DESCRIPTIONS AND AGRONOMIC EVALUATIONS OF F_2 AND F_3 POPULATIONS OF TWO WHEAT CROSSES

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By

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OF F_2 AND F_3 POPULATIONS OF

TWO WHEAT CROSSES

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INTRODUCTION

The wheat breeder is always in quest of more desirable varieties of wheat. He may be looking for one specific character; although most generally he is searching for several characters such as higher yield, more desirable milling and baking qualities, insect and disease resistance, ease of mechanical harvesting, early to medium maturity and other desirable "agronomic" characters.

In most instances, these desired characters are not all present in one variety or species but are found in several varieties or species. It is then the responsibility of the plant breeder to obtain the varieties and species which contain the desired characters and make the appropriate crosses, striving to combine these desirable characters into one strain.

The wheat breeding program at the Oklahoma Experiment Station, of which this study was a part, is toward this goal.

Some of the experimental material of considerable importance are crosses of Triticum spp. X Agropyron elongatum (Host) Beauv., with high leaf rust resistance, backcrossed to common wheat Triticum vulgare Vill. This material is quite variable in rust reaction and other plant characters.

This study deals with the rust reaction and other plant characters of the crosses of Concho X Triticum spp.- Agropyron elongatum and (Timstein X Comanche F_1) X Concho.

REVIEW OF THE LITERATURE

Inheritance of Chaff Color

Biffen (3)[1] was among the first to report that red glumes are dominant over white and inherited in a monohybrid ratio. Since then, several authors, (10, 15, 17, 21, 30, 32, 34, 35, 36, 37, 40, 44, 50) have reported the inheritance of glume color on a one factor basis with red glumes being dominant over white.

In crosses between Kota and Hard Federation, Clark (7) reported there was evidence of a slight maternal effect in reciprocal crosses, there being more white-glumed plants when Kota was used as the female and more bronze-glumed plants when Hard Federation was used as the female than would be expected. Of 28 families which were classified as white in the F_2 generation that segregated in the F_3 generation, 19 families produced more white-glumed plants than bronze-glumed plants. The author thought, in spite of the several unexpected segregations and ratios in the F_2 and F_3 generations, there was no reliable evidence of more than one genetic factor involved in glume color in this specific cross. He thought the lack of a good fit to a monohybrid ratio was probably due to environment but that it could have been due to natural crossing and maternal effect. On the other hand, Clark and Hooker (8) in studies of the cross Marquis X Hard Federation found no evidence of maternal influence in reciprocal crosses although there were slight consistent differences in the percentages; however, in all cases the differences

/1 Figures in parentheses refer to "Literature Cited" page 46.

were not sufficiently large enough to be significant. They also explained their results on a monohybrid basis.

Stewart and Nelson (39) reported that in a cross of Sevier 59 X Ridit, the F_1 glume color was intermediate. In the F_2 and F_3 there were degrees of bronzing varying from the dark bronze of Sevier 59 to so light a bronze it was almost indistinguishable from the plants classed as white-glumed. They came to the conclusion that, although these two facts suggested incomplete dominance of the factors for bronze, the F_3 segregation seemed to prove the dominance of bronze chaff in a ratio of 1:2:1.

In reporting the work of Nilsson-Ehle involving crosses of some of the red-glumed Swedish "Landwheats," Percival (21) reported a dihybrid ratio, 15 red:1 white in the F_2 and that in the F_3, some of the plants classified as white in the F_2 segregated into red, pale red and white. He states, "Owing to the confusion between heterozygous white and pure white, the experimental results of segregation may not appear to conform to the ordinary 3:1 or 15:1 ratios." He then showed that the red glume color in these cases is not due to a single factor pair but to two separately inherited factors, each of which, when alone, produces a red tint that is not necessarily the same degree of intensity but when acting together, have a cumulative effect.

Inheritance of Awns

The literature dealing with the inheritance of awns in wheat, includes a number of different ratios. Some authors felt that awns were inherited on a monohybrid basis, others postulated they were inherited on a dihybrid basis and still others came to the conclusion that they were inherited on a trihybrid basis in various crosses of wheat.

One Factor Difference

As early as 1905 Biffen (3) stated, "The beardless condition is a dominant, the bearded a recessive character."

In crosses of bearded X tip-awned wheats, Howard and Howard (15) reported that the F_1's were intermediate and half awned and the F_2 segregated into a monohybrid ratio, while Percival (21) reported segregation in numerous crosses to approach a 1:2:1 ratio when intermediates occur. Several authors, (2, 11, 30, 32, 34, 35, 36, 39, 40, 41) using various varieties of wheat, have reported the inheritance of awns on a 1-factor basis.

Two Factor Difference

In crosses of beardless X bearded, Howard and Howard (15) reported the F_1's were tip-awned. By grouping together all of the plants which produced any degree of awns, they came to the conclusion that a dihybrid ratio would explain the data, with fully awned being the dominant character. Fully awned as the dominant character was also reported in a cross of Sevier X Federation by Stewart (33). He reported that two linked factors with 35 per cent crossing over would explain the inheritance of awns in this cross.

Crossing two awnletted varieties of wheat, Quisenberry and Clark (46) reported 5 per cent were awned and 13.2 per cent were completely awnless in the F_2, with segregation suggesting a two major factor difference, fully awned being the recessive character. They also reported the F_2 segregation of Sonora X Reliance could not be completely explained on a single major factor difference. Several authors (2, 8, 9, 10, 12, 36, 37, 44) have reported the inheritance of awns in various crosses of wheat on a 2-factor basis with fully awned the recessive character.

In the cross Kota X Hard Federation, Stewart and Judd (38) reported a 2-factor difference in the inheritance of awns while Clark (7), working with the same cross, could not entirely explain the inheritance of awns on a 2-factor basis. The difference came in the F_2 when Clark reported five true breeding awn classes and Stewart and Judd reported only four true breeding awn classes. According to Clark, the fully awned and short awned classes did not breed true in the F_3. He states, "Complete homozygosity for awned or awnless strains apparently is due to multiple factors."

Three Factor Difference

The inheritance of awns in a Hard Federation X Propo cross was reported by Clark, Florell and Hooker (9) to be on a 3-factor difference. They postulated two major factors and one minor factor.

After crossing many varieties and species, Watkins and Ellerton (48) stated, "Actually none of the awn genes are completely dominant or completely recessive." They believe the bearded type should receive the recessive symbol. They also came to the conclusion that there are five major genes which lead to the production of the major awn classes.

They denoted these genes with their phenotypes as follows:

B_1	Tipped 1
b_1^a	Half-awned (allelomorphic with B_1 and b_1)
B_2	Tipped 2
A	Half-awned
Hd	Hooded

They also stated that awn length of <u>Triticum</u> is affected by major and modifying genes and chromosome number.

In crossing Marquis and certain nullisomic lines from the Chinese variety, O'Mara (20) confirmed the work of Watkins and Ellerton (48). He reported the F_2 segregated into a full series of awn types from fully awned to completely awnless. The ratio obtained was a trihybrid with the homozygous triple recessive fully awned.

Agropyron Hybrids

Between 1932 and 1941, Lapchenko (18) reported *Agropyron glancum* and *Agropyron elongatum* had been crossed with over 200 different varieties of wheat. He stated that of these, the hybrids with *Agropyron elongatum* as a parent contained a larger proportion of perennial and wild types which he believed must be backcrossed to wheat at least 2 or 3 times before desirable types can be produced.

Morphological Characters of *Triticum* X *Agropyron* Hybrids

The F_1 of *Triticum* X *Agropyron* according to Cicin (6), is characterized by the absence of lethal characters, domination of *Agropyron* characters such as perennialism, type of roots, structure of ear, vigor of tillering, and the presence of self-fertile and self-sterile forms. The F_1 of crosses of *Triticum* X *Agropyron elongatum* were characterized by Armstrong (1) as perennial in habit and intermediate in character but tending toward the *Agropyron* parent.

In the segregation of the F_2 and following generations, Cicin (6) reported forms which resembled squareheaded, branched and other wheat types. Working on perennial wheats of *Triticum* X *Agropyron* parentage, Suneson and Pope (42) reported that none of their perennial derivatives were stabilized at the end of seven years, while Schmidt et al. (27)

observed three broad classes, vis., grass-like, intermediate and wheat-like in *Triticum* X *Agropyron* hybrids.

After observing some wheat X *Agropyron* crosses, Tzitzin (45) stated, "Some of the hybrids proved to be of an uncommon degree of drought resistance, tolerance of various different kinds of drought being observed among them."

Backcrossing *Triticum* X *Agropyron* Hybrids with Wheat

After backcrossing *Triticum* X *Agropyron elongatum* to Marquis and Turkey in the F_1 and F_2, Armstrong (1) reported the winter survival was decreased and the fertility was increased while with *Triticum* X *Agropyron* hybrids backcrossed to wheat, White (49) reported the number of annual forms were increased and the winter survival was reduced. He also reported transgressive segregation of awns in the F_2 and F_3.

Reitz et al. (22) reported two annual strains of *Triticum* spp. X *Agropyron elongatum* backcrossed to wheat have been grown in the nursery for several years. They stated that although neither strain has yielded as much grain or forage per unit area as has the Turkey check, one of the strains looks very much like common wheat in plant characters and survives the winter with good stands.

Disease Resistance

After testing *Agropyron elongatum* and two F_3 lines of *Triticum vulgare* X *Agropyron elongatum* to leaf rust races 5, 9, 15, 28, and 37, Johnston (16) reported that all of the *Agropyron elongatum* showed an immune reaction, while the two hybrids exhibited near immunity to all of the leaf rust races used in the test. The wheat parent of the hybrids was resistant to race 9.

In crossing Apex and Thatcher with perennial wheat for stem rust resistance, Shebeski and Wu (29) reported three complementary factors controlling resistance in both cases. The resistance of perennial wheat was the dominant character.

Schmidt (26) reported that a high degree of resistance to *Septoria tritici* is evident in the *Triticum* X *Agropyron* hybrids he studied.

Inheritance of Spike Density

According to Boshnakian (4), squareheadness is a quantitative character. He believes it is a result of a combination of growth characters and shows a complex mode of inheritance. To determine the coefficient of squareheadedness, he divided the number of rachis internodes in the terminal third of the rachis by the number of internodes in the central third. Spike density was defined as the average internode length.

