PERFORMANCE OF THE F_1 AND F_2 GENERATIONS OF A MALE-STERILE X RESTORER WINTER WHEAT HYBRID AT FIVE SEEDING RATES

By

CONRAD L. EVANS

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1950

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1978

PERFORMANCE OF THE F_1 AND F_2 GENERATIONS

OF A MALE-STERILE X RESTORER WINTER

WHEAT HYBRID AT FIVE SEEDING RATES

Thesis Approved:

Edward L. Smith
Thesis Adviser

Lavoy I. Croy

Robert M. Reed

Lewis H. Edwards

Norman N Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

The author is grateful to the Agronomy Department of the Oklahoma State University for the facilities which made this study possible.

Special appreciation is extended to Dr. Edward L. Smith for his guidance, counseling and patience throughout the duration of this study. I would also like to thank Dr. Lewis Edwards, Dr. Robert Reed and Dr. Lavoy Croy, who so graciously consented to serve on my graduate committee. Grateful acknowledgment is given to Dr. Robert D. Morrison, for his assistance with the statistical analysis of this study.

I would like also to thank my wife and children for their continued encouragement and patience during many absent hours.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	3
	Population Levels	3
	Heterosis in Wheat	7
III.	MATERIALS AND METHODS	12
	Hybrids and Parental Lines	12
	Experimental Design	13
	Characters Evaluated	14
	Grain Yield	15
	Kernel Weight	15
	Tiller Number	15
	Kernels per Spike	15
	Heading Date	16
	Plant Height	16
	Statistical Analysis	16
IV.	RESULTS AND DISCUSSION	17
	Yield	17
	Tillers	21
	Kernel Weight	22
	Kernels/Spikes	22
	Plant Height	23
	Heading Date	24
V.	SUMMARY AND CONCLUSIONS	25
LITERATURE CITED		47

LIST OF TABLES

Table | Page

I. Combined Analysis of Variance for Yield of Four Genotypes Grown at Two Locations for Two Years at Five Seeding Rates 29

II. Individual Year and Location Analysis of Variance for Yield of Four Genotypes at Five Seeding Rates 30

III. Comparison of Mean Yields (kg/ha) of Four Genotypes by Year, Location and Seeding Rate. 31

IV. Combined Analysis for Tiller Number Per Unit Area of Four Genotypes Grown at Two Locations for Two Years at Five Seeding Rates 32

V. Individual Year and Location Analysis of Variance for Tiller Number Per Unit Area of Four Genotypes at Five Seeding Rates 33

VI. Combined Analysis of Variance for Kernel Weight of Four Genotypes Grown at Two Locations for Two Years at Five Seeding Rates 34

VII. Individual Year and Location Analysis of Variance for Kernel Weight of Four Genotypes at Five Seeding Rates 35

VIII. Means for Kernels/Spike by Year, Location and Seeding Rate. 36

IX. Means for Plant Height (cm) by Year, Location and Seeding Rate. 37

X. Means for Heading Date by Year, Location and Seeding Rate. 38

LIST OF FIGURES

Figure		Page
1.	Grain Yield Relationship Among Five Seeding Rates in Years and Locations with Genotypes Combined.	39
2.	Grain Yield Relationship Among Five Seeding Rates in Individual Years and Locations with Genotypes Combined	40
3.	Grain Yield Relationship Among Four Genotypes in Years and Locations with Seeding Rates Combined. . .	41
4.	Grain Yield Relationship Among Four Genotypes at Locations in Years with Seeding Rates Combined	42
5.	Grain Yield Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location. . . .	43
6.	Tiller Number per Unit Area Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location	44
7.	Kernel Weight Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location .	45
8.	Kernels/Spike Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location .	46

CHAPTER I

INTRODUCTION

The development of wheat hybrids is a scientific reality. The twentieth century has witnessed the commercial hybridization of many of our major crops. The use of F_1 hybrids has resulted in substantial yield increases in many crops. So far this has not been true with wheat, since acceptable commercial hybrids are still in the developmental stage.

Plant breeders working with hybrid corn and grain sorghum have had much success with yield increases while utilizing normal or near normal seeding rates. This has been a great economic boon to the farmer, since it gives him greater production per unit area without parallel increases in seed cost; hence, greater profits per unit area.

Wheat farmers have not been able to capitalize on such good fortune. To date, plant breeders have not been able to achieve the high levels of heterosis so readily attained in corn, grain sorghum and other crops. Wheat normally returns, in yield, thirty times its' planting rate while corn and grain sorghum may give an increase of nearly five hundred times their normal seeding rate.

The success of hybrid wheat hinges on several factors, one of which is the cost of hybrid seed. With wheat, different cultural and management procedures may be required to offset the probably increased cost of seed and still assure the grower a high level of production.

Seeding rates (population density per unit area) may be one practice which could be modified to improve the economics of production.

The objectives of this study are: (a) to determine the performance of a male sterile by restorer F_1 hybrid, the F_2, and the two parental cultivars for yield and the components of yield (tiller number, kernel weight and number of seeds per spike), (b) to determine the lowest feasible seeding rate for the F_1 hybrid and (c) to determine the level of inbreeding depression in the F_2. The F_2 was included because it has been suggested by some researchers that the F_2 generation could be used as a source of commercial planting seed.

CHAPTER II

REVIEW OF LITERATURE

Population Levels

Increased yield has been achieved by the use of superior varieties, control of disease and insect pests, increased use of commercial fertilizer and better cultural practices which includes proper plant population. Cereal growers at an early date came to realize that the numbers of plants per unit area were directly related to yield. Many scientists are engaged in research to find optimum planting rates for specific varieties within species, especially within particular climatic environments.

Rate of seeding trials with wheat were conducted extensively in some areas of the United States as early as 1920 and in some areas even earlier. These trials were usually conducted with the most common variety grown in the region and at the most representative dates of seeding. Such trials resulted in some general principles in relation to moisture level, fertility level and wheat types.

Kiesselbach and Lyness (14) conducted a rate of seeding study with "Turkey" hard red winter wheat in Nebraska for the twenty-two year period from 1919 to 1940. With rates of 45, 60, 75 and 90 lbs. per acre, the grain yields were 24.9, 26.2, 26.5 and 27.1 bushels per acre, respectively.

Robertson et al. (25), in Colorado, instituted a rate and date trial with "Kanred" hard red winter wheat which ran for 12 years on cornland and for 13 years on summer fallow between 1920 and 1937. The seeding rates were 15, 30, 45, 60 and 90 lbs. per acre. Detailed data reveals that seeding rates produced relatively minor yield differences when sown on or near optimum dates. However, the heavier seeding rates produced appreciably higher yields when sown earlier or later than the optimum date.

In early investigations, Montgomery (20) concluded that high yields of wheat could be obtained over a wide range of seeding rates (45 lbs. per acre to 125 lbs. per acre). These results were verified by other workers of this period. Montgomery also reported that the number of tillers per plant decreased rapidly as seeding rates were increased with practically no additional tillers developing when seeding rates above 180 lbs. per acre were used. Grantham (9) found, with wheat, that in the heavier seeded plots the numbers of tillers was decreased by 39 percent and the yield per plant decreased by 48 percent. However, total yield for the high and low seeded plots was about the same.

Atkinson (1) found that on the average the returns from heavier seeding of spring wheat under irrigation were much better than from light seeding (heavy seeding being 90 lbs. per acre and above). Researchers using winter wheat, however, reported markedly varying results to those mentioned above. Jardine (12) reported that there was little difference in wheat yields from plots seeded at various rates. There was, however, a distinct relationship between the rate of seeding and the time of seeding on yield.

Environment was early recognized to play an important role in the yield performance of any variety. Martin (19) reported that, in wheat, tillering, number of heads which emerge from the sheath, length of heads and development and size of kernels all depended on suitable environmental and nutritional factors during each stage of growth. If the plants were overcrowded, the weak ones died, especially when moisture was limited.

Godel (8) found that the yield difference between light and heavy seeding rates was usually not significant, but that light seeded crops exhibited more tillering, had larger heads and greater straw strength. The heavier seeding rates did not give sufficient yield increases to warrant the cost of extra seed. Woodward (35) also reported no significant difference in yield from various seeding rates. He also found that the lighter seeding rates resulted in stronger straw, larger spikes and kernels and higher test weight per bushel. He also reported an interaction between rate and variety which affected yield.

Locke et al. (17) concluded that more than 60 percent of the variation in yield of wheat was a result of the number of heads per unit area. Quinsenberry (24) substantiated a portion of Locke's findings. He reported that the number of heads per unit area was one of the most important factors in determining yield of wheat, closely followed by the number of kernels per spike. Kernel weight was not as important a yield factor as the two mentioned previously. Peck (23) also reported that the number of heads per unit area was correlated with wheat yields.

The advent of more specialized varieties and physiological explanations for higher yield brought about a renewed interest in population levels and spatial arrangement.

Several experiments have been conducted in which distance between plants in the row as well as distance between rows have been the means for controlling population density. Lashin and Schrimpf (16) found that of three winter wheat varieties used in row spacing tests, one yielded consistently less at the wider spacing, another had its highest yield at intermediate spacing and the third behaved differently at different spacing and planting dates. Seimens (28) conducted experiments with various row spacings and their effect on yield and other agronomic characters with wheat, barley, oats and flax. He reported a decrease in yield as row spacing was increased but seed return per bushel seeded went up as inter-row width increased. Kinra et al. (15) also reported similar results, with wheat, while using four row spacing distances. A trend of yield decline occurred when row spacing was increased. Holliday (11) theorized that an interaction between row spacing and seeding rate may exist. He stated that when the rows are too far apart, the seeding rate has a greater effect on yield than does row spacing. He found that for the same seeding rate, grain yield decreased as row width increases and this effect is more pronounced as seeding rate becomes very low or very high.

Studies conducted by Bleasdale (2) indicated that lower plant densities reduced the influence of spatial arrangements on crop yield. Stickler (32) planted a winter wheat variety at seeding rates of 30, 60 and 90 lbs. per acre and three row widths. All possible combinations of row spacings and rate were studied to determine the effect on yield and components of yield. Grain yield was affected more by row width than by seeding rate.

Experiments involving seeding rates with standard pure-line varieties indicates that there is little difference in grain yields from low to high seeding rates when environmental influences are considered. However, with the advent of hybrid wheat and its possible high seed costs, further experimentation with seeding rates seem necessary.

Rosenquist (26), as early as 1931, while studying hybrids and parents under conditions of close spacing, stated that a hybrid may show heterosis when growing under conditions which allow ample space for development. This may not mean, however, that it will be fully as vigorous when grown under conditions more nearly like those under which it receives its final test. Engledow (5) had earlier concluded that varieties behaved quite differently under different population densities and spacing conditions, showing changes in ranking with thick and thin planting.

Heterosis in Wheat

Rosenquist (26) studied 1,590 F_1 wheat hybrids and 2,692 parent plants over a period of three years. All components of yield were measured and 61 percent of the hybrids were found to be consistently higher in yield than the parental averages. The magnitude of this increase, however, was seldom sufficient to be statistically significant.

