F_3 FAMILIES FOR EACH OF FOUR CROSSES

Cross No.	Source of Variation	df	Heading Date	Height	Tillers/ Hill	Grain Yield	Spikelets x 2	Kernels/ Spike	Kernel Weight	Fertility Index
	Replication	4	33.4**	582.5**	73.7**	129.5**	7.3	49.9	30.4*	388.0
1	Resistance Category	2	9.3	173.2**	4.3	542.7**	289.7**	1593.8**	145.5**	3616.6**
	Family	73	82.9**	135.0**	40.5**	96.8**	31.4**	120.7**	35.3**	584.1**
	Error	300	5.0	24.6	17.1	34.5	8.5	40.5	11.1	193.2
	C. V.		10.3	6.6	24.0	30.2	8.0	13.8	9.0	11.0
	Replication	4	5.7	613.9**	34.0*	87.9**	19.2**	30.8	38.7*	486.9*
2	Resistance Category	2	8.6	366.7**	49.3*	1835.3**	464.6**	1961.1**	643.4**	3188.1**
	Family	73	46.6**	128.6**	36.2**	82.9**	27.1**	83.0**	44.0**	526.8**
	Error	300	3.9	15.8	11.9	21.9	5.6	26.0	15.4	163.1
	C. V.		8.9	5.0	18.8	21.5	6.7	11.4	9.7	10.0
	Replication	4	32.0**	65.2**	16.1	61.6*	0.2	84.8	61.7**	557.4*
3	Resistance Category	2	29.8**	68.7*	42.1*	746.0**	139.0**	1719.5**	381.1**	5481.0**
	Family	73	79.5**	88.3**	19.1**	68.3**	24.5**	136.1**	48.9**	553.5**
	Error	300	3.5	14.8	9.3	23.0	5.6	39.3	14.8	192.1
	C. V.		8.7	5.2	21.2	27.9	6.7	12.1	11.0	9.9
	Replication	4	49.7**	467.2**	77.8**	62.4*	2.1	152.3*	17.4	1331.6**
4	Resistance Category	2	218.9**	91.1**	158.3**	296.5**	232.3**	1129.4**	69.6**	2035.7**
	Family	73	61.0**	70.0**	29.5**	81.3**	24.9**	132.2**	48.8**	518.5**
	Error	300	5.2	17.9	13.4	22.9	5.4	48.4	13.2	247.5
	C. V.		9.2	5.5	23.0	29.4	6.5	14.5	10.7	11.9

*,**Significant at the 0.05 and 0.01 levels of probability, respectively.

TABLE V

NUMBER OF FAMILIES PER RESISTANCE CATEGORY AND MEANS FOR EIGHT AGRONOMIC CHARACTERS FOR 76 F_3 FAMILIES CROSS 1 (OK754615/9387A)

WSMV Resistance Category[1] (No. of Families)		Heading Date[2]	Height (cm)	Tillers (No./Hill)	Yield (g/Hill)	Spikelets x 2	Kernels/ Spike	Kernel Weight (g/1000)	Fertility Index
1	(55)	21.8	76.3	17.3	20.4	37.1	47.9	37.5	129.0
2	(11)	21.2	75.3	16.8	17.5	35.9	42.5	36.3	118.1
3	(10)	21.9	73.5	17.3	15.9	33.5	40.4	35.1	120.7
F_3 Mean		21.7	75.8	17.2	19.4	36.5	46.1	37.0	126.3
t-Test for Significance									
Category 1 vs 2		ns	ns	ns	ns	ns	*	ns	*
Category 1 vs 3		ns	ns	ns	*	**	**	*	ns
Category 2 vs 3		ns	ns	ns	ns	ns	ns	ns	ns

[1] Resistance levels indicated by 1, 2, and 3 are 0-10%, >10<50%, >50% resistant families, respectively.
[2] Days after March 31.
*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

TABLE VI

NUMBER OF FAMILIES PER RESISTANCE CATEGORY AND MEANS FOR EIGHT AGRONOMIC CHARACTERS FOR 76 F_3 FAMILIES CROSS 2 (9387A/TAM W-101)