Hayes and Garber (13) in reporting the work of Nilsson-Ehle involving crosses between compact and middense wheats stated that the F_2 segregated for compact, middense, and lax. Nilsson-Ehle assumed the dense form had the genetic compositon $CCL_1L_1L_2L_2$ in which the C factor was thought to inhibit the expression of the lengthening factors L_1 and L_2 and also to produce spikes with short internodes.

In a cross of Dicklow X Servier, Stewart (35) reported that a monohybrid ratio would explain the inheritance of spike density. However, there seemed to be some tendency toward transgressive segregation in both directions. Several other authors (24, 36, 37, 39, 41) have reported the inheritance of spike density on a monohybrid basis.

Inheritance of Resistance to Leaf Rust

According to Chester (5) resistance to leaf rust is inherited in a single Mendelian fashion when hybrids from pure lines of wheat are tested with pure races of leaf rust. He reported a number of crosses in which resistance to certain races is a recessive character on a monohybrid basis and an equal number of crosses in which the resistance depended on a single dominant character. Resistance may be dependent on a single hereditary factor in several vulgare crosses Sax (23) reported. In species hybrids, many factors, acting either directly or indirectly, may influence the physiologic balance which determines resistance and susceptibility, he stated.

In inheritance studies using leaf rust races 9, 12, and 45 on F_2 and F_3 hybrid material, Schlehuber (25) reported resistance to race 9 could be explained by a single recessive factor pair in 4 crosses. Using races 12 and 45 the mode of inheritance could not be determined.

In crossing two susceptible varieties, Swenson, Buchholtz and Grafius (43) reported a resistant F_1 which they attributed to complementary gene action. The F_2 and F_3 segregation was reported to be in a dihybrid ratio. Transgressive segregation for resistance to leaf rust in the F_2 was reported by Wismer (51) in a cross of two susceptible varieties, indicating both parents carry factors for resistance. Certain groups of F_4 lines from particular F_3 lines were uniformly resistant while others were uniformly susceptible. The mode of inheritance of resistance was explained on a multiple factor basis.

The resistance of Kanred may depend on several factors according to Mains, Leighty and Johnston (19), while Hayes, Parker and Kurtzweil (14) came to the conclusion that linkage prevents the free assortment of rust resistant factors in crosses of Emmer X *Triticum vulgare*.

MATERIALS AND METHODS

Experimental Materials

The seed of two F_1 plants from the cross Concho X Triticum spp.- Agropyron elongatum, designated as plants 5731-2 and 5731-3, and the seed of two F_1 plants of the cross (Timstein X Comanche F_1) X Concho were used in this study. Comanche C.I. 11673,[2] Ponca C. I. 12128, and Concho C.I. 12517 were included as comparison varieties.

The Triticum spp.- Agropyron elongatum which was used as one of the parents was tip-awned, white-chaffed and fusiform headed.

Timstein, C.I. 12347, is a cross of Triticum timopheevi and Steinwedel, a soft white Triticum vulgare. It is a spring wheat that is white-chaffed, awnletted and white seeded. The variety is resistant to most races of stem rust.

Comanche is a fifth generation selection from a cross of Oro X Tenmarq Selection. It is white-chaffed, fully awned, medium in maturity and possesses desirable "agronomic" characteristics. The variety has marked resistance to bunt and moderate resistance to several races of leaf rust. It is more winter hardy than Ponca and is widely adapted to the Southern Great Plains.

Concho is a selection from the cross Comanche X Blackhull-Hard Federation. It is fully awned, lax headed and bronze-chaffed although a

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[2] C.I. numbers are the accession numbers of the Division of Cereal Crops and Diseases, U. S. Department of Agriculture.

few white-chaffed types occasionally appear. The variety is highly resistant to bunt but it is somewhat less resistant than Ponca, to leaf rust.

Ponca is a selection of the cross (Kawvale-Marquillo) X (Kawvale-Tenmarq). The variety is white-chaffed, fully awned and medium to early in maturity. It possesses a high degree of resistance to leaf rust and the hessian fly, but it is susceptible to bunt.

Both F_1 plants of the cross Concho X Triticum spp.- Agropyron elongatum were bronze-chaffed, fully-awned and resistant to leaf in the field. The seeds were hard in texture and red in color. Winter survival for the F_1 plants of this cross was 100 per cent. The F_1 plants of the cross (Timstein X Comanche F_1) X Concho were bronze-chaffed, heterozygous for awns and exhibited an "X" type reaction for leaf rust. The seeds were hard in texture and red in color. Winter survival for the F_1 plants of this cross was 75 per cent.

Experimental Methods

All of the material in this study, after being treated with Ceresan M, was space planted 6 inches apart within 10-foot rows which were spaced 1-foot apart. Spaced in this manner, 20 seeds were planted in each row. This spacing was employed to enable the study and selection of individual plants.

Six-hundred seeds from each F_1 plant of Concho X Triticum spp-Agropyron elongatum and 400 seeds from each F_1 plant of (Timstein X Comanche F_1) X Concho and the varieties used for comparison were space planted October 11, 1951 on the Agronomy Farm at Stillwater, Oklahoma. Fall stands were taken December 1 by counting the number of plants which had emerged.

Heading dates of the F_2 plants were taken in the field by attaching a white marking tag with the date written on it to the tiller which headed first on each plant. To be tagged as headed, the "collar" of the spike was above the top of the leaf sheath. The reverse side of the tag was marked with the date the spike "bloomed" which was the day the anthers were visible between the lemma and palea.

Height of each F_2 plant was taken in the field using a measuring stick graduated in inches. This measurement was from the ground to the tip of the spike, excluding the awns on the awned plants.

Leaf rust readings on the F_2 plants were taken in the field using the modified Cobb scale (5). No leaf rust readings were taken in the field on the F_3 lines because there was very little leaf rust present on the Agronomy Farm in 1953.

Individual F_2 plants were harvested and taken to the laboratory for detailed study. Here the plants were checked for chaff color (whether bronze or white), awn condition (whether fully awned or only partially awned), total number of tillers, tillers with fertile heads and the degree of clavateness.

To determine the degree of clavateness, the total number of spikelets on the spike and the the number of spikelets in the top half were counted. To obtain an index, the number of spikelets in the top half of the spike was divided into the total number of spikelets. This index was used only for the cross of Concho X Triticum spp.- Agropyron elongatum since there was no clavateness in the hybrids of (Timstein X Comanche F_1) X Concho.

After examination, the hybrids were threshed individually using a Waring Blendor. The threshed seed from each plant was then weighed to the nearest gram and classified for texture, color and plumpness.

Texture was classified by biting the seed to determine the degree of hardness while color and plumpness were determined by visual observation. The survival percentages of the F_2 populations were calculated by dividing the fall stand into the number of plants which were harvested.

Criteria for the selection of individual F_2 plants for the production of F_3 lines of the cross Concho X *Triticum* spp.- *Agropyron elongatum* were:

1. The plant must have produced at least 40 seeds.
2. It must have headed before May 16, except in cases of the plant showing immunity to leaf rust in the field.
3. It must have been resistant to leaf rust in the field.
4. It must have had a clavateness index of 1.83 or greater.
5. The threshed seed must have been medium hard to hard in texture and a plumpness of 75 per cent or greater.

Standards for the selection of individual F_2 plants for the production of F_3 lines of (Timstein X Comanche F_1) X Concho were:

1. The plant must have produced at least 40 seeds.
2. It must have headed before May 12.
3. The plants must have possessed a low prevalence and severity of leaf rust in the field.
4. The threshed seed had to be hard in texture, red in color and have a plumpness of 80 per cent or greater.

Two hundred forty-three F_2 plants of Concho X *Triticum* spp.- *Agropyron elongatum* and 106 F_2 plants of (Timstein X Comanche F_1) X Concho were carried on as F_3 lines. These lines were space planted in two 10-foot row plots December 8, 1952 on the Agronomy Farm at Stillwater, Oklahoma. No fall stands were taken because of the late date of planting.

The F_3 plots were marked headed when 75 per cent of the plants within the plot were headed. Chaff color was recorded as to whether the line was bronze, white or segregating. In the segregating lines, the number of bronze-chaffed plants and the number of white-chaffed plants were counted and recorded. The awn type was placed in the following 5 classes:

1. Completely awnless
2. Tip-awned
3. Awns nearly to the base of the spike
4. Fully awned with short or twisted awns at the base of the spike
5. Fully awned

The degree of clavateness was checked by visual observation and the number of lax and clavate spiked plants was recorded within each line of the cross Concho X Triticum spp.- Agropyron elongatum. Clavateness indices were determined on certain lines after the more desirable plants had been selected. This index was used to check the accuracy of the F_2 classification.

A leaf rust test was carried on in the greenhouse in the fall of 1953. Seventy-five F_4 lines grown from F_3 plants selected for their "agronomic" characters were tested for resistance to race 105B. This race was used because Concho is susceptible to it and because it appears to be the most virulent race of leaf rust found in Oklahoma, if virulence is measured by the diversity of varieties or strains which are attacked.

Fifteen to 20 seeds of each F_4 selection were planted in 4-inch flower pots, two selections to the pot. They were allowed to grow for eight days and were then inoculated with leaf rust race 105B. Twelve days after inoculation the plants were rated for the prevalence and severity of leaf rust. These ratings were recorded along with the number of resistant and susceptible plants within the segregating lines.

All methods used in the statistical analyses were taken from Snedecor (31).

EXPERIMENTAL RESULTS AND DISCUSSION

(Timstein X Comanche F_1) X Concho

F_2 Survival and the Number of Plants in the F_3 Plots

The survival percentage of (Timstein X Comanche F_1) X Concho in the F_2 was 91.52 with Concho, Comanche and Ponca having survival percentages of 88.78, 87.36 and 87.10 respectively. Survival of the hybrid was high for a cross involving a spring wheat; however, the relatively mild winter of 1951-52 will possibly account for this.

The average number of plants in the F_3 plots of (Timstein X Comanche F_1) X Concho, Comanche, Ponca and Concho was 19.53, 16.00, 11.25 and 10.75 respectively. These low numbers of plants in the plots was possibly the result of late seeding, inadequate moisture and other unfavorable environmental conditions.