Pal and Nek Alam (21) concluded that expression of heterosis in wheat is greatly influenced by environmental conditions, one of which was spacing of plants within rows. Briggle et al. (3) reported a significant entry x planting rate interaction for weight of grain and for plant height. When a wheat hybrid and parents were grown in hills at three different planting rates at four plants each per hill, the F_1's produced significantly more than either parent. At lower rates (one and two plants per hill), the F_1's did not differ from the parents.

Patterson and Bitzer (22) conducted tests with hybrids involving a seven-parent intercross (21 hybrids) and a six-parent cross (15 hybrids). Results ranged from zero to 70 percent greater yield of the hybrids over the better parent. They suggested that hybrid vigor in wheat could be as great as that in corn or sorghum. Their current estimate is that 15 to 30 percent of the extra yield from hybrids will go to pay for seed costs alone.

Brown et al. (4) failed to find the high level of heterosis reported by Patterson in 1966. The highest expression of heterosis amounted to only 31 percent greater yield than the best parent. Using the estimate of cost for hybrid seed suggested by Patterson et al. (22), this would only represent a break-even situation for a wheat farmer wishing to utilize hybrid wheat.

Gyawali et al. (10), in a study of 21 hybrids, found only 10 to exhibit significant heterosis when compared to the better parent and on the average this amounted to only 21 percent. Glover (7) studied heterosis for yield in eight wheat hybrids. Three of the eight hybrids expressed significant high-parent heterosis of 16 to 18 percent; however, no hybrids were significantly higher in yield than the best check variety. Similar results were obtained by Sidwell (30), who studied five hybrids for heterosis of yield. Only two hybrids were significantly higher than the highest check variety and the higher yielding hybrid exceeded the check by only nine percent. Johnson et al. (13) found that the F_1 wheat hybrid in a study of inheritance for grain yield exceeded the high parent by only 12.9 percent. Such results are questionable when considered as a level necessary to repay the producer the cost of hybrid seed. It must be reported, however, that Gyawali's parent material represented a wide diversity of genetic material and may not have represented the best choice for high yielding F_1's.

Fonseca and Patterson (6) in a series of tests involving one hard red winter wheat, one soft white winter wheat and five soft red winter varieties reported varying levels of heterosis for the F_1. The highest F_1 yielded 171 percent of the highest parent but the F_2 yielded only 129 percent of the higher parent in 1963-64. They reported no seeding rate x variety interaction although nurseries seeded in rows tended to produce more than nurseries planted in hills. Shebeski (29) reported that from a test of 14 hybrids only three were significantly higher yielding than the high parent, with increases up to 26 percent greater than the high parent. Shebeski postulated that yield components were not transmitted from parent to hybrid in a consistent manner, indicating that component values of parents are not good indicators of hybrid performance.

Most of the earlier tests of seeding rates and heterotic expression of hybrids was conducted with hand-made hybrids. These hybrids were produced by hand emasculation and hand pollination. Obviously, this method could not be used to produce the vast quantities of commercial hybrid seed needed to plant a major portion of the wheat acreage of the United States.

In 1961, Wilson and Ross (33) obtained stable cytoplasmic-male-sterile bread-wheat by crossing T. timopheevi (2n = 28), as the female parent, with a winter variety of T. aestivum (2n = 42), called "Bison." For the cytoplasmic-male-sterile system to be useful in producing hybrid wheat, a corresponding fertility-restoring mechanism had to be found. Seed used by the farmer to plant his hybrid crop must have, in the resulting plants, the capacity for male fertility. In 1962 Wilson and Ross (34) suggested that restorer-genes must exist in T. timopheevi, since it carried the sterile cytoplasm. Schmidt, Johnson and Mann (27) of the Nebraska Experiment Station, soon verified this and, Wilson, working independently, reported similar results.

Nearly all programs of hybrid seed production are based upon the cytoplasmic male sterility and fertility restoration mechanism. However, this system has not yet been perfected to the point where it is entirely satisfactory. Research continues, therefore, in an effort to find new techniques of producing hybrids more efficiently. The need for this is prompted, in part, by poor seed set from most hybrids when grown under field conditions. This does not allow the producer to gain maximum results from heterosis expressed in the F_1 generation.

Fertility restoration lines have been developed by the standard backcross method of introducing one or more restorer genes into the best varieties. At first this system was limited to restorer genes found in T. timopheevi and apparently some restoration loss occurred during the backcross process.

Recently, Lucken (18) reported that interactions between sterility found in Ae. speltiodes and restorer genes found in T. zhukovsky may give rise to a more efficient hybrid breeding program. Male sterile lines containing *speltoides* cytoplasm when backcrossed with a restorer gene (R5) from *T. zhukovsky* gives a stable male sterile line that can be used as a female parent, since male fertility in this system is completely inhibited. When crossed with certain R-lines the *speltoides*-R5 system results in high degrees of hybrid fertility. Restoration with the use of the *speltoides*-R5 system in many cases is higher than that obtained with the *T. timopheevi* system. Thus, the *speltoides*-R5 system gives the breeder several options in developing and using parents for producing hybrid wheats.

The literature indicates that there is enough genetic diversity available to the wheat breeder to warrant production of both varieties and hybrids. In fact, it seems that one compliments the other. Research indicates, however, that there is little or no seeding rate by variety or genotype interaction. Certainly seed of hybrids will be more expensive than that of pure line varieties. Every effort must be made to keep production costs of wheat at a minimum. Growers of hybrid wheat may not be able to afford the luxury of heavy seeding rates.

CHAPTER III

MATERIALS AND METHODS

Hybrids and Parental Lines

The material used in this study consisted of one cultivar of hard red winter wheat, its A-line (male sterile) counterpart, one fertility restorer line, the F_1 hybrid developed by crossing the A-line and R-line, and the F_2 generation of this same cross. The male sterile A-line (A-"Agent") contained the cytoplasmic male sterility factor derived from _T. timopheevi_ and the R-line (R92-25) contained fertility restoring genes derived also from _T. timopheevi_.

The cultivar, "Agent" was chosen for its good adaptation to Oklahoma conditions and its potential as a possible sterile line for future hybrid studies. Agent was developed at the Oklahoma Agricultural Experiment Station and released in 1967. It is described by Smith et al. (31) as being resistant to all common races of leaf rust, mid-season in maturity and mid-tall with white glumes.

The restorer line, R92-25, is an Oklahoma selection which traces to a single plant selection from the Nebraska 542437 restorer population obtained from Dr. J. C. Craddock in 1963. The pedigree of this restorer population (542437) is _T. timopheevi_ x (Hussar-Hard Federation)^2 x (Comet-Hussar-Hard Federation) x Nebred. The population consisted of two lots of seed designated as Lot 1 and Lot 2. Reports from Nebraska indicated that Lot 1 carried two major genes for fertility restoration, while Lot 2 carried a single major gene with possibly some minor genes. The F_2 generation of these lots was grown at Stillwater in 1964 with Lot 1 designated as plot 5892 and Lot 2 as plot 5893. Individual F_3 plants were selected from each lot and the resulting selections were numbered Stw. 645892 and Stw. 645893, respectively.

The restorer used in this study was taken from the Stw. 645892 group (Lot 1 = 2-gene restorer population) and carried the designation R92-25. This choice was made on the basis of degree of fertility restoration and desired agronomic characteristics. The cross A-Agent x R92-25 was made in 1967 (Cross No. H67 x 262a). This was grown as the F_1 generation in 1968 and the seed produced on these F_1 plants was the source for the F_2 generation in this study. A-Agent x R92-25 cross was remade in 1968 (Cross No. H68 x 134). This seed was used as the source of F_1 generations in this study.

Experimental Design

A split-plot design was chosen with main plots consisting of seeding rates and subplots consisting of genotypes. There were four genotypes (P_1 = Agent, P_2 = R92-25, F_1 and F_2). Plots were replicated four times. Plots in all cases were two rows, 3 m in length with 30 cm spacing between rows.

The five seeding rates were 17, 34, 50, 67 and 84 kg/ha. The 67 kg/ha seeding rate approximates the seeding rate for wheat in Oklahoma of one bu/a. Henceforth, the above listed seeding rates will be referred to as seeding rates 1, 2, 3, 4 and 5, respectively.

In order to insure that equivalent numbers of seed were planted for each genotype at each seeding rate, the following calculation was used:

> Grams of seed necessary for planting 3 m of row = average kernel weight of each genotype (in grams) x desired number of seeds per 3 m of row at a given seeding rate.

The study was conducted at two locations: the Agronomy Research Station, Stillwater, Oklahoma, and the Southern Great Plains Field Station, Woodward, Oklahoma. The study was conducted for a period of two years, 1969 and 1970. Henceforth, Stillwater will be referred to as Location 1 and Woodward will be referred to as Location 2. The 1969 harvest year will be referred to as Year 1 and the 1970 harvest year will be referred to as Year 2.

The entries were planted in Year 1 and Location 1 and Location 2 on October 10 and October 3, respectively, with a tractor-pulled belt planter. In Year 2 at Location 1 and Location 2 the entries were planted on October 15 and October 7, respectively, with a tractor-mounted cone planter.

Plots at Location 1 received a preplant treatment of 34 kg/ha of P_2O_5 as superphosphate and 34 kg/ha of NH_4NO_3 in both years, followed by a topdressing of 100 kg/ha of NH_4NO_3 in March.

Characters Evaluated

Observations were recorded on each plot. Characters measured were: (a) grain yield per plot, (b) kernel weight, (c) tiller number, (d) heading date and (e) plant height.

Grain Yield

Yield was determined by weighing the threshed grain from two 2.4 m rows which were prepared by discarding 30 cm from the end of each of the two rows. Yield was recorded as grams per plot but was converted to kg/ha for statistical calculations. Graphic representations for yield were shown as quintals per hectare.

Kernel Weight

Kernel weight was determined by weighing 200 kernels taken at random from the threshed yield sample collected from each plot. This trait was expressed as grams per 200 kernels.

Tiller Number

Tiller number was determined by counting the number of tillers in a 30 cm section of row selected at random in each of two rows in each plot. Tiller number was expressed as the average number of seed bearing tillers per 30 cm^2 area. This figure was obtained by averaging the two counts from each plot.

Kernels per Spike

The three yield components, tiller number, kernel weight and kernels/spike, when measured without error, account for total grain yield. In the present study, kernels/spike was not measured directly. Values for this character were calculated by the following formula: Yield (grams/plot) ÷ tiller number (number/30 cm^2 x 16) x average kernel weight in grams.

Heading Date

Heading date was used as a measure of relative maturity in a comparison of parents to both the F_1 and F_2. Heading date was recorded as the number of days from April 1 to the time when approximately 75 percent of the heads in the plot had emerged from the boot.

Plant Height

Plant height was recorded in cm from ground level to the top of the awns when held upright. This measurement consisted of an average of two readings per plot.

Statistical Analysis

An analysis of variance was conducted for the following: combined years and locations; and an analysis of rates and genotypes in years and locations for yield, kernel weight and tiller number. Significance among mean squares was denoted by a single asterisk (*) for the .05 level of probability and by a double asterisk (**) for the .01 level of probability.