WSMV Resistance Category[1/] (No. of Families)		Heading Date[2/]	Height (cm)	Tillers (No./Hill)	Yield (g/Hill)	Spikelets x 2	Kernels/ Spike	Kernel Weight (g/1000)	Fertility Index
1	(49)	22.3	81.0	18.7	23.9	36.1	47.1	41.6	130.7
2	(18)	22.1	80.0	17.8	18.9	34.2	41.4	38.8	121.4
3	(9)	22.8	76.7	17.4	15.5	31.4	38.8	36.5	123.9
F_3 Mean		22.3	80.3	18.3	21.7	35.1	44.7	40.3	127.7
t-Test for Significance									
Category 1 vs 2		ns	ns	ns	**	**	**	*	*
Category 1 vs 3		ns	**	ns	**	**	**	**	ns
Category 2 vs 3		ns	*	ns	ns	**	ns	ns	ns

1/ Resistance levels indicated by 1, 2, and 3 are 0-10%, >10<50%, >50% resistant families, respectively.
2/ Days after March 31.
*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

TABLE VII

NUMBER OF FAMILIES PER RESISTANCE CATEGORY AND MEANS FOR EIGHT AGRONOMIC CHARACTERS FOR 76 F_3 FAMILIES CROSS 3 (9387A/VONA)

WSMV Resistance Category 1/ (No. of Families)	Heading Date 2/	Height (cm)	Tillers (No./Hill)	Yield (g/Hill)	Spikelets x 2	Kernels/ Spike	Kernel Weight (g/1000)	Fertility Index
1 (66)	21.8	74.7	14.5	18.0	37.3	52.9	35.5	141.7
2 (8)	20.6	72.7	13.1	11.9	34.9	43.3	31.6	124.2
3 (2)	22.4	73.7	15.5	13.2	34.4	48.0	30.2	139.3
F_3 Mean	21.7	74.4	14.4	17.2	37.0	51.8	34.9	139.8
t-Test for Significance								
Category 1 vs 2	ns	ns	ns	**	**	**	**	**
Category 1 vs 3	ns	ns	ns	ns	**	*	ns	ns
Category 2 vs 3	ns	ns	ns	ns	ns	ns	ns	ns

1/Resistance levels indicated by 1, 2, and 3 are 0-10%, >10<50%, >50% resistant famlies, respectively.
2/Days after March 31.
*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

TABLE VIII

NUMBER OF FAMILIES PER RESISTANCE CATEGORY AND MEANS FOR
EIGHT AGRONOMIC CHARACTERS FOR 76 F_3 FAMILIES
CROSS 4 (9387A/CENTURK 78)

WSMV Resistance Category[1] (No. of Families)		Heading Date[2]	Height (cm)	Tillers (No./Hill)	Yield (g/Hill)	Spikelets x 2	Kernels/ Spike	Kernel Weight (g/1000)	Fertility Index
1	(64)	25.0	77.7	16.0	16.9	36.5	49.0	34.0	133.7
2	(10)	22.8	76.0	14.7	13.2	33.5	43.5	32.7	129.9
3	(2)	29.5	75.0	20.8	14.8	33.4	38.2	31.3	114.4
F_3 Mean		24.8	77.4	15.9	16.3	36.1	48.0	33.8	132.7
t-Test for Significance									
Category 1 vs 2		*	ns	ns	*	**	*	ns	ns
Category 1 vs 3		**	ns	ns	ns	ns	*	ns	ns
Category 2 vs 3		**	ns	ns	ns	ns	ns	ns	ns

[1]Resistance levels indicated by 1, 2, and 3 are 0-10%, >10<50%, >50% resistant families, respectively.
[2]Days after March 31.
*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

TABLE IX

AMONG-FAMILY CORRELATION COEFFICIENTS OF FOUR CROSSES FOR ALL POSSIBLE COMPARISONS WITH PERCENT RESISTANT PLANTS OF 76 F_3 FAMILIES PER CROSS