Inheritance of Awns

The original classification of the awns of (Timstein X Comanche F_1) X Concho F_2 was 476 incompletely awned plants to 128 completely awned plants. In studying 106 F_3 lines of this material, it was found that one line or 1.28 per cent of the 78 lines classified as incompletely awned in the F_2, should have been placed in the completely awned class. Of 28 F_3 lines grown from plants classified as completely awned in the F_2, one line produced class 2 awns and one line segregated, a total of two lines or 7.14 per cent of the completely awned class should have been placed in the incompletely awned class. The classification of the original F_2 population was corrected on this basis, assuming the F_3 lines were selected at random.

Table 1 presents data for the inheritance of awns in the F_2 and F_3. The P value of .01-.02 in the F_2 for a 3:1 ratio is considered to be a poor fit but the breeding behavior of the F_3 lines gave a P value of .70-.80 for a 1:2:1 ratio which suggests the inheritance of awns in this cross is on a monohybrid basis with fully awned being the recessive character.

If this assumption is correct, Concho is of the genotype aa (fully awned) and the ovules of the (Timstein X Comanche F_1) used in this cross carried the dominant gamete A (awnless), to produce the results presented in Table 1. Since we know that Timstein is awnletted and Comanche is awned, the F_0 (crossed seed) was heterozygous or of the genotype Aa if one factor pair is assumed. When this seed was planted, it produced an F_1 plant which had the genotype Aa in its anthers and ovaries. Pollen from Concho was apparently placed on A gametic ovaries and in this manner produced heterozygous F_1 plants, the seed of which was used in this study.

Inheritance of Chaff Color

A ratio of 444 bronze-chaffed plants to 160 white-chaffed plants was observed in the F_2 of (Timstein X Comanche F_1) X Concho. Of the 106 F_3 lines which were grown, 85 of the plants had been classified as bronze-chaffed and 21 had been classified as white-chaffed in the F_2. When they were studied in the field in the F_3, it was found that one line or 1.18 per cent of the lines classified as bronze-chaffed had been misclassified in the F_2 and 3 lines or 14.29 per cent of those classified

Table 1.—Inheritance of awns in a cross of (Timstein X Comanche F_1) X Concho at Stillwater, Oklahoma, 1951-52 and 1952-53.

Observed* or Expected	Incompletely Awned	Segregating For Awns	Completely Awned	Chi-Square	P Value
		F_2 Plants			
Obs.	479	-	125	5.969	.01-.02
E(3:1)	453	-	151		
		F_3 Lines From Selected F_2 Plants			
Obs.	23	56	27	0.641	.70-.80
E(1:2:1)	26.5	53	26.5		

* Obs. means observed number and E means expected number.

as white-chaffed in the F_2, should have been placed in the bronze-chaffed class. The original F_2 classification was corrected on this basis, assuming the plants selected for the F_3 lines were at random.

In the F_3, 52 lines produced all bronze-chaffed plants, 35 lines segregated and 19 lines produced all white-chaffed plants. Because of the relatively low number of segregating lines, they were grouped together with the lines which produced all bronze-chaffed plants. The low number of segregating lines could be due to low numbers of plants in some of the lines producing all bronze-chaffed progenies. These lines ranged from 1 to 33 plants per line.

The data for the inheritance of chaff color of the corrected F_2 ratio, the F_3 lines and the bronze and white plants in the 35 segregating lines of the cross (Timstein X Comanche F_1) X Concho are presented in Table 2. These data suggest the inheritance of chaff color is on a monohybrid ratio with white-chaff color a recessive character. Assuming this is correct, Concho is of the genotype BB (bronze-chaffed) and Timstein X Comanche F_1 is of the genotype bb (white-chaffed).

Other Plant Characters

Figures 1, 3 and 5 show the distribution of total number of tillers, tillers with fertile heads and height of plants respectively of (Timstein X Comanche F_1) X Concho F_2, Comanche, and Ponca. Figures 2, 4 and 6 show the distribution of the same characters of (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca (See App. Tables 1, 2 and 3 for the actual data).

Table 2.--Inheritance of chaff color in a cross of (Timstein X Comanche F_1) X Concho at Stillwater, Oklahoma, 1951-52 and 1952-53.

Observed* or Expected	Bronze	White	Chi-Square	P Value
		F_2 Plants		
Obs.	462	142	0.715	.30-.50
E(3:1)	453	151		
		F_3 Lines From Selected F_2 Plants		
Obs.	87	19	2.831	.02-.05
E(3:1)	79.5	26.5		
		Plants Within The 35 F_3 Segregating Lines		
Obs.	557	179	0.181	.50-.70
E(3:1)	552	184		

* Obs. means observed number and E means expected number.

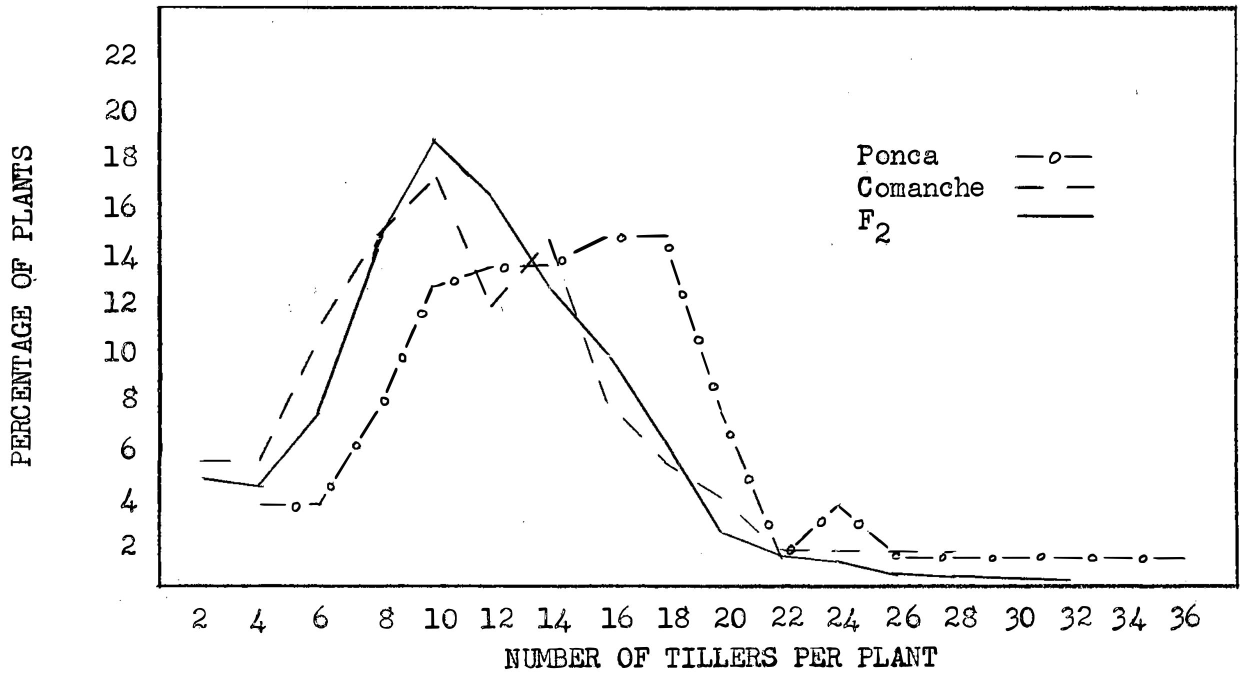

Fig. 1.--Distribution of total number of tillers per plant of (Timstein X Comanche F_1) X Concho F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

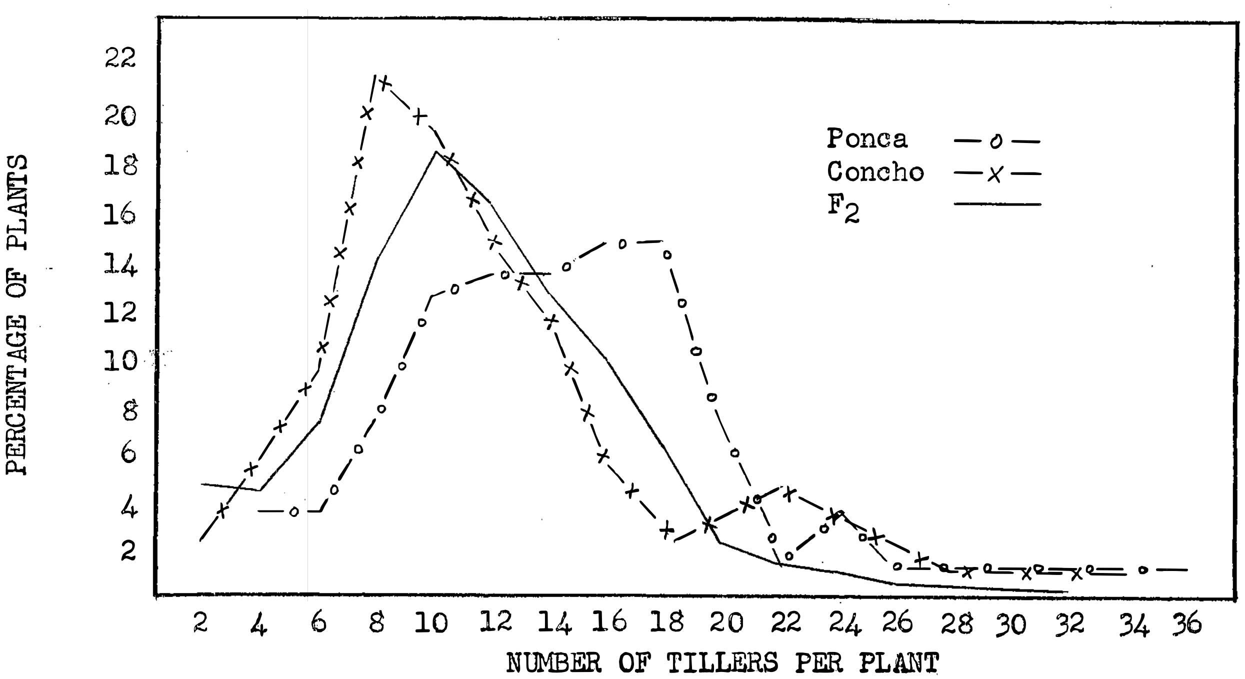

Fig. 2.--Distribution of total number of tillers per plant of (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