Duncan's Multiple Range test was used to determine significant differences for yield among seeding rates within genotypes. LSD values at the .01 probability level were used to determine significant differences for yield among genotypes within seeding rates.

Analysis of variance was not conducted for plant height and heading date but mean values for these characters are presented.

CHAPTER IV

RESULTS AND DISCUSSION

Yield and components of yield were measured and analyzed in an attempt to determine if reduced seeding rates could be used to lower seeding costs for hybrid wheat and at the same time maintain profitable levels of production. This study was also conducted to measure the performance of hybrid generations in comparison to parental lines at various population levels and to determine the feasibility of using the F_2 generation as a source of commercial planting seed.

As indicated by the mean yields of P_1 (Agent), average growing conditions prevailed at three of the tests while above average conditions were encountered at the fourth test.

The mean yields of the P_1 were as follows:

Location 1 (Stillwater), Year 1 = 2292 kg/ha (34.2 bu/a)

Location 1 (Stillwater), Year 2 = 2358 kg/ha (35.1 bu/a)

Location 2 (Woodward), Year 1 = 3732 kg/ha (55.6 bu/a)

Location 2 (Woodward), Year 2 = 2477 kg/ha (32.4 bu/a)

Light infections of leaf rust were present at both locations in both years. There were no serious problems with insects, logding or shattering.

Yield

The combined analysis of variance for yield indicated that there was a significant difference among seeding rates (Table I). Neither the first order interaction or rate by year nor rate by location interaction was statistically significant. The second order interaction of rate by year by location was significant.

An analysis of individual tests in locations, by years (Table II) showed a significant difference among seeding rates at Stillwater (Location 1) in both years but failed to show any statistical difference among seeding rates at Woodward (Location 2) in either year.

An examination of seeding rate means over individual tests (Table III) showed that yields increased slightly with increased seeding rates from rate 1 through rate 3, then decreased slightly from Rate 4 through 5. However, there is considerable fluctuation of yield at the various seeding rates when individual tests are examined.

There was little difference in yield among genotypes in Year 1 (Figure 1a) or Year 2; however, yields in Year 2 were considerably lower than Year 1. Seeding rate 4 (67 kg/ha) produced the highest yield in Year 1 but dropped to fourth place in Year 2.

Seeding rate by location data (years combined) (Figure 1b) revealed that yield did not vary greatly among seeding rates at either location. There was considerable difference in yields between locations, with yields at Location 2 registering much higher. Seeding Rate 2 (34 kg/ha) produced the lowest yield at Location 1 but registered the highest yield at Location 2. Rate 5 (84 kg/ha) produced the highest yield at Location 1 but fell to fourth place at Location 2.

Yield response to seeding rate studied at Locations 1 and 2 in Year 1 (Figure 2a) revealed much lower yields at Location 1 than at

Location 2. Seeding rate 1 which produced the highest yield at Location 1 produced the lowest yield at Location 2. Much the same was evidenced in Year 2 where rates 1 and 2 produced the lower yields at Location 1 but ranked highest at Location 2 (Figure 2b). Rates 3, 4 and 5 ranked highest at Location 1 but scored lowest at Location 2. Yields were not greatly different at either location but yields produced by seeding rates 1 and 2 tended to be more nearly the same at both locations while seeding rates 3, 4 and 5 tended to produce similar yields at the same locations.

The combined analysis of variance for yield (Table I) indicates a significant difference among genotypes as well as genotypes by year, genotype by location and genotype by year and location. Genotype by rate interaction was not statistically significant. Genotype by rate by year also indicated a significant interaction as did genotype by rate by location, while the third order interaction genotype by rate by year by location was not significant.

In sixteen comparisons involving genotypes (Table II), all but one were statistically significant. This one was the F_2 vs other genotypes contrasted by Location 2, Year 2. On the basis of the individual test analysis there was only one significant interaction involving genotypes by rates. This was the genotype by rate interaction at Location 1 in Year 1.

Combined over tests and seeding rates the F_1 (A-Agent x R92-25) produced the highest yields (Table III). Next in order were P_1 (Agent), F_2 and P_2 (R92-25). The F_1 exceeded all other genotypes for yield in three of four tests, each consisting of five seeding rates. P_1 ranked higher than the F_1 at Location 1 in Year 1.

Response patterns for yield of genotypes, averaged across seeding rates and locations, indicate that yields were slightly higher in Year 1 than in Year 2 (Figure 3a). Both years had similar response patterns with highest to lowest yield ratings being F_1, P_1, F_2 and P_2. Genotype response patterns were similar at both locations when averaged across seeding rates and years (Figure 3b). Again, the highest to lowest ranking was F_1, P_1, F_2, P_2.

In individual tests where yield was averaged across seeding rates (Figure 4a), P_1 exceeded the F_1 for yield in Year 1 at Location 1 while in Year 1 Location 2 the F_1 exceeded P_1. Genotype response patterns were similar for both locations in Year 2 (Figure 4b).

Figure 5 shows response patterns for yield of individual genotypes at each seeding rate at each location in each year. In the combined analysis of variance (Table I) the genotype by rate interaction was not significant. It was significant, however, for Location 1, Year 1 (Table II). This interaction is shown in Figure 5a where the response of the F_1 to seeding rate 3 was particularly striking. This drop to last place at rate 3 cannot be explained. Yields for all four replications of the F_1 in this test at seeding rate 3, Location 1, Year 1 were exceptionally low. Yields tended to rank from highest to lowest in the following order: F_1, P_1, F_2, P_2, with P_2 being consistently the lowest. A slight increase in yield followed a seeding rate increase. Yields for genotypes at Location 2 in Year 2 tended to decrease with increased seeding rates.

One of the objectives of this study was to determine the lowest, economically feasible seeding rate for the F_1 (to offset the probable higher cost of F_1 seed).

Examination of individual tests (Table III) shows that the F_1 had a significantly lower yield at seeding rate 3 at Location 1 in Year 1, but no difference at rates 1, 2, 4 and 5. At Location 1 in Year 2 the F_1 did not differ significantly at seeding rates 2, 3, 4 and 5 but rate 1 was significantly lower for yield response than rates 3 and 5. There was no significant difference for yield of the F_1 at rates 2, 3, 4 and 5 at Location 2 in Year 1; however, rate 1 was significantly lower than rates 2 and 4. At Location 2, Year 2 the F_1 did not differ significantly in yield at rates 1, 2 and 3 but rates 4 and 5 were significantly lower than rate 2.

In general, seeding rate 3 (50 hg/ha) was not significantly different from the highest yield-seeding rate combination in the test.

In every comparison except one (Location 1, Year 1) the F_1 exceeded the yield of the F_2 and in many of these comparisons the difference was statistically significant as compared by the LSD value and Duncan's Multiple Range Test (Table III). At each seeding rate averaged over years and locations, the F_1 exceeded the F_2 for yield by 18, 21, 7, 18 and 23 percent, respectively, at seeding rates 1, 2, 3, 4 and 5.

Tillers

Seeding rate had a significant influence upon tiller number per unit area when data from two years, two locations, five seeding rates and four genotypes were analyzed (Table IV). This finding was verified when data were analyzed by year and location (Table V). Location 1 in Year 1 failed to show a significant interaction with seeding rate for tiller number. The greatest tiller number tended to be expressed at the highest seeding rates (Figure 6).

Genotype had little effect upon tiller number with the two parents, P_1 and P_2, being significantly different from each other at only one location in one year.

Kernel Weight

Seeding rate was responsible for a significant variance at only one location in one year (Table VII). Genotype was most responsible for a significant effect upon kernel weight (Table VI). There was also a genotype by year interaction which had a significant influence upon kernel weight.

The F_1 entry was not significantly different from either of its parents at Location 1 in Year 2. Genotype by seeding rate interaction failed to have any significant effect on kernel weight at any location in any year.

The F_1 tended to express the greatest kernel weight of all entries over all seeding rates (Figure 7) followed by P_1 and F_2. The P_2 entry was consistently lowest in kernel weight except for Location 2, Year 2 (Figure 7d).

Kernels/Spikes

No analysis of variance was conducted for the variable, kernels/spike. This trait was not measured. Means shown in Figure 8 were calculated by formula from the variables yield, tillers and kernel weight. Any variance that might be shown for kernels/spike would be reflected in variances expressed in the three measured traits mentioned above. The derived means (Figure 8) are considered useful as a tool for further evaluation of genotypic performance at various seeding rates in years and locations.

Kernels/spike tended to be higher at the lower seeding rates for all entries which is similar to findings of at least one other researcher (4). The F_1 was exceeded in kernels/spike by P_1 over all seeding rates at all locations in all years (Figure 8). In Location 2, Year 2, the kernels/spike of the F_1 generation was exceeded by both the P_1 and F_2 entries for all seeding rates except the highest where kernels/spike for the F_1 was slightly more than the F_2. At all other locations and years the F_1 and F_2 were intermediate and followed the approximate same pattern of expression for kernels/spike. The P_2 ranked lowest in kernels/spike on most occasions. At Location 2, Year 1, the P_2 entry exceeded the F_1 entry for kernels/spike, at seeding rates 3 and 4. At Location 1, Year 1, the P_2 entry exceeded all other entries at seeding rate 2 and exceeded the F_2 at seeding rate 1.

Plant Height

Means for plant height are presented in Table IX. This character is often used as a measure of heterosis when comparing F_1 and F_2 generations to parental lines.

The F_1 in this study expressed no striking difference in plant height when compared to the taller parent, P_1. The F_1 generation and P_1 approximated each other for plant height at all locations in all years. The F_2 followed the same pattern of expression for plant height as the F_1 and P_1 entries at Locations 1 and 2 in Year 1 but resembled the shorter parent P_2 at Locations 1 and 2 in Year 2.

Differences expressed by either of the hybrids were not indicative of a high level of heterosis.

Heading Date

Differences in heading date were much more marked when measured between years and locations than when measured between genotypes in any given year at any location (Table IX). The greatest difference was between years at locations with genotypes heading approximately one week later in Year 1 than in Year 2 at both locations.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were: (a) to determine the performance of a male sterile by restorer F_1 hybrid, the F_2, and the two parental cultivars for yield and the components of yield (tiller number, kernel weight and kernels/spike), (b) to determine the lowest feasible seeding rate for the F_1 hybrid and (c) to determine the level of inbreeding depression in the F_2 which would indicate its usefulness as a source of commercial seed.

The parental cultivars for this study were chosen for adaptability to Oklahoma growing conditions and levels of fertility restoration. The F_1 hybrid was produced by a cross of cytoplasmic male-sterile "Agent" (A-Agent) and a restorer (R92-25). Both the sterility and restoration factors were derived from _T. timopheevi_. The four genotypes were F_1, F_2, P_1 (Agent) and P_2 (R92-25).

This study was conducted at two locations over a period of two years. Plots consisted of two, 3 m rows, spaced 30 cm apart and were replicated four times. A split-plot design was used with main plots consisting of seeding rates and sub-plots consisting of genotypes. Five seeding rates were chosen.