Percent Resistance Correlated With	Cross 1 OK754615/9387A	Cross 2 9387A/TAM W-101	Cross 3 9387A/Vona	Cross 4 9387A/Centurk 78
Heading Date	-0.026	0.093	-0.052	0.057
Height	-0.156	-0.279*	-0.080	-0.199
Tillers	0.024	-0.140	-0.036	0.224
Yield	-0.342**	-0.571**	-0.383**	-0.207
Spikelets x 2	-0.467**	-0.531**	-0.319**	-0.408**
Kernels/Spike	-0.460**	-0.567**	-0.370**	-0.455**
Kernel Weight	-0.329**	-0.528**	-0.364**	-0.252*
Fertility Index	-0.244*	-0.281*	-0.277*	-0.338**

*,**Significant at the 0.05 and 0.01 levels, respectively.

TABLE X

RANKED MEAN YIELDS OF TOP 30 F_3 FAMILIES IN COMPARISON WITH PARENTS, CHECKS, AND TEST MEAN CROSS 1 (OK754615/9387A)

Family No.	Yield	Percent WSMV Resistant Plants	Tillers	Kernels/ Spike	Kernel Weight
27	30.2	2.9	22.0	53.6	37.1
40	29.8	2.2	18.8	59.8	39.8
73	29.2	2.1	23.0	47.2	41.2
49	28.3	2.3	22.8	49.4	35.6
25	28.2	15.8	24.0	48.0	37.2
19	27.8	2.4	21.4	58.2	41.7
16	27.2	6.5	20.0	49.4	40.9
56	26.7	5.0	22.2	45.8	37.2
18	26.5	4.9	21.6	50.8	34.3
30	25.6	5.0	19.8	50.4	39.7
59	25.5	0.0	19.2	49.6	38.7
4	25.4	2.0	19.6	50.0	39.3
42	25.2	0.0	18.8	51.2	39.7
28	24.3	5.0	19.4	50.0	35.9
72	24.3	8.9	23.8	51.2	35.9
3	23.7	0.0	17.4	48.4	39.9
54	23.6	2.1	17.8	56.0	36.7
69	23.3	2.2	18.8	56.0	34.7
63	22.5	7.3	19.2	52.6	33.5
20	22.1	0.0	16.0	50.4	37.8
29	21.6	0.0	18.4	44.6	41.4
37	21.1	2.5	19.8	49.2	37.6
21	21.0	2.0	16.6	47.8	38.3
17	20.9	5.0	17.0	47.8	37.0
44	20.4	0.0	18.6	52.0	34.8
48	20.3	7.5	18.0	50.2	38.5
50	20.3	0.0	16.2	49.0	40.1
70	20.2	0.0	15.6	45.8	40.2
52	19.9	4.4	17.6	40.6	38.4
34	19.9	9.2	16.8	43.4	40.8
9387A (P_1)	17.1	81.5	18.6	42.2	35.5
OK754615 (P_2)	22.5	2.0	15.6	48.2	43.1
Payne (Ck)	23.0	2.3	21.0	47.6	34.8
Osage (Ck)	22.4	2.3	22.0	50.4	37.6
Newton (Ck)	25.5	29.9	20.0	56.0	37.0
Test Mean	19.4	16.2	17.2	46.1	37.0

TABLE XI

RANKED MEAN YIELDS OF TOP 30 F_3 FAMILIES IN COMPARISON WITH PARENTS, CHECKS, AND TEST MEAN CROSS 2 (9387A/TAM W-101)