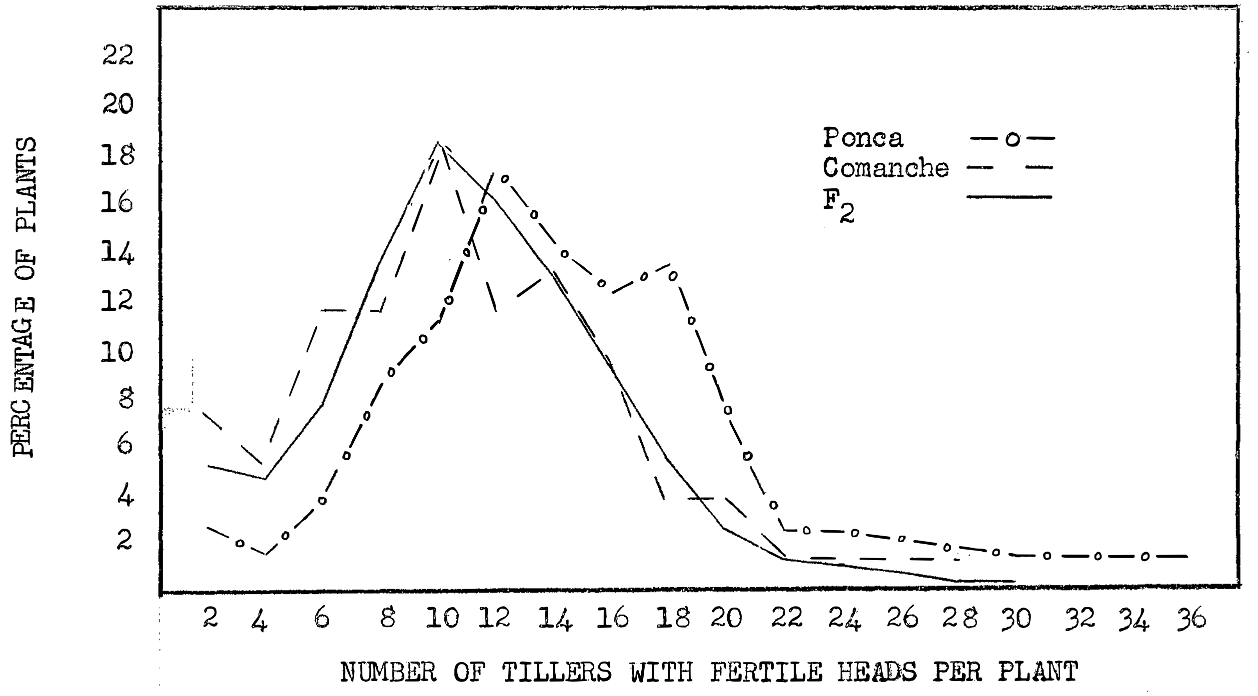

Fig. 3.--Distribution of tillers with fertile heads per plant of (Timstein X Comanche F_1) X Concho F_2, Comanche, and Ponca at Stillwater, Oklahoma, 1951-52.

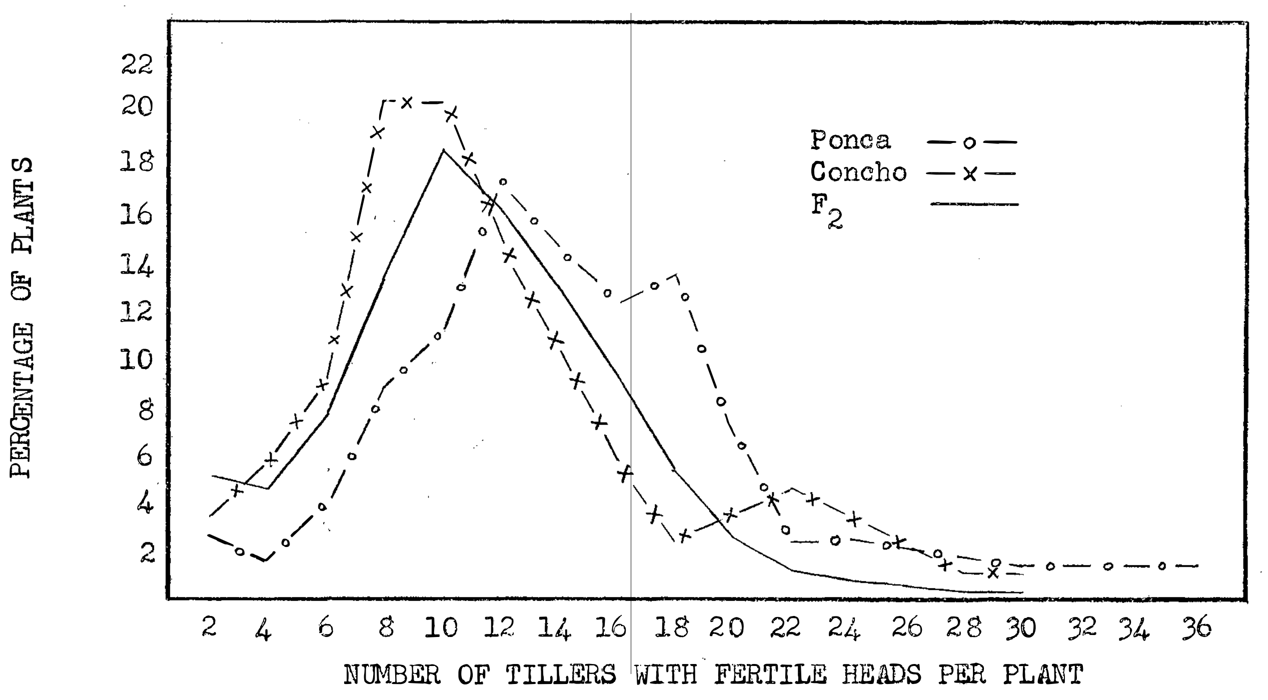

Fig. 4.--Distribution of tillers with fertile heads per plant of (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

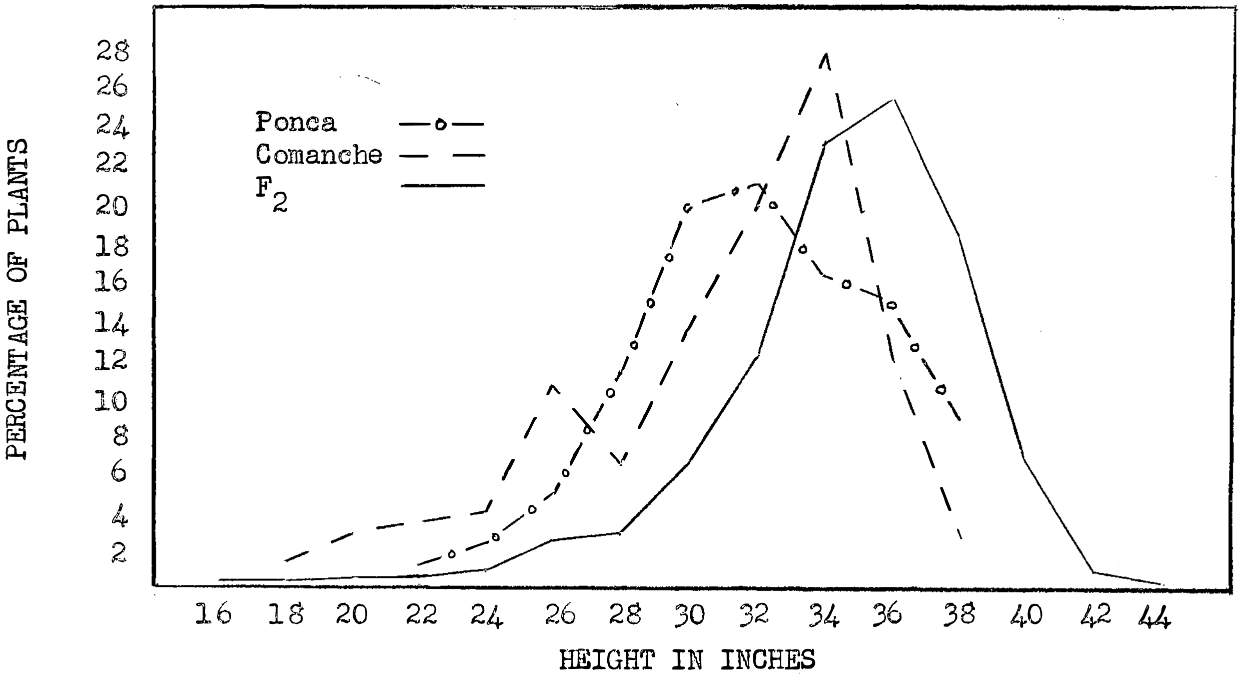

Fig. 5.--Distribution of height of plants of (Timstein X Comanche F_1) X Concho F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

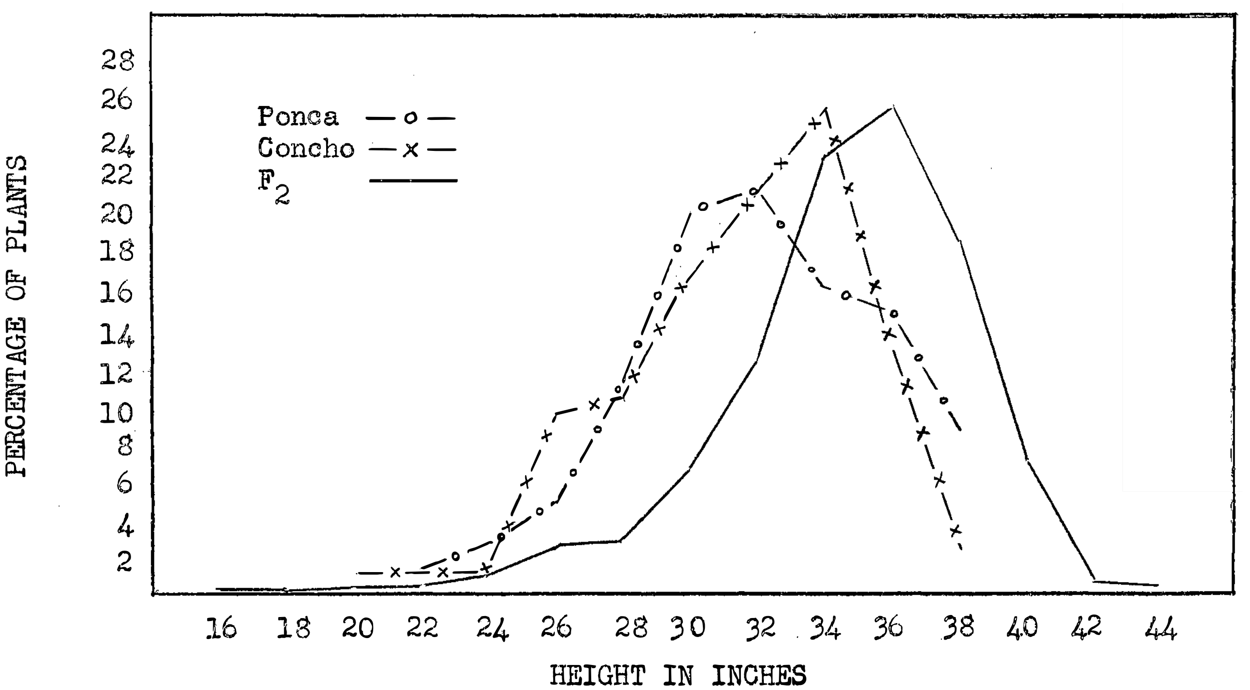

Fig. 6.-- Distribution of height of plants of (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

The number of plants, mean and standard deviation for the mentioned characters are shown in Table 3.