Seeding rate 1 = 17 kg/ha (15 lbs/A)
Seeding rate 2 = 34 kg/ha (30 lbs/A)
Seeding rate 3 = 50 kg/ha (45 lbs/A)
Seeding rate 4 = 67 kg/ha (60 lbs/A)
Seeding rate 5 = 84 kg/ha (75 lbs/A)

These rates were chosen to represent the range of seeding rates possible in the growing areas where the study was conducted. The lowest rate is 25 percent of the normal seeding rate while the highest is 125 percent of normal.

Characters evaluated were yield and the components of yield (tiller number, kernel weight and kernels/spike). Plant height and maturity date were observed and recorded but were not evaluated statistically.

Seeding rate was responsible for a significant difference in yield when averaged over years, locations, rates and genotypes. However, seeding rate by year or seeding rate by location interactions were not significant for combined data. Individual tests, however, indicated a significant difference for yield among seeding rates in Location 1 in both Years 1 and 2. Seeding rate, when applied to a specific genotype, was not a significant factor in yield.

Genotypes were responsible for a significant difference in yield at both locations in both years. The only genotype by seeding rate interaction on an individual test basis was at Location 1, Year 1 where the F_1 reacted markedly to seeding rate 3. This reaction could not be explained.

Data for yield (rates, locations and years combined) reveals that the F_1 was the highest yielding genotype followed by P_1, F_2 and P_2, respectively. Yield of the F_1 was 106 percent of the high parent, P_1, while yield of the F_2 was only 90.4 percent of the high parent. The F_2 yield was only 85.3 percent of the yield of the F_1. The P_2 genotype was considerably below the F_1, P_1 and F_2 in yield which was expected because of its lack of adaptability to Oklahoma growing conditions.

The relatively low level of heterosis exhibited by the F_1 (106 percent of P_1) in this study is not of the magnitude generally believed necessary for economical production of hybrid wheat. No doubt superior hybrid combinations exist and will be found. The poor performance of the F_2 in comparison to the F_1 obtained in this study indicates a high level of inbreeding depression which would tend to remove it from consideration as a source of commercial planting seed.

The components of yield (tiller number, kernel weight and kernels/spike) were not influenced greatly by seeding rates. Most of the variance for yield associated with these factors was contributed by genotypes. The greatest number of tillers tended to be produced at the higher seeding rates for all genotypes. The highest kernel weights were produced at the lower seeding rates and the greatest number of seeds per spike also tended to be produced at the lower seeding rates. The F_1 ranked highest in kernel weight and tiller number when means were averaged over rates, years and locations but was exceeded by P_1 in number of seeds per spike. The F_1 produced its heaviest kernel weights and greatest number of seeds per spike at the lower seeding rates which would indicate the possibility of lower than normal seeding rates for the F_1 without sacrificing yield.

The F_2, P_1 and P_2 produced their highest total yield at rate 3 while the F_1 produced its highest total yield at rate 2 (combined locations and years); however, there was a decline in yield at rate 3 for the F_1. Based on general situations, rate 3 was an effective planting rate for F_2, P_1 and P_2, and the data indicates that the F_1 could be seeded at a slightly lower rate of 34 kg/ha (30 lb/A).

The scope of this test was preliminary in nature to study the performance of a male-sterile x restorer hybrid and determine the feasibility of reduced seeding rates for male-sterile x restorer hybrid generations. These findings indicate that reduced seeding rates for the F_1 generation may be a means for lowering seeding costs of hybrid wheat.

TABLE I

COMBINED ANALYSIS OF VARIANCE FOR YIELD OF FOUR GENOTYPES GROWN AT TWO LOCATIONS FOR TWO YEARS AT FIVE SEEDING RATES

Source of Variation	D.F.	Mean Square	F
Rate	4	864,665	5.29**
Rate x Year	4	403,356	2.46
Rate x Location	4	173,890	1.06
Rate x Year x Location	4	662,503	4.05**
Error B	48	163,346	
Genotype	3	8,698,927	138.66**
Genotype x Year	3	503,274	8.02**
Genotype x Location	3	178,401	2.84**
Genotype x Year x Location	3	1,281,411	20.42**
Genotype x Rate	12	93,414	1.48
Genotype x Rate x Year	12	209,188	3.33**
Genotype x Rate x Location	12	157,599	2.51**
Genotype x Rate x Year x Location	12	103,400	1.65
Error C	180	62,734	

**Significant at probability .01

*Significant at probability .05

TABLE II

INDIVIDUAL YEAR AND LOCATION ANALYSIS OF VARIANCE FOR YIELD OF FOUR GENOTYPES AT FIVE SEEDING RATES

		Location 1				Location 2			
		Year 1		Year 2		Year 1		Year 2	
	d.f.	m.s.	F	m.s.	F	m.s.	F	m.s.	F
Rate	4	284.2	4.40*	931.6	11.18**	462.4	2.17	426.2	1.46
Error A	12	64.5		83.3		212.3		293.3	
Genotypes	3	1941.9	24.89**	2611.7	37.04**	5358.1	101.54**	750.3	15.10**
F_2 vs Others		648.9	8.32**	1112.0	15.77**	2614.3	49.54**	197.4	3.97
F_1 vs P_1, P_2		2136.4	27.39**	1278.8	18.14**	429.6	8.14**	206.4	4.15*
P_1 vs P_2		4727.0	60.60**	2444.9	34.68**	7542.8	142.94**	1154.1	23.20**
Genotype x Rate	12	401.1	5.14**	31.1	.44	74.4	1.41	57.0	1.14
Rate x F_2 vs Others		59.7	.76	2.6	.03	7.6	.14	5.1	.10
Rate x F_1 vs P_1, P_2		301.6	3.87	2.0	.02	48.7	.92	.1	.00
Rate x P_1 vs P_2		39.8	.51	26.4	.38	18.1	.34	62.2	1.25
Error B	45	78.0		70.5		52.8		49.7	

**Significant at probability .01

*Significant at probability .05

TABLE III

COMPARISON OF MEAN YIELDS (kg/ha) OF FOUR GENOTYPES BY YEAR, LOCATION AND SEEDING RATE

Generation	Year 1 Seeding Rate 1	2	3	4	5	Av.	Generation	Year 2 Seeding Rate 1	2	3	4	5	Av.
Location 1													
F_1	2522a[1]	2213a	1386b	2260a	2300a	2136	F_1	2361c	2583abc	2939ab	2751abc	2980a	2723
F_2	2025ab	1560c	2065a	2045ab	1325c	1804	F_2	1843c	2072abc	2361a	2260ab	2240abc	2155
P_1	2320a	2179a	2408a	2146a	2408a	2292	P_1	2034d	2125cd	2549ab	2495abc	2576a	2358
P_2	1870a	1406b	1706ab	1332b	1708ab	1604	P_2	1500c	1648c	1890abc	2119ab	2166a	1865
Av.	2184	1840	1890	1946	1935		Av.	1937	2107	2435	2406	2491	
2/ LSD** between any two means at the same seeding rate = 530 kg/ha							LSD** between any two means at the same seeding rate = 504 kg/ha						
Location 2													
F_1	3800c	4271ab	4069abc	4284a	4022abc	4089	F_1	2253abc	2482a	2401ab	2011c	2051bc	2240
F_2	3336c	3820ab	3841a	3632abc	3659abc	3658	F_2	2179a	2038ab	1803b	1755b	1877ab	1930
P_1	3444c	3538c	3935ab	3955a	3787abc	3732	P_1	2361a	2327ab	1977b	2099ab	2119ab	2177
P_2	2630b	2724b	2899ab	3114a	2959ab	2865	P_2	1971ab	2112a	1863abc	1688bc	1544c	1838
Av.	3303	3588	3686	3746	3607		Av.	2191	2240	2011	1888	1900	
LSD** between any two means at the same seeding rate = 436 kg/ha							LSD** between any two means at the same seeding rate = 423 kg/ha						

1/ Means followed by the same letter are not significantly different (Duncan's Multiple Range .01 probability level). Read across only

2/ LSD** (.01 probability level) comparison applies to values within same seeding rate only.

TABLE IV

COMBINED ANALYSIS FOR TILLER NUMBER PER UNIT AREA OF FOUR GENOTYPES GROWN AT TWO LOCATIONS FOR TWO YEARS AT FIVE SEEDING RATES

Source of Variation	d.f.	Mean Square	F
Rate	4	419.1561	4.39**
Rate x Year	4	134.0359	1.41
Rate x Location	4	593.1516	6.22**
Rate x Year x Location	4	673.6047	7.07**
Error B	48	95.3193	
Genotype	3	401.6458	5.87**
Genotype x Year	3	216.6833	3.17*
Genotype x Location	3	132.1792	1.93
Genotype x Year x Location	3	131.0667	1.91
Genotype x Rate	12	98.7786	1.44
Genotype x Rate x Year	12	107.1964	1.56
Genotype x Rate x Location	12	91.1036	1.33
Genotype x Rate x Year x Location	12	56.0484	.82
Error C	180	68.3819	

**Significant at probability .01

*Significant at probability .05

TABLE V

INDIVIDUAL YEAR AND LOCATION ANALYSIS OF VARIANCE FOR TILLER NUMBER PER UNIT AREA OF FOUR GENOTYPES AT FIVE SEEDING RATES

Source	d.f.	Location 1 Year 1 m.s.	Location 1 Year 1 F	Location 1 Year 2 m.s.	Location 1 Year 2 F	Location 2 Year 1 m.s.	Location 2 Year 1 F	Location 2 Year 2 m.s.	Location 2 Year 2 F
Rate	4	299.6	1.88	775.8	15.15**	223.2	4.43*	521.2	4.30*
Error A	12	162.2		50.7		45.2		122.9	
Genotype	3	59.9	.84	546.8	5.85**	105.5	2.88	175.3	2.54
F_1 vs Others	(1)	24.1	.52	10.9	.11	31.1	.31	24.5	.36
F_1 vs P_1, P_2	(1)	78.1	1.22	232.8	2.48	90.3	1.42	1.2	.18
P_1 vs P_2	(1)	156.0	2.45	324.9	3.48*	46.2	.95	152.1	2.20
Rate x Genotype	12	76.8	1.20	126.0	1.34	42.4	.87	107.9	1.56
Rate x F_2 vs Others	(4)	13.6	2.13	40.7	.41	14.3	.29	14.5	.21
Rate x F_1 vs P_1, P_2	(4)	44.5	.70	25.5	.25	29.1	.61	34.4	.50
Rate x P_1 vs P_2		135.0	2.12	110.9	1.18	85.8	1.37	127.8	1.85
Error B	45	63.8		92.5		48.3		69.0	

**Significant at .01 probability level

*Significant at .05 probability level

TABLE VI

COMBINED ANALYSIS OF VARIANCE FOR KERNEL WEIGHT OF FOUR GENOTYPES GROWN AT TWO LOCATIONS FOR TWO YEARS AT FIVE SEEDING RATES

Source of Variation	D.F.	Mean Square	F
Rate	4	30.6045	3.99**
Rate x Year	4	11.5064	1.50
Rate x Location	4	35.4172	4.62**
Rate x Year x Location	4	25.1651	3.28*
Error B	48	7.6551	
Genotype	3	245.0811	67.98**
Genotype x Year	3	31.2490	8.66**
Genotype x Location	3	9.6478	2.67
Genotype x Year x Location	3	8.3778	2.32
Genotype x Rate	12	3.5083	.97
Genotype x Rate x Year	12	5.0019	1.38
Genotype x Rate x Location	12	1.3679	.37
Genotype x Rate x Year x Location	12	3.5062	.97
Error C	180	3.6056	