Family No.	Yield	Percent WSMV Resistant Plants	Tillers	Kernels/ Spike	Kernel Weight
61	32.6	2.2	21.2	54.6	44.7
28	31.4	0.0	21.4	47.8	45.7
51	31.1	8.0	23.2	50.8	41.7
42	30.6	0.0	19.6	57.6	46.6
57	29.9	5.0	19.0	51.8	43.3
67	29.5	2.0	21.6	45.4	44.4
9	29.5	0.0	18.4	51.2	45.5
17	29.1	0.0	20.4	54.4	45.8
76	28.8	2.0	19.4	50.6	45.6
5	28.6	0.0	20.8	49.0	42.0
21	28.3	0.0	20.6	49.0	43.3
18	28.3	0.0	21.0	52.0	38.1
8	28.1	0.0	22.6	44.8	40.8
32	28.1	0.0	17.2	51.6	43.6
3	27.9	3.6	23.2	41.6	43.1
14	27.4	0.0	21.2	50.2	39.0
38	26.7	2.2	18.4	43.2	47.1
25	26.3	0.0	23.2	43.2	39.6
29	26.1	2.4	22.8	41.0	43.4
1	26.0	0.0	19.0	46.8	46.4
33	25.2	0.0	23.2	50.4	42.3
53	24.6	4.0	20.0	45.8	39.2
40	24.5	29.3	25.0	41.4	37.9
16	24.3	26.2	23.8	42.2	35.9
6	24.1	4.3	16.0	54.0	44.5
52	24.0	5.3	18.8	44.4	41.3
64	23.2	2.5	18.0	45.6	44.9
65	22.9	6.8	18.0	48.2	42.0
49	22.6	19.6	17.6	43.4	43.8
20	22.4	4.4	17.4	55.2	42.7
9387A (P_1)	13.4	85.1	14.8	40.6	34.4
TAM W-101 (P_2)	26.8	2.1	20.6	46.2	46.5
Payne (Ck)	18.8	0.0	16.8	49.0	34.7
Osage (Ck)	18.8	7.7	19.4	46.4	39.5
Newton (Ck)	22.0	9.1	18.0	60.8	35.3
Test Mean	21.7	17.3	18.3	44.7	40.3

TABLE XII

RANKED MEAN YIELDS OF TOP 30 F_3 FAMILIES IN COMPARISON WITH PARENTS, CHECKS, AND TEST MEAN CROSS 3 (9387A/Vona)

Family No.	Yield	Percent WSMV Resistant Plants	Tillers	Kernels/ Spike	Kernel Weight
37	27.8	0.0	21.0	52.6	38.7
59	24.2	4.8	16.2	56.6	37.5
4	24.0	0.0	16.8	59.2	36.5
19	23.6	0.0	17.0	55.4	39.2
42	23.6	0.0	13.8	60.0	42.8
6	22.9	0.0	15.0	61.6	35.9
43	22.7	0.0	16.6	57.2	39.4
23	22.4	0.0	15.6	55.8	37.2
65	22.3	2.1	18.0	49.6	34.5
69	22.2	5.0	15.6	48.0	37.8
32	22.1	2.2	15.0	53.6	39.6
21	21.8	0.0	15.8	50.0	33.6
60	21.6	0.0	17.6	53.0	33.8
51	21.5	0.0	14.0	63.4	38.4
11	21.1	2.3	16.0	58.2	37.0
57	21.0	0.0	17.4	55.2	32.9
1	21.0	4.3	16.2	55.6	38.3
33	20.8	0.0	15.4	55.4	35.5
20	20.7	9.1	15.8	56.2	34.2
27	20.2	0.0	14.2	53.8	37.7
26	20.1	0.0	14.0	52.6	38.3
30	19.7	0.0	14.8	54.6	39.0
54	19.4	0.0	14.6	51.8	41.1
14	19.4	9.1	17.0	55.8	38.5
52	19.3	0.0	15.0	50.0	35.6
29	19.2	5.0	13.8	64.0	33.9
66	18.9	8.9	14.4	54.4	34.1
48	18.8	0.0	15.0	48.2	37.2
12	18.7	0.0	14.0	65.4	33.7
50	18.7	8.9	16.6	48.2	34.0
9387A (P_1)	13.1	88.6	13.4	39.2	38.0
Vona (P_2)	21.6	0.0	17.6	53.8	35.4
Payne (Ck)	20.1	0.0	18.2	50.6	32.2
Osage (Ck)	24.0	2.2	22.4	52.0	34.6
Newton (Ck)	20.4	0.0	18.2	61.2	34.4
Test Mean	17.2	6.7	14.4	51.8	34.9