The distribution of date of heading of (Timstein X Comanche F_1) X Concho F_2, Comanche and Ponca and (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca are shown in Figures 7 and 8 respectively (See App. Table 4 for the actual data). The number of individuals, mean and standard deviation for this character in addition to the blossoming date are presented in Table 3. A correlation study of date of heading of 106 F_3 lines and their F_2 parent plants gave a correlation coefficient of 0.453 which is highly significant, indicating that heading date, as an index of maturity, could be selected in the F_2 of this material.

As a whole, the entire population of this cross appeared to be susceptible to leaf rust in the field in 1952. Only a very few late plants appeared resistant. It is, of course, possible that these late plants simply escaped infection. Consequently, no genetical analysis of the inheritance of leaf rust is presented.

Disposal of Material

Eighty-seven F_4 lines, from selected F_3 plants, were planted on the Stillwater Agronomy Farm in 1953-54 to be carried on in the wheat breeding program. These lines will be rigorously selected and only the more promising lines will be retained.

Concho X *Triticum* spp. - *Agropyron elongatum*

F_2 Survival and the Number of Plants in the F_3 Plots

The winter survival percentage of Concho X *Triticum* spp. - *Agropyron elongatum* F_2 was 92.95 with Ponca, Comanche and Concho having winter

Table 3.--Number of plants, mean and standard deviation of some characters of Concho, Comanche, Ponca and (Timstein X Comanche F_1) X Concho F_2 at Stillwater, Oklahoma, 1951-52.

Plant Character	Number of Plants	Mean	Standard Deviation
(Concho)			
Total Tillers (No.)	87	10.55	5.41
Tillers with Fertile Heads (No.)	87	10.29	5.24
Height of Tillers (Inches)	87	31.09	3.60
Date Headed (May)	87	9.91	3.61
Date Blossomed (May)	82	10.84	2.49
(Comanche)			
Total Tillers (No.)	76	10.79	5.31
Tillers with Fertile Heads (No.)	76	10.58	5.35
Height of Tillers (Inches)	76	30.67	4.24
Date Headed (May)	76	12.33	4.82
Date Blossomed (May)	72	12.90	3.94
(Ponca)			
Total Tillers (No.)	81	14.00	5.74
Tillers with Fertile Heads (No.)	81	13.62	5.58
Height of Tillers (Inches)	81	31.42	3.51
Date Headed (May)	80	12.64	4.55
Date Blossomed (May)	79	13.13	4.19
(Timstein X Comanche F_1) X Concho F_2)			
Total Tillers (No.)	604	10.96	4.91
Tillers with Fertile Heads (No.)	604	10.76	4.65
Height of Tillers (Inches)	604	34.16	3.69
Date Headed (May)	603	8.31	4.04
Date Blossomed (May)	594	9.78	3.48

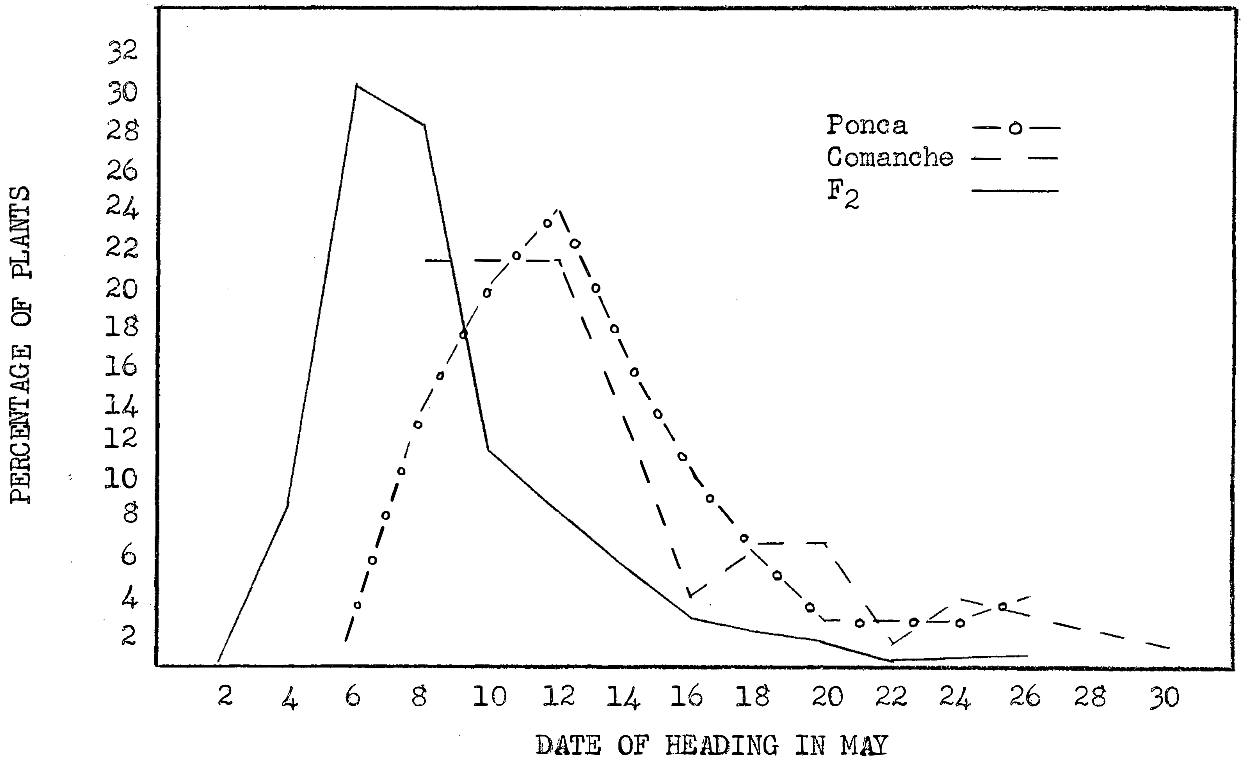

Fig. 7.--Distribution of date of heading of (Timstein X Comanche F_1) X Concho F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

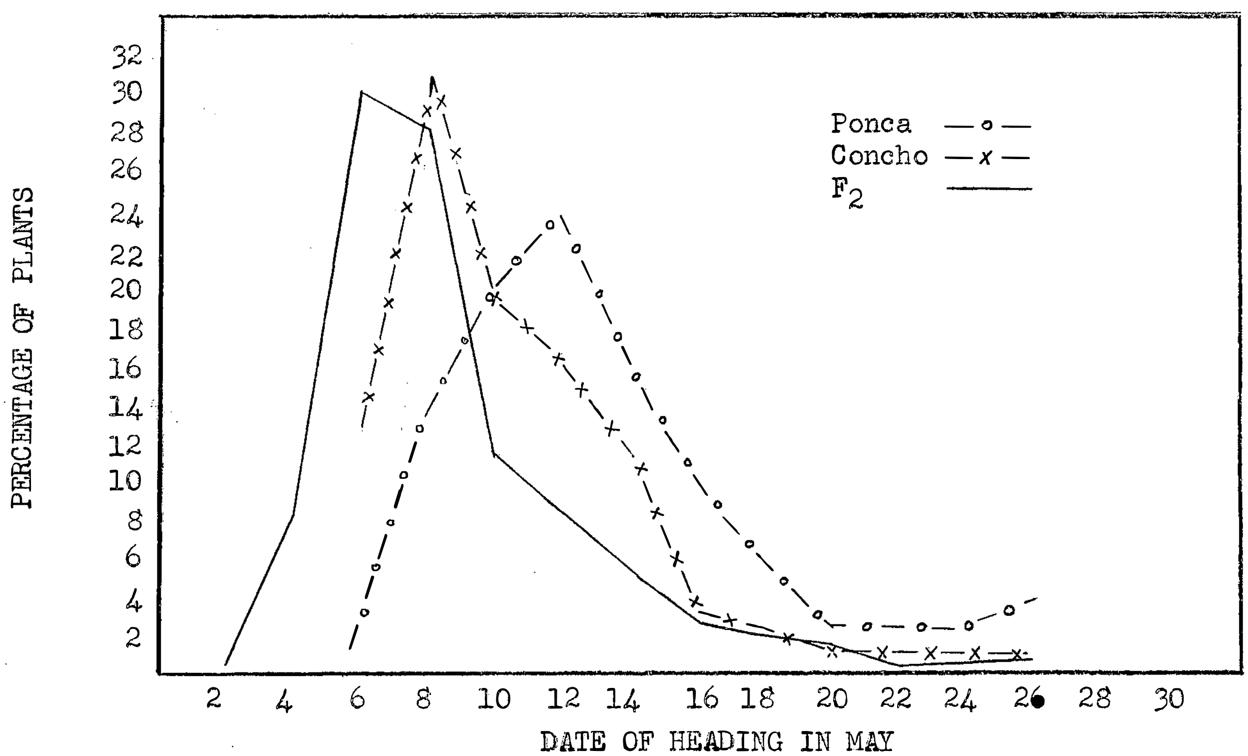

Fig. 8.--Distribution of date of heading of (Timstein X Comanche F_1) X Concho F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

survival percentages of 94.52, 92.50 and 88.02 respectively. In the F_3 lines, the average number of plants per plot was 15.00, 14.19, 14.11 and 13.89 for Comanche, the hybrid, Concho and Ponca respectively. These low numbers were possibly due to the late date of seeding and unfavorable environmental conditions.