**Significant at probability .01

*Significant at probability .05

TABLE VII

INDIVIDUAL YEAR AND LOCATION ANALYSIS OF VARIANCE FOR KERNEL WEIGHT OF FOUR GENOTYPES AT FIVE SEEDING RATES

		Location 1				Location 2			
		Year 1		Year 2		Year 1		Year 2	
	d.f.	m.s.	F	m.s.	F	m.s.	F	m.s.	F
Rate	4	1.62	.21	8.32	1.11	4.70	.73	88.05	5.50**
Error A	12	.76		7.49		6.52		15.85	
Genotype	3	92.60	24.83**	37.35	7.25**	136.00	50.30**	28.40	9.79**
F_2 vs Others	(1)	41.52	10.33**	15.70	3.74*	65.06	24.00**	12.31	4.24*
F_1 vs P_1, P_2	(1)	91.79	24.19**	5.75	1.15	160.86	39.50**	39.98	13.70**
P_1 vs P_2	(1)	42.33	11.27**	47.31	9.24**	40.20	14.88**	.73	.29
Genotype x Rate	12	5.23	1.36	2.63	.52	3.29	1.22	2.22	.77
Rate x F_2 vs Others	(4)	.52	.13	1.00	.20	.53	.20	.13	.04
Rate x F_1 vs P_1, P_2	(4)	2.53	.68	1.01	.29	2.09	.77	1.28	.44
Rate x P_1 vs P_2	(4)	3.13	.81	2.64	.53	1.73	.64	3.38	1.16
Error B	45	3.82		4.99		2.70		2.92	

**Significant at .01 probability level

*Significant at .05 probability level

TABLE VIII

MEANS FOR KERNELS/SPIKE BY YEAR, LOCATION AND SEEDING RATE

Seeding Rate	Location 1, Year 1 Generation F_1	F_2	P_1	P_2
1	18.25	15.49	20.05	15.33
2	13.97	11.47	16.24	10.82
3	10.65	15.39	18.12	13.56
4	14.37	13.99	17.82	7.80
5	11.48	9.28	11.42	12.06
Av.	13.74	13.12	16.73	11.91

Seeding Rate	Location 1, Year 2 Generation F_1	F_2	P_1	P_2
1	16.47	14.41	18.03	14.70
2	15.46	17.12	16.80	13.81
3	16.73	16.04	19.92	15.72
4	14.82	16.54	17.16	11.24
5	16.24	16.54	16.67	13.18
Av.	15.94	16.13	17.72	13.73

Seeding Rate	Location 2, Year 1 Generation F_1	F_2	P_1	P_2
1	24.19	31.28	31.99	19.05
2	24.27	25.51	28.71	20.26
3	22.64	23.73	26.48	22.95
4	21.82	25.64	25.27	22.22
5	21.77	20.59	22.27	19.88
Av.	22.94	25.35	26.94	20.87

Seeding Rate	Location 2, Year 2 Generation F_1	F_2	P_1	P_2
1	12.34	16.49	16.35	14.90
2	14.31	14.44	15.49	16.03
3	14.94	11.37	16.44	13.06
4	12.66	12.92	14.04	11.64
5	12.70	12.87	12.50	10.96
Av.	13.39	13.62	14.98	13.32

TABLE IX

MEANS FOR PLANT HEIGHT (cm) BY YEAR, LOCATION AND SEEDING RATE

Location 1, Year 1

Seeding Rate	Generation F_1	F_2	P_1	P_2
1	105	105	105	103
2	106	105	106	96
3	100	104	111	95
4	105	102	112	95
5	104	102	107	94
Av.	104	104	104	97

Location 1, Year 2

Seeding Rate	Generation F_1	F_2	P_1	P_2
1	98	93	94	95
2	101	93	94	95
3	96	93	97	94
4	97	94	97	91
5	95	91	98	92
Av.	97	93	96	93

Location 2, Year 1

Seeding Rate	Generation F_1	F_2	P_1	P_2
1	108	108	110	98
2	112	110	113	102
3	114	111	114	104
4	114	114	118	104
5	114	110	113	95
Av.	112	111	114	101

Location 2, Year 2

Seeding Rate	Generation F_1	F_2	P_1	P_2
1	99	96	101	92
2	99	97	100	92
3	100	97	100	93
4	100	99	100	94
5	99	98	100	93
	99	97	100	93

TABLE X

MEANS FOR HEADING DATE* BY YEAR, LOCATION AND SEEDING RATE

Seeding Rate	Location 1, Year 1 F_1	F_2	P_1	P_2	Seeding Rate	Location 1, Year 2 Generation F_1	F_2	P_1	P_2
1	40	41	41	40	1	34	36	35	36
2	41	40	40	41	2	34	35	35	36
3	40	40	41	41	3	35	35	34	36
4	39	40	40	40	4	34	35	34	35
5	39	39	39	40	5	35	34	35	35
Av.	40	40	40	40	Av.	34	35	34	36

Seeding Rate	Location 2, Year 1 Generation F_1	F_2	P_1	P_2	Seeding Rate	Location 2, Year 2 Generation F_1	F_2	P_1	P_2
1	44	44	44	44	1	38	37	37	38
2	43	43	43	43	2	37	37	37	37
3	43	43	43	43	3	37	37	37	37
4	43	43	43	43	4	37	37	37	37
5	43	43	43	43	5	37	37	36	37
Av.	43	43	43	43	Av.	37	37	37	37

*Values indicate number of days from March 31 to 75 percent head exertion.

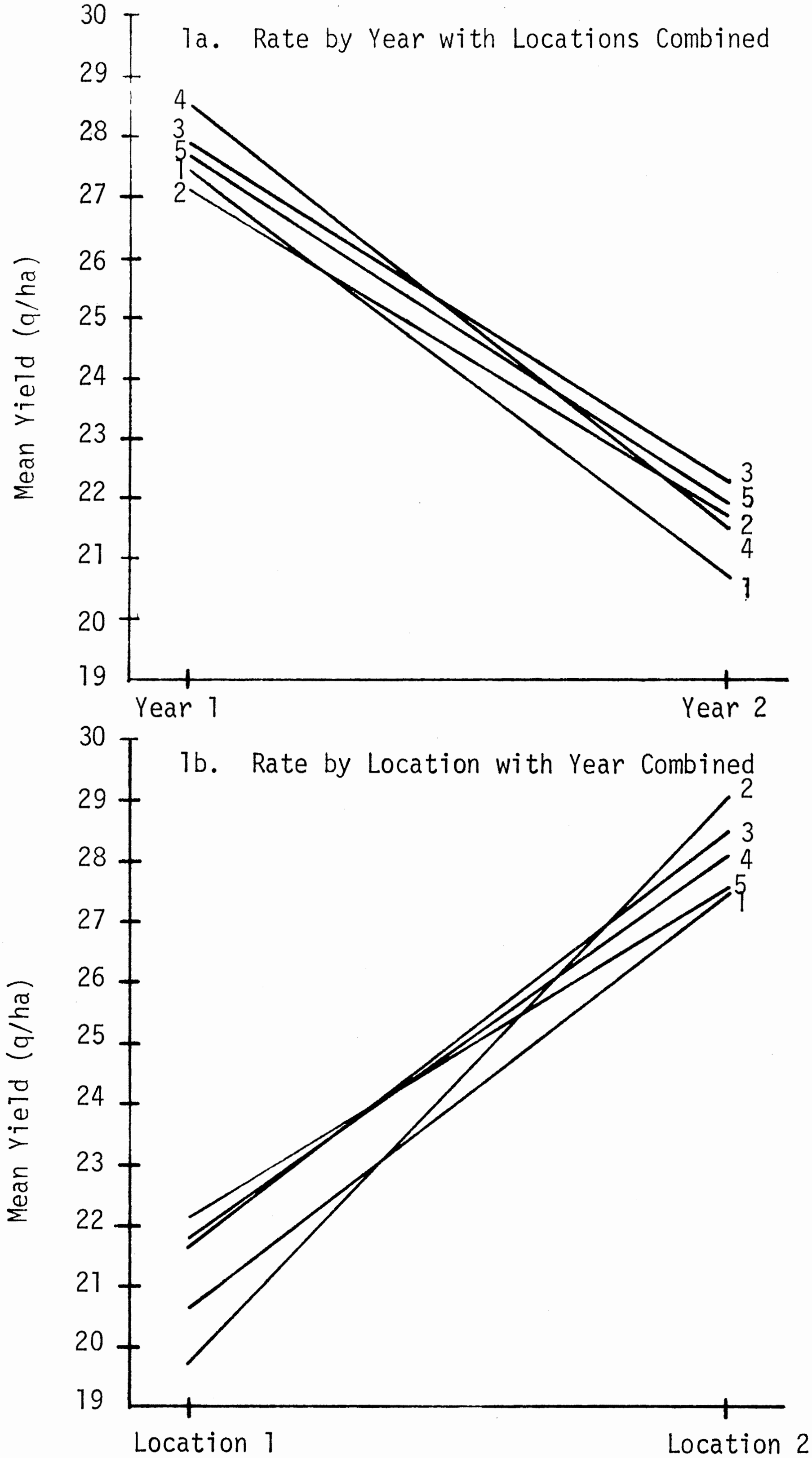

Figure 1. Grain Yield Relationship Among Five Seeding Rates in Years and Locations with Genotypes Combined