TABLE XIII

RANKED MEAN YIELDS OF TOP 30 F_3 FAMILIES IN COMPARISON WITH PARENTS, CHECKS, AND TEST MEAN CROSS 4 (9387A/CENTURK 78)

Family No.	Yield	Percent WSMV Resistant Plants	Tillers	Kernels/ Spike	Kernel Weight
58	27.2	4.3	22.0	57.4	28.3
2	26.3	4.3	20.2	55.8	33.0
56	25.2	2.6	20.6	56.2	37.2
4	24.0	4.1	18.0	56.4	36.6
29	23.9	6.3	20.0	49.2	36.6
8	23.7	0.0	17.8	51.4	35.3
41	23.0	0.0	20.0	57.2	33.5
38	21.8	2.4	18.8	54.8	33.1
36	21.4	0.0	17.2	52.6	36.2
31	21.1	0.0	18.6	48.8	36.8
13	21.2	0.0	17.4	54.2	36.1
15	21.1	5.0	18.6	47.6	37.9
33	20.8	6.3	20.6	55.4	32.7
26	20.2	0.0	16.2	52.0	35.1
19	20.1	0.0	17.8	50.4	35.4
61	20.0	2.1	18.2	51.4	33.6
54	19.9	0.0	17.6	51.2	34.3
28	19.1	2.5	16.4	55.0	33.4
46	18.6	0.0	16.4	48.2	36.3
22	18.3	2.1	16.2	55.4	36.6
16	18.3	2.2	16.0	49.6	37.9
24	18.2	0.0	16.6	47.4	36.5
5	18.1	0.0	14.0	45.4	39.8
9	18.0	0.0	15.0	58.4	33.1
43	18.0	0.0	18.0	50.4	35.0
67	17.8	0.0	16.2	56.0	32.3
27	17.8	4.5	16.8	47.8	34.5
63	17.8	0.0	18.8	52.0	29.2
52	17.6	0.0	18.6	48.2	35.7
12	17.6	0.0	14.6	47.2	35.5
9387A (P_1)	12.5	75.2	14.6	41.0	32.3
Centurk 78 (P_2)	22.6	0.0	22.6	57.8	32.0
Payne (Ck)	22.6	0.0	20.2	47.8	35.6
Osage (Ck)	20.2	0.0	20.4	47.4	34.1
Newton (Ck)	18.8	0.0	19.6	61.4	31.4
Test Mean	16.3	6.2	15.9	48.0	33.8

TABLE XIV

POTENTIALLY PROMISING FAMILIES

Cross No.	Family I.D.No.	Yield (g/Hill)	Percent Resistant Plants	Heading Date[1]	Height (cm)	Tillers (No./Hill)	Spikelets x2	Kernels/ Spike	Kernel Weight (g/1000)	Fertility Index
1	25	28.2	15.8	19.6	69.2	24.0	36.4	48.0	37.2	131.9
1	16	27.2	6.5	23.0	79.6	20.0	38.0	49.4	40.9	129.9
1	72	24.3	8.9	28.0	68.6	23.8	41.6	51.2	35.9	123.0
2	51	31.1	8.0	24.8	85.4	23.2	36.4	50.8	41.6	139.7
2	57	29.9	5.0	19.8	83.6	19.0	38.4	51.8	43.3	134.1
2	40	24.5	29.3	23.2	85.0	25.0	36.4	41.4	37.9	113.7
2	16	24.3	26.2	20.4	80.8	23.8	33.6	42.2	35.9	125.8
3	69	22.2	5.0	21.2	82.2	15.6	38.0	48.0	37.8	126.0
3	20	20.7	9.1	25.2	71.6	15.8	41.2	56.2	34.2	136.5
4	29	23.9	6.3	22.6	84.4	20.0	36.0	49.2	36.6	136.6

[1]/Days after March 31.

VITA

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Candidate for the Degree of

Master of Science

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