Inheritance of Chaff Color

Bronze-chaff appeared to be dominant in the F_2 populations of plants 5731-2 and 5731-3 with ratios of 331:191 and 294:226 respectively being observed. Of 111 F_3 lines which were grown from selected F_2 plants of 5731-2, four lines or 5.97 per cent of the 67 which had been classified bronze-chaffed in the F_2 and 19 lines or 43.18 per cent of the 44 classified as white-chaffed in the F_2 had been placed in the wrong class. Upon examination of 129 F_3 lines grown from plants selected from the F_2 population of 5731-3, it was found that two lines or 2.56 per cent of the 78 which had been classified as bronze-chaffed in the F_2, were misclassified. It was also found that of the 51 lines classified as white-chaffed in the F_2, 21 lines or 41.18 per cent should have been placed in the bronze-chaffed group. Assuming random selection in the F_3 lines, the original F_2 classification was corrected on the performance of the F_3 lines.

Table 4 presents the data for the corrected F_2 population and the F_3 lines tested by Chi-square for goodness of fit to a 3:1 ratio of plants 5731-2 and 5731-3. These data indicate the inheritance of chaff color of this cross, Concho X *Triticum* spp.- *Agropyron elongatum*, is on a 1-factor pair basis, bronze-chaff dominant over white-chaff. If this is correct, Concho is then of the genotype BB (bronze-chaff) and *Triticum* spp.- *Agropyron elongatum* used in this cross has the genotype bb (white-chaff).

Table 4.—Inheritance of chaff color in a cross of Concho X *Triticum* spp.-*Agropyron elongatum* at Stillwater, Oklahoma, 1951-52 and 1952-53.

F_1 Plant No.	Observed* or Expected	Bronze	White	Chi-Square	P Value
		F_2 Plants			
5731-2	Obs.	393	129	0.023	.80-.90
	E(3:1)	391.5	130.5		
5731-3	Obs.	379	141	1.240	.20-.30
	E(3:1)	390	130		
		F_3 Lines From Selected F_2 Plants			
5731-2	Obs.	82	29	0.048	.80-.90
	E(3:1)	83	28		
5731-3	Obs.	98	31	0.041	.80-.90
	E(3:1)	97	32		

*Obs. means observed number and E means expected number.

Inheritance of Awns

Awns appeared to be dominant in the F_2 populations of both F_1 plants 5731-2 and 5731-3 with ratios of 300:222 and 318:202 respectively being observed. The breeding behaviors of 111 F_3 lines of plant 5731-2 and 129 F_3 lines of plant 5731-3 along with the percentage of each class are presented in Table 5 (See App. Tables 5 and 6 for the actual data).

There were 4 true breeding awn classes and 7 segregating classes in the F_3 lines of plant 5731-2 and 3 true breeding awn classes and 4 segregating classes in the F_3 lines of plant 5731-3. However, attention should be called to the fact that in progenies of both plants 5731-2 and 5731-3 there were a low number of lines segregating the full range of awn classes in each case and also there were a high number of lines in the fully awned classes. Perhaps meiotic instability will explain this in part since after examining advanced generations of Triticum spp.- Agropyron elongatum, Sebesta (28) reported that some were very stable while when additional wheat chromosomes were introduced as in the crosses of Concho X Triticum spp.- Agropyron elongatum F_2, Triumph X Triticum spp.- Agropyron elongatum F_2 and Triticum spp.- Agropyron elongatum X Pawnee F_2, there was a high rate of meiotic instability. When still additional wheat chromosomes were introduced, as in the crosses of Pawnee X (Triticum spp.- Agropyron elongatum X Pawnee F_1) F_2, (Triticum spp.- Agropyron elongatum X Pawnee F_1) X Concho F_2 and Ponca X (Triticum spp.- Agropyron elongatum X Pawnee F_1) F_2, he reported that more regular pairing of chromosomes occurred and fewer micronuclei were formed.

Table 5.--Classification of awns of F_3 lines of a cross of Concho X *Triticum* spp.--*Agropyron elongatum* grown at Stillwater, Oklahoma, 1952-53.

	Homozygous for: Awn Class				Heterozygous for: Awn Class							
	2	3	4	5	2-3	3-4	4-5	2-3-4	3-4-5	2-4-5	2-3-4-5	3-5
				F_1 plant No. 5731-2								
No. F_3 Lines	1	1	7	33	2	7	34	1	21	1	3	
% F_3 Lines	0.90	0.90	6.31	29.73	1.80	6.31	30.63	0.90	18.92	0.90	2.70	
				F_1 plant No. 5731-3								
No. F_3 Lines		6	30	59		4	19		10			1
% F_3 Lines		4.65	23.26	45.74		3.10	14.73		7.75			0.78

Inheritance of Resistance to Leaf Rust

F_2 populations of 5731-2 and 5731-3 suggested that resistance to leaf rust was recessive in character with ratios of 344:178 and 332:188 respectively being observed in the field in 1952. No leaf rust readings were taken in the field in 1953.

In greenhouse tests of 75 F_4 lines selected from F_3 plants of Concho X *Triticum* spp.- *Agropyron elongatum* for resistance to leaf rust race 105B, 9 lines were resistant, 20 lines segregated and 46 lines were susceptible. Because of selection for leaf rust resistance in the F_2, no genetical analysis of the entire group tested was determined. Within the 20 segregating lines, the number of resistant and susceptible plants were tested by Chi-square for goodness of fit to a 3: 1 ratio as presented in Table 6. These data indicate that the inheritance of resistance is on a monohybrid basis with resistance being the recessive character. If resistance to leaf rust race 105B is recessive in character and inherited on a monohybrid basis, Concho is of the genotype RR (susceptible) and the *Triticum* spp.- *Agropyron elongatum* used in this cross is of the genotype rr (resistant).

Inheritance of Clavate Spikes

Degrees of clavateness as found in the F_2 population are illustrated in Figure 9. Figure 10 shows the distribution of spike clavateness, as measured by the clavateness index of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Comanche and Ponca while Figure 11 shows this same character of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Concho and Ponca. (See App. Table 7 for the actual data). The number of individuals, mean and standard deviation of the hybrid and the parent and check varieties are presented in Table 7.

Table 6.--Inheritance of resistance to leaf rust race 105 B within 20 segregating lines of Concho X *Triticum* spp.- *Agropyron elongatum* F_4 at Stillwater, Oklahoma in 1953.

Observed* or Expected	Susceptible	Resistant	Chi-Square	P Value
Obs.	205	78	0.921	.30-.50
E(3:1)	212	71		

*Obs. means observed number and E means expected number.

Fig. 9. (Left to right) Clavateness indices of 1.50, 1.60, 1.70, 1.80, 1.90 and 2.00 of Concho X *Triticum* spp.- *Agropyron elongatum* F_2 at Stillwater, Oklahoma, 1951-52.

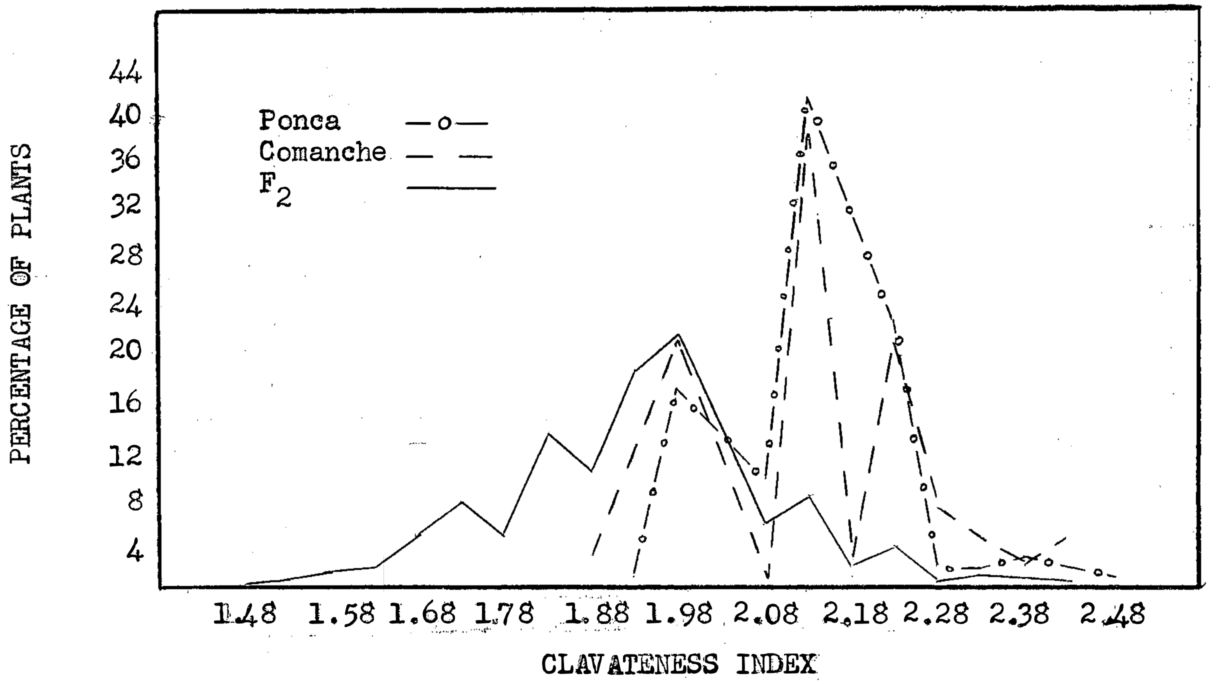

Fig. 10.—Distribution of the clavateness indices of Concho X Triticum spp. - Agropyron elongatum F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