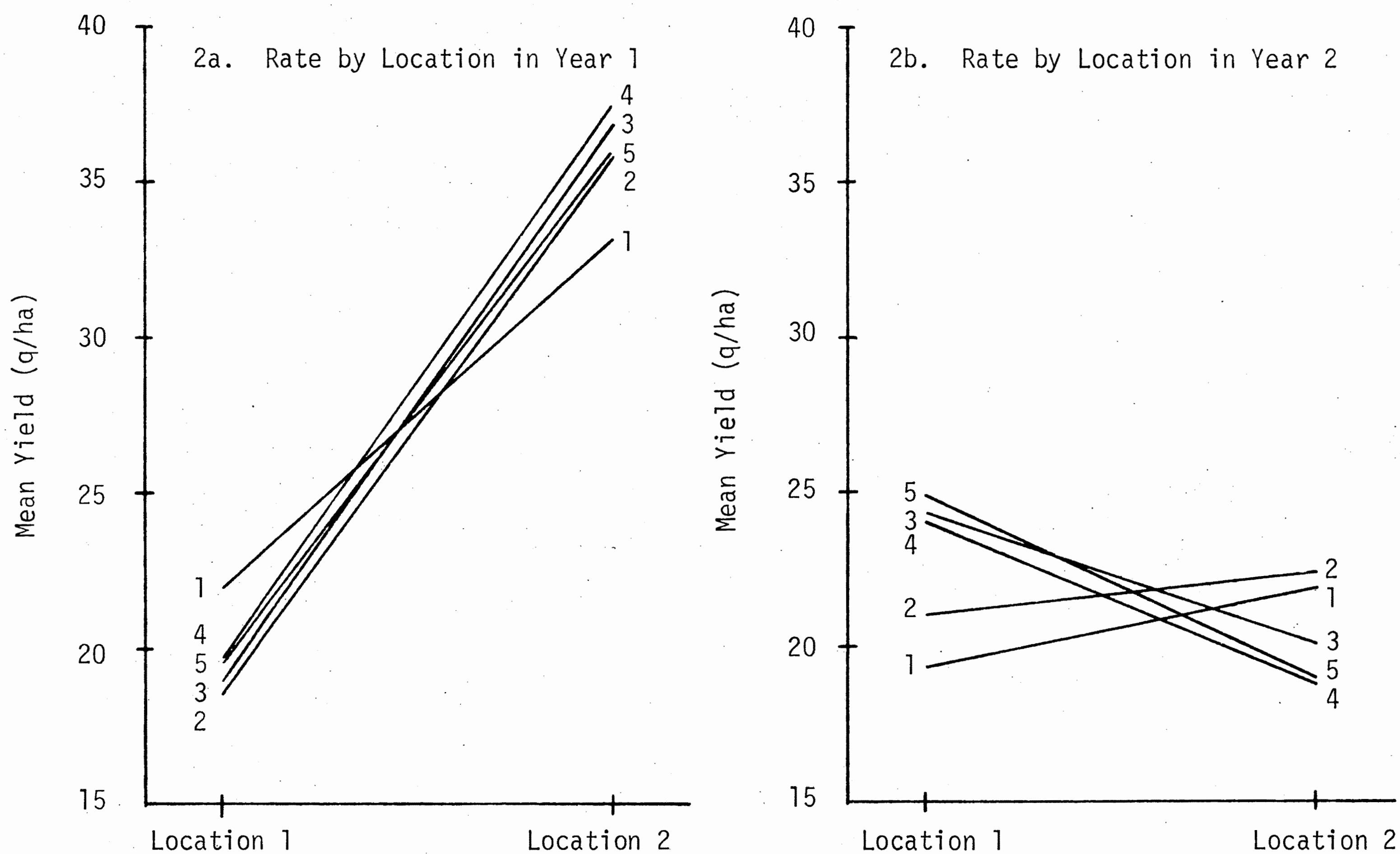

Figure 2. Grain Yield Relationship Among Five Seeding Rates in Individual Years and Locations with Genotypes Combined

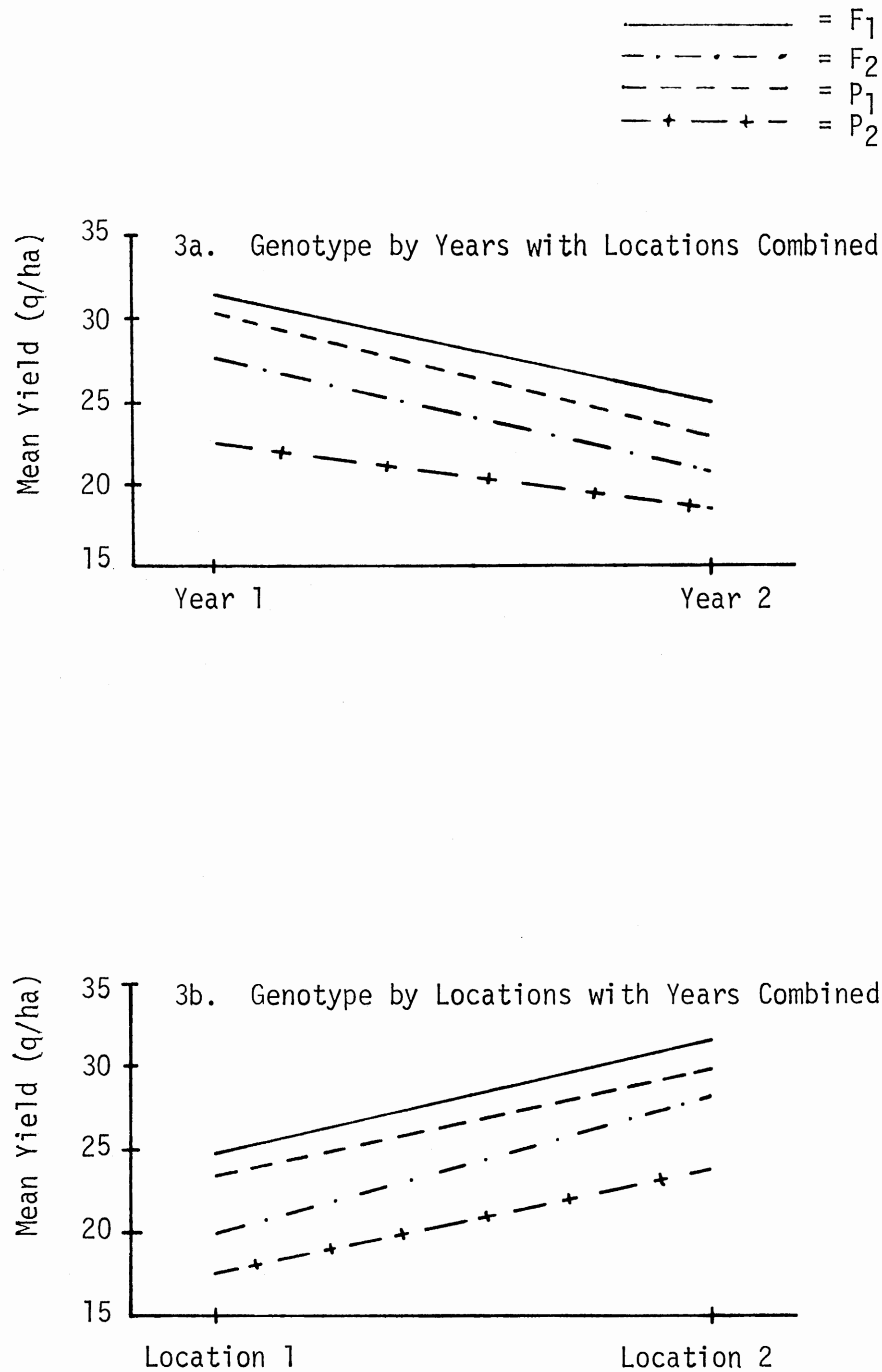

Figure 3. Grain Yield Relationship Among Four Genotypes in Years and Locations with Seeding Rates Combined

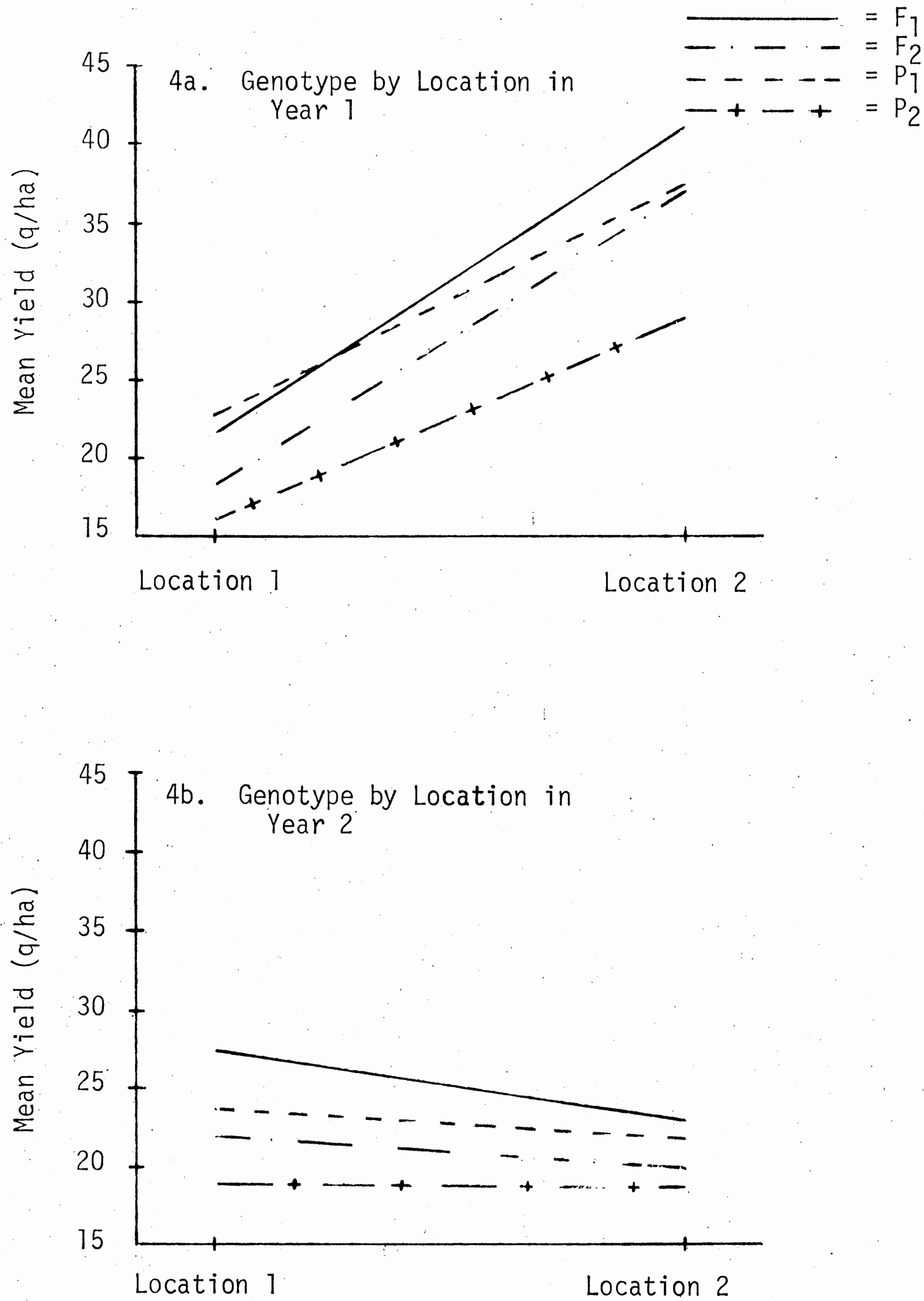

Figure 4. Grain Yield Relationship Among Four Genotypes at Locations in Years with Seeding Rates Combined