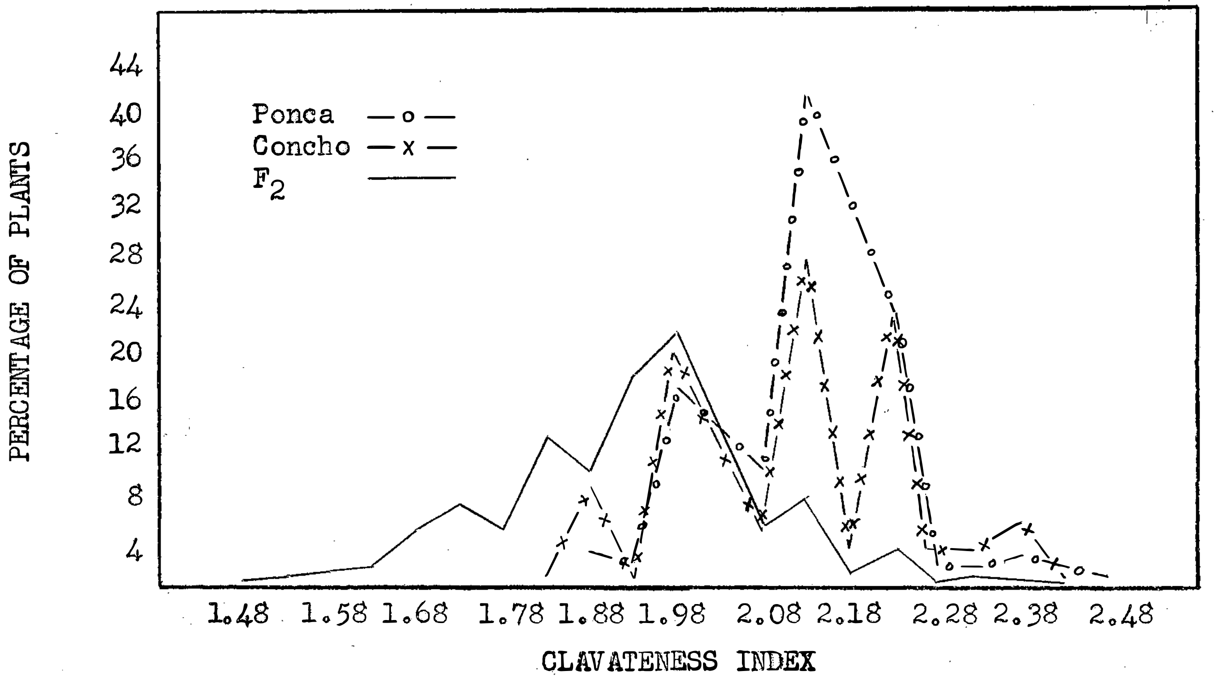

Fig. 11.—Distribution of the clavateness indices of Concho X Triticum spp. - Agropyron elongatum F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

Table 7.--Number of plants, mean and standard deviation of some characters of Concho, Ponca, Comanche and Concho X *Triticum* spp.-*Agropyron elongatum* F_2 at Stillwater, Oklahoma, 1951-52.

Plant Character	Number of Plants	Mean	Standard Deviation
(Concho)			
Total Tillers (No.)	147	9.57	4.05
Tillers with Fertile Heads (No.)	147	9.39	3.96
Height of Tillers (Inches)	147	29.63	3.08
Clavateness (Index)	147	2.13	0.13
Date Headed (May)	147	9.40	3.42
Date Blossomed (May)	146	10.12	2.62
(Comanche)			
Total Tillers (No.)	148	9.74	4.68
Tillers with Fertile Heads (No.)	148	9.15	4.60
Height of Tillers (Inches)	148	29.43	3.74
Clavateness (Index)	148	2.16	0.13
Date Headed (May)	147	11.33	3.97
Date Blossomed (May)	145	11.70	3.18
(Ponca)			
Total Tillers (No.)	138	14.00	5.09
Tillers with Fertile Heads (No.)	138	13.25	4.99
Height of Tillers (Inches)	138	30.32	3.58
Clavateness (Index)	138	2.13	0.11
Date Headed (May)	138	10.87	3.34
Date Blossomed (May)	138	11.30	3.17
(Concho X *Triticum* spp. X *Agropyron elongatum* F_2)			
Total Tillers (No.)	1042	10.09	4.44
Tillers with Fertile Heads (No.)	1042	9.75	4.39
Height of Tillers (Inches)	1040	28.46	4.15
Clavateness (Index)	1042	1.92	0.15
Date Headed (May)	1033	10.91	4.49
Date Blossomed (May)	1025	11.37	3.78

Clavate spikes appeared to be the recessive character in the F_2 populations of both F_1 plants 5731-2 and 5731-3 with ratios of 371:151 and 402:118 respectively being observed. These ratios are tested for goodness of fit to a 3:1 ratio in Table 8. Selection against clavateness was practiced in the F_2 plants to be carried on in F_3 lines and consequently no genetic ratios for the F_3 lines could be determined. The only determination of the degree of clavateness made on the F_3 lines was the checking of the clavateness of the plants remaining in 32 lines, after the more desirable plants had been selected. The average clavateness index of these lines is compared with the clavateness index of the F_2 parent plant in Table 9, which shows the method used in determining the degree of clavateness was relatively satisfactory.

Other Plant Characters

The distribution of total number of tillers, tillers with fertile heads and height of plants for Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Comanche and Ponca are shown in Figures 12, 14 and 16 while the distribution of these same characters for Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Concho and Ponca are shown in Figures 13, 15 and 17 (See App. Tables 8, 9 and 10 for the actual data). The number of individuals, mean and standard deviation for these characters are given in Table 7.

Distributions of date of heading of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Comanche and Ponca are shown in Figure 18 while the distributions of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Concho and Ponca are shown in Figure 19 (See App. Table 11 for the actual data). In Table 7, the number of plants, mean and standard deviation of date of heading and also date of "blossoming" are presented. A

Table 8.—Inheritance lax and clavate spikes in the F_2 of Concho X Triticum spp.- Agropyron elongatum at Stillwater, Oklahoma, 1951-52.

F_1 Plant No.	Observed or Expected*	Lax	Clavate	Chi-Square	P Value
5731-2	Obs.	371	151	4.293	.02-.05
	E(3:1)	391.5	130.5		
5731-3	Obs.	402	118	1.447	.20-.30
	E(3:1)	390	130		

* Obs. means observed number E means expected number.

Table 9.--Clavateness indices of F_2 plants and average clavateness indices of the F_3 lines of Concho X Triticum spp.-Agropyron elongatum at Stillwater, Oklahoma, 1951-52.

F_2 Plant Number	F_2 Clavateness Index	Average Clavateness Index of F_3	No. F_3 Heads Measured
4721-5	1.80	1.86	4
4723-2	1.82	1.85	17
4706-14	1.82	1.86	19
4708-4	1.83	1.81	18
4735-16	1.83	1.83	17
4707-11	1.83	1.91	13
4708-15	1.85	1.99	25
4725-1	1.90	1.84	16
4719-7	1.90	1.84	17
4722-2	1.90	1.92	18
4751-2	1.91	1.85	16
4707-13	1.91	1.91	24
4707-2	1.91	1.92	19
4708-6	1.91	1.92	22
4707-9	1.91	1.93	18
4706-11	1.91	1.99	18
4738-15	1.91	2.09	19
4708-3	1.92	1.85	16
4734-11	1.92	1.87	20
4711-5	1.92	1.91	18
4705-6	1.92	1.96	20
4708-14	2.00	1.91	23
4709-5	2.00	1.92	25
4707-4	2.00	1.92	19
4708-11	2.00	1.93	25
4736-12	2.00	2.00	20
4736-17	2.00	2.01	21
4709-7	2.11	1.79	15
4707-5	2.11	2.04	14
4711-4	2.22	1.93	22
4706-10	2.22	2.00	16
4755-15	2.22	2.04	19

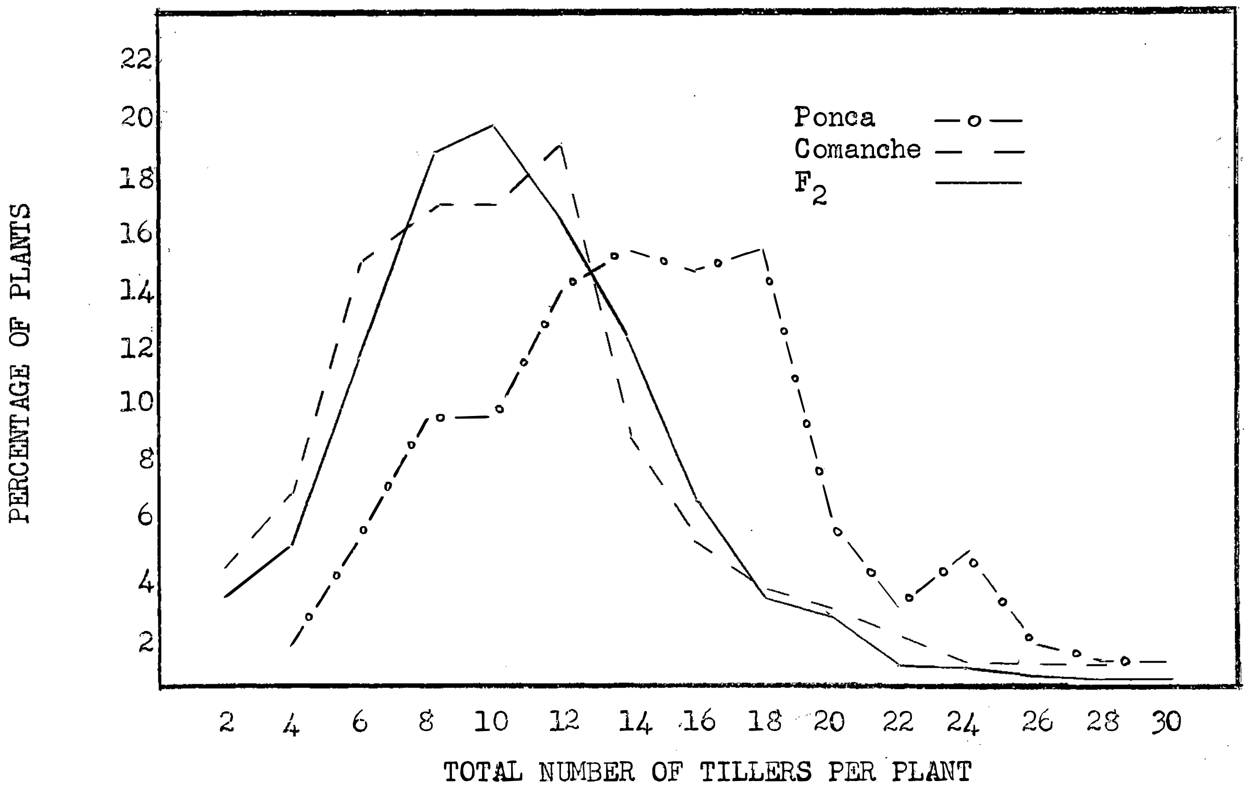

Fig. 12.—Distribution of total number of tillers per plant of Concho X Triticum spp. - Agropyron elongatum F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