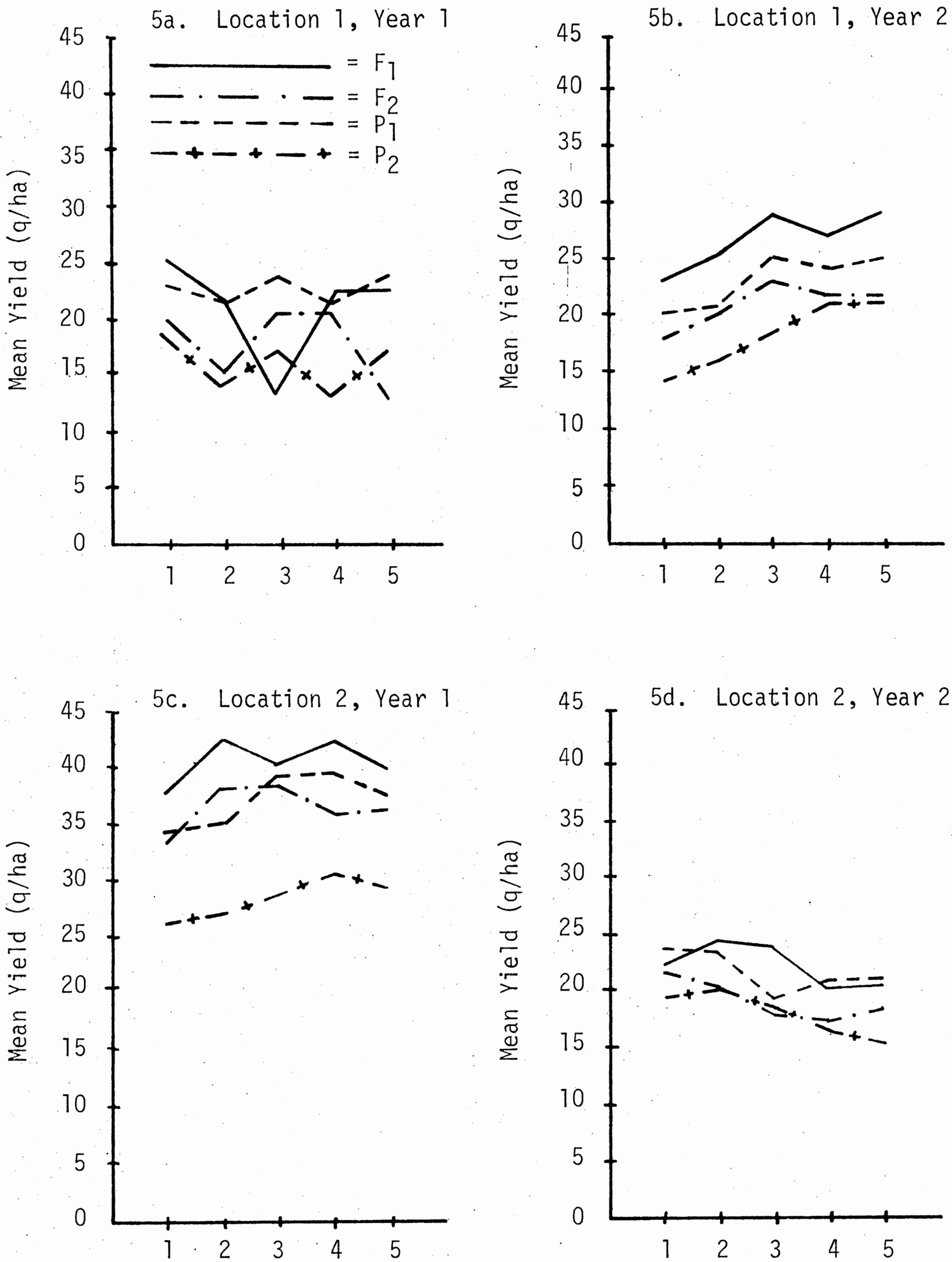

Figure 5. Grain Yield Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location

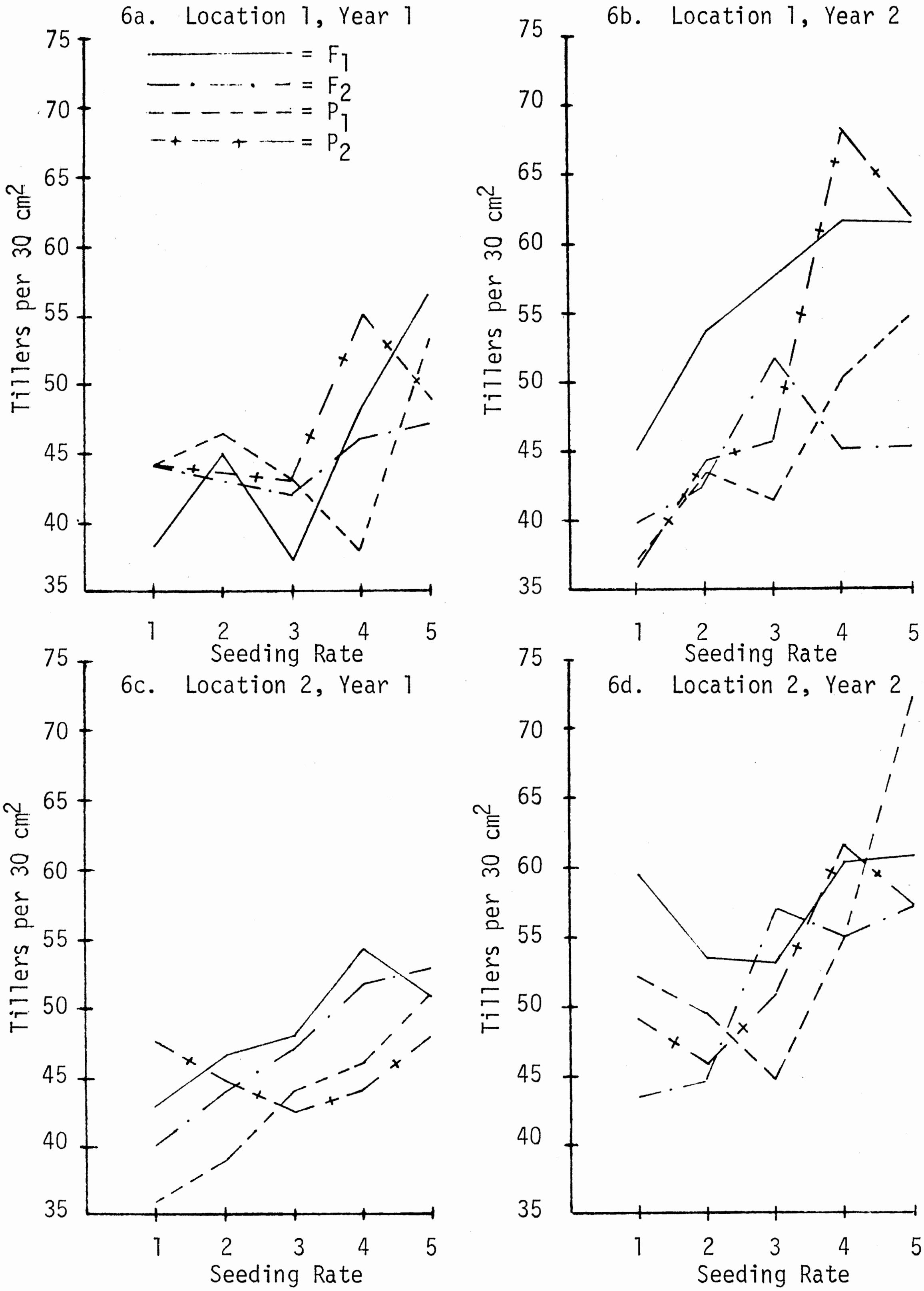

Figure 6. Tiller Number per Unit Area Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location

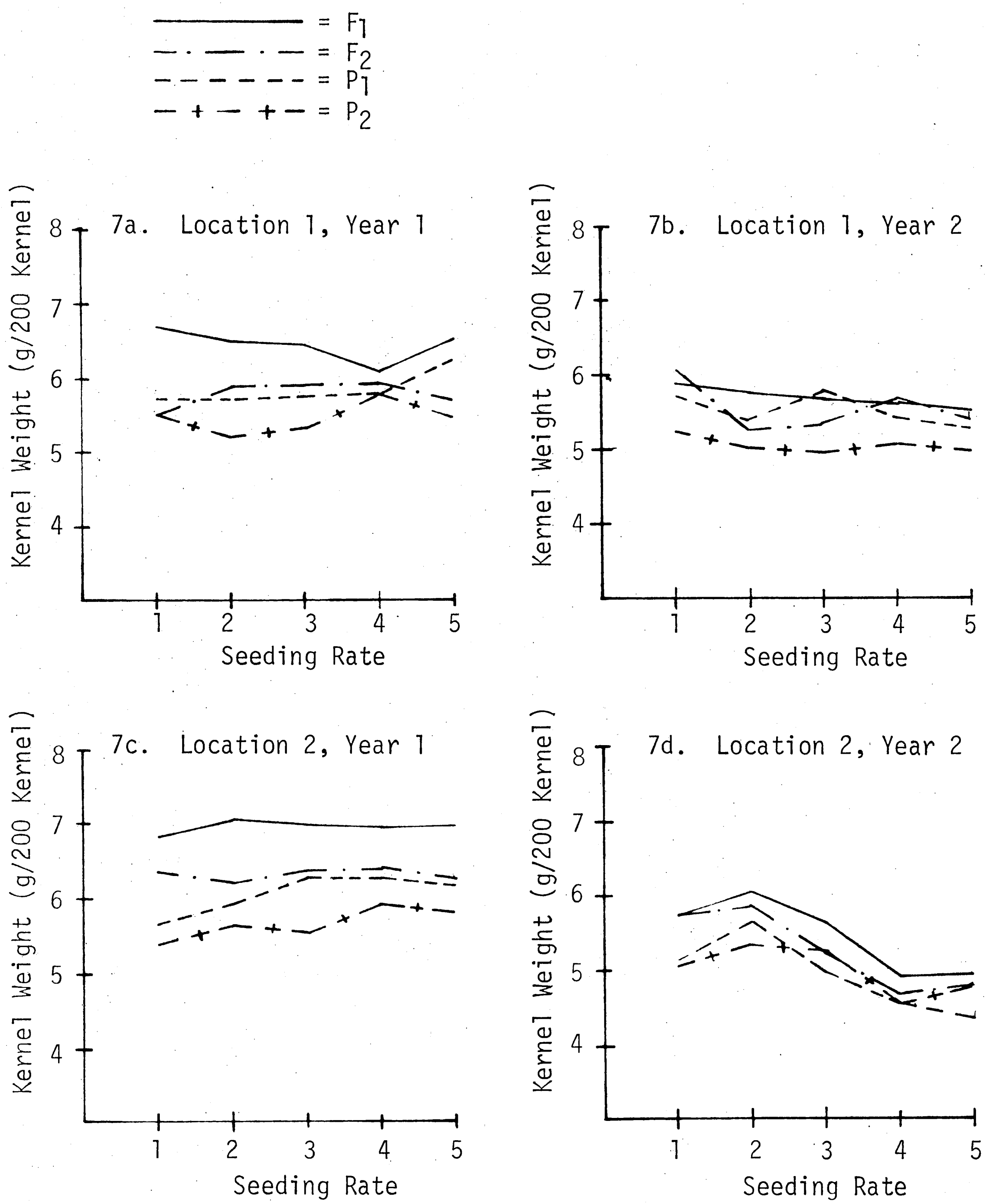

Figure 7. Kernel Weight Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location

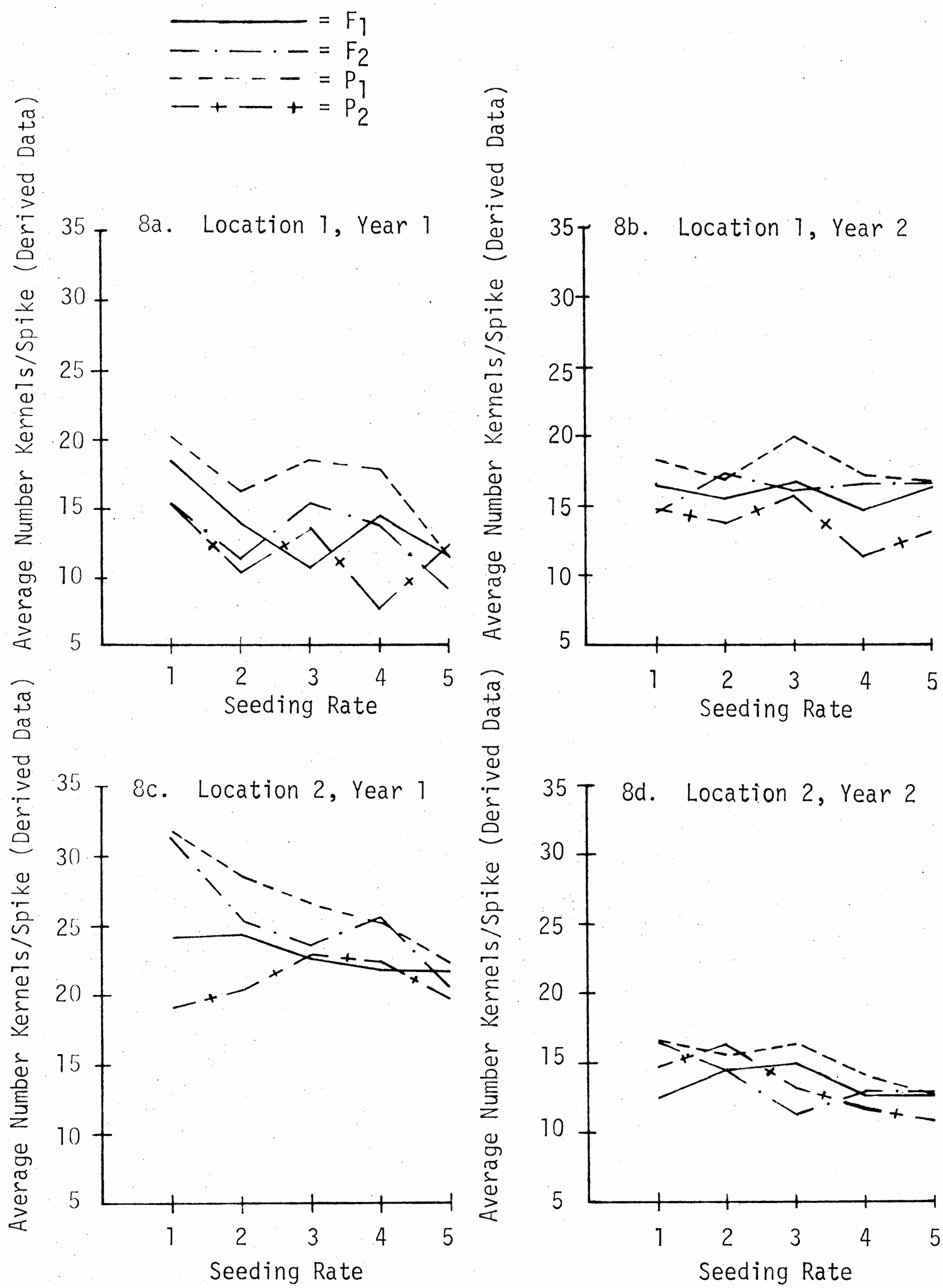

Figure 8. Kernels/Spike Relationship Among Four Genotypes at Five Seeding Rates by Individual Year and Location

LITERATURE CITED

1. Atkinson, A. 1917. Date and rate of seeding tests with spring grains under irrigation. Mont. Expt. Sta. Bull. 120.

2. Bleasdale, J. K. A. 1960. Studies on plant competition. Symp. Brit. Ecol. Soc. 1:133-142.

3. Briggle, L. W., R. J. Daum and Harland Stevens. 1964. Expression of heterosis in two wheat crosses. Crop Sci. 4:220-223.

4. Brown, C. M., R. O. Weibel and R. D. Seif. 1966. Heterosis and combining ability in common winter wheat. Crop. Sci. 6: 382-383.

5. Engledow, F. L. 1925. Investigations on yield in the cereals. II. A spacing experiment with wheat. J. Agr. Sci. 15: 125-146.

6. Fonseca, S. and F. L. Patterson. 1968. Hybrid vigor in a seven-parent diallel cross in common winter wheat. Crop Sci. 8: 85-88.

7. Glover, C. R. 1970. Heterosis and combining ability estimates of hybrids involving selected restorer and male sterile winter wheats. (Unpub. Ph.D. thesis, Oklahoma State University.)

8. Godel, G. L. 1935. Relation between rate of seeding and yield of cereal crops in competition with weeds. Sci. Agr. 16: 165-168.

9. Grantham, A. E. 1917. The tillering of winter wheat. Del. Agr. Expt. Sta. Bul. 117:21-33.

10. Gyawali, K. K., C. O. Qualset and W. F. Yamazaki. 1968. Estimates of heterosis and combining ability in winter wheat. Crop Sci. 8:322-324.

11. Holliday, R. 1963. The effect of row width on the yield of cereals. Field Crop Abstr. 16:71-81.

12. Jardine, W. M. 1938. Effect of rate and date of seeding on yield of winter wheat. J. Am. Soc. Agron. 30:610-615.

13. Johnson, V. A., K. J. Biever, A. Hanould and J. W. Schmidt. 1966. Inheritance of plant height yield of grain and other plant and seed characteristics in a cross of hard red winter wheat. Triticum aestivum L. Crop Sci. 6:336-338.

14. Kesselbach, T. A. and W. E. Lyness. 1948. Growing the winter wheat crop. Nebr. Agr. Exp. Sta. Bul. 389.

15. Kinra, K. L., H. D. Roth, L. S. Robertson and H. M. Brown. 1963. Effect of seeding rate, row spacing and rate of placement of fertilizer on winter wheat performances in Michigan. Agron. J. 55:24-27.

16. Lashin, M. and K. Schrimpf. 1962. Analysis of yield structure in winter wheat varieties, with particular reference to the yield determining factors. Field Crops Abstr. 16:83-85.

17. Locke, L. F., O. E. Ranchschwalbe and O. R. Matthews. 1928. The relations to yield of certain plant character determining yields in fields of winter and spring wheat. J. Am. Soc. Agron. 20:492-499.

18. Lucken, K. A. 1973. Comparative use of cytoplasmic male sterility-fertility restoration systems in hybrid-wheat breeding. Proc. 4th Intl. Wheat Genetics Sym. Columbia, Mo., pp. 361-366.

19. Martin, J. H. 1926. Factors influencing results from rate and date of seeding experiments with wheat in the western United States. J. Am. Soc. Agron. 18:193-225.

20. Montgomery, E. G. 1912. Competition in cereals. Nebr. Agr. Exp. Sta. Bull. 127.

21. Pal, B. P. and Nek Alam. 1938. The effect of certain external factors upon the manifestation of hybrid vigor in wheat. Proc. Indian Acad. Sci. 7:109-124.

22. Patterson, F. L. and M. J. Bitzer. Feb. 1966. Hybrid wheat research at Purdue University. Res. Prog. Rept. 22. Purdue Univ. Lafayette, Ind.

23. Peck, R. A. 1955. The reaction of four hard red winter wheat varieties in a composite. (Unpublished Master's thesis, Oklahoma Agr. and Mech. College, Stillwater.)

24. Quisenberry, K. S. 1928. Some plant characteristics determining yield in fields of winter and spring wheat. J. Am. Soc. Agron. 20:492-499.

25. Robertson, D. W., O. H. Coleman, J. F. Brandon, H. Fellows and J. J. Curtis. 1942. Rate and date of seeding winter wheat and the relation of seeding date to dry-land root rot at Akron, Colo. J. Agr. Res. 64:339-356.

26. Rosenquist, C. E. 1931. Hybrid vigor in Wheat. J. Amer. Soc. of Agron. 23:99-103.

27. Schmidt, J. W., V. A. Johnson and S. S. Mann. 1962. Hybrid wheat. Nebr. Exp. Sta. Quar. 9(3):9.

28. Seimens, L. B. 1963. The effect of varying rows spacing on the agronomic and quality characteristics of cereals and flax. Can. J. Plant Sci. 43:119-130.

29. Shebeski, L. H. 1966. Quality and yield studies in hybrid wheat. (*T. aestivum L.*) Can. J. Genet. Cytol. 8:375-386.

30. Sidwell, R. J. 1971. The performance of hybrids and various hybrid-parent mixtures of five sets of hard red winter wheat (*T. aestivum* L.) crosses. (Unpub. Master's thesis, Oklahoma State University.)

31. Smith, E. L., A. M. Schlehuber, H. C. Young, Jr. and L. H. Edwards. 1968. Registration of Agent wheat. Crop Sci. 8: 511-512.

32. Stickler, F. C. 1961. Row width and seeding rate as factors influencing winter wheat yields and components of yield. Trans. Kan. Acad. Sci. 64:1-6.

33. Wilson, J. A. and W. M. Ross. 1962. Male sterility interactions of the *T. aestivum* nucleus and *T. timopheevi* cytoplasm. Wheat Inf. Serv. No. 12:29-30.

34. Wilson, J. A. and W. M. Ross. 1962. Cross breeding in wheat, *Triticum aestivum* L., II: Hybrid seed set on a cytoplasmic male-sterile winter wheat composite subjected to cross pollination. Crop Sci. 5:415-417.

35. Woodward, R. W. 1956. The effect of rate and date of seeding of small grains on yields. Agron. J. 48:160-162.

VITA

Conrad L. Evans

Candidate for the Degree of

Master of Science

Thesis: PERFORMANCE OF THE F_1 AND F_2 GENERATIONS OF A MALE-STERILE X RESTORER WINTER WHEAT HYBRID AT FIVE SEEDING RATES

Major Field: Agronomy

Biographical:

Personal Data: Born in Nash, Oklahoma, January 6, 1927, the son of Russell and Elva Evans.

Education: Attended Canyon Ridge Elementary School and graduated from Nash High School in Nash, Oklahoma, in 1944. Attended Phillips University, Enid, Oklahoma; Central College, Fayette, Missouri; Rensselaer Polytechnic Institute, Troy, New York. Graduated from Oklahoma State University with a Bachelor of Science degree in Agronomy in 1950, completed requirements for the Master of Science degree in July, 1978.

Professional Experience: Farmer and rancher, 1949-1956. School teacher, Hennessey Public Schools, Hennessey, Oklahoma, 1955-1956. Oklahoma State University Ethiopia contract, 1956-1968. Director of Foundation Seed Stocks, Oklahoma State University, 1970-1973. Manager of Denison Peanut Company, Denison, Texas, 1973-1977. Administrative Associate, International Programs, Oklahoma State University, 1978 to present.