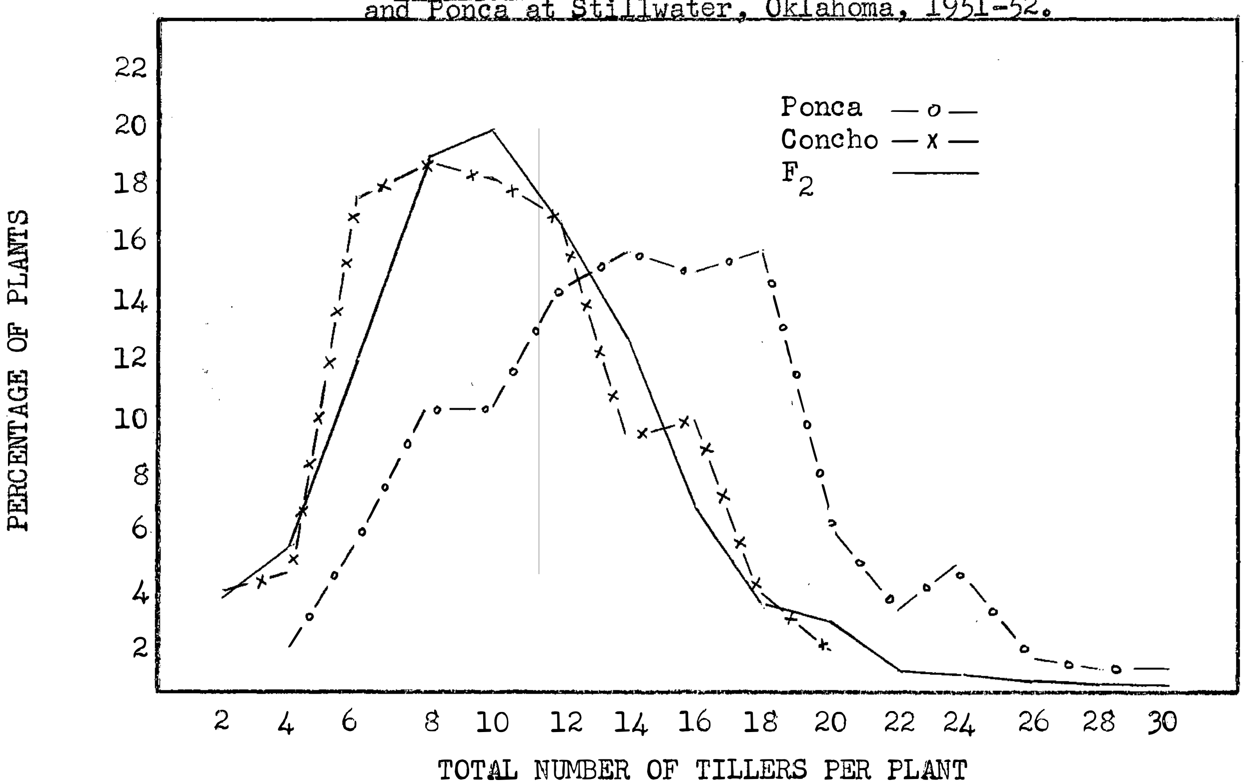

Fig. 13.—Distribution of total number of tillers per plant of Concho X Triticum spp. - Agropyron elongatum F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

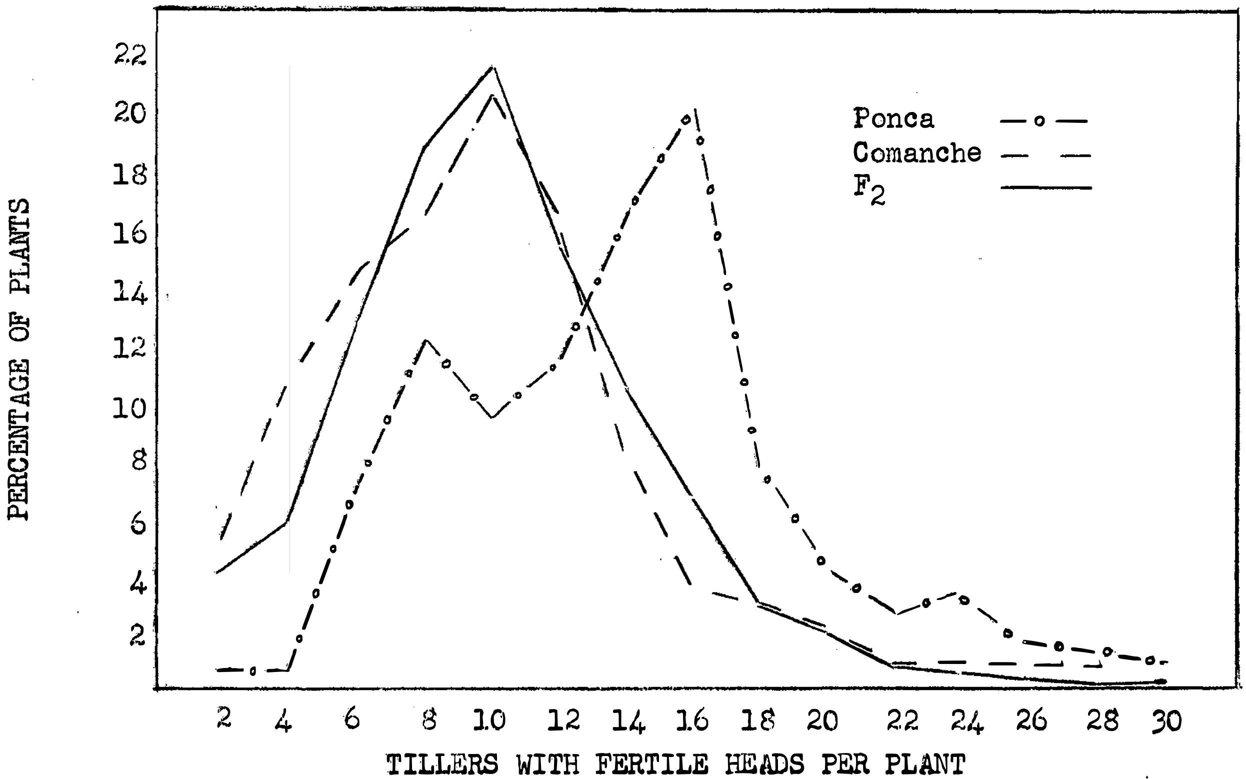

Fig. 14.—Distribution of tillers with fertile heads per plant of Concho X *Triticum* spp. - *Agropyron elongatum* F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

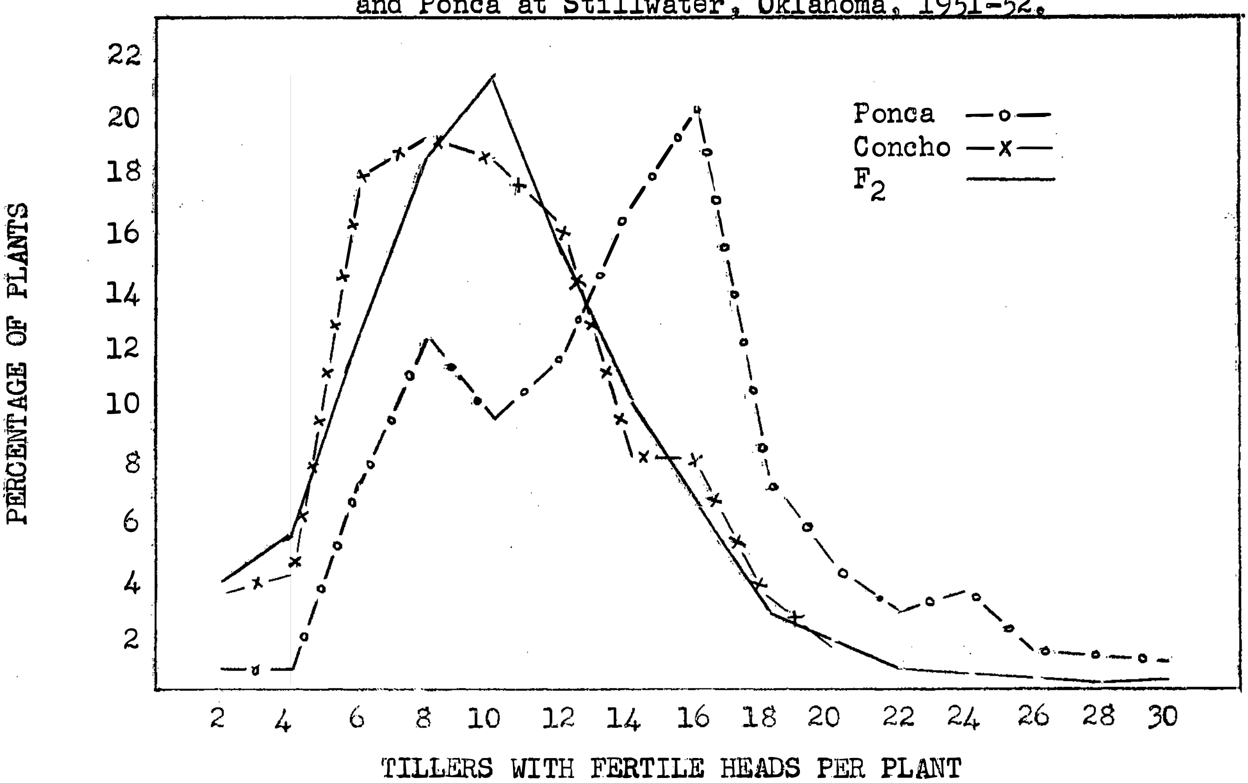

Fig. 15.—Distribution of tillers with fertile heads per plant of Concho X *Triticum* spp. - *Agropyron elongatum* F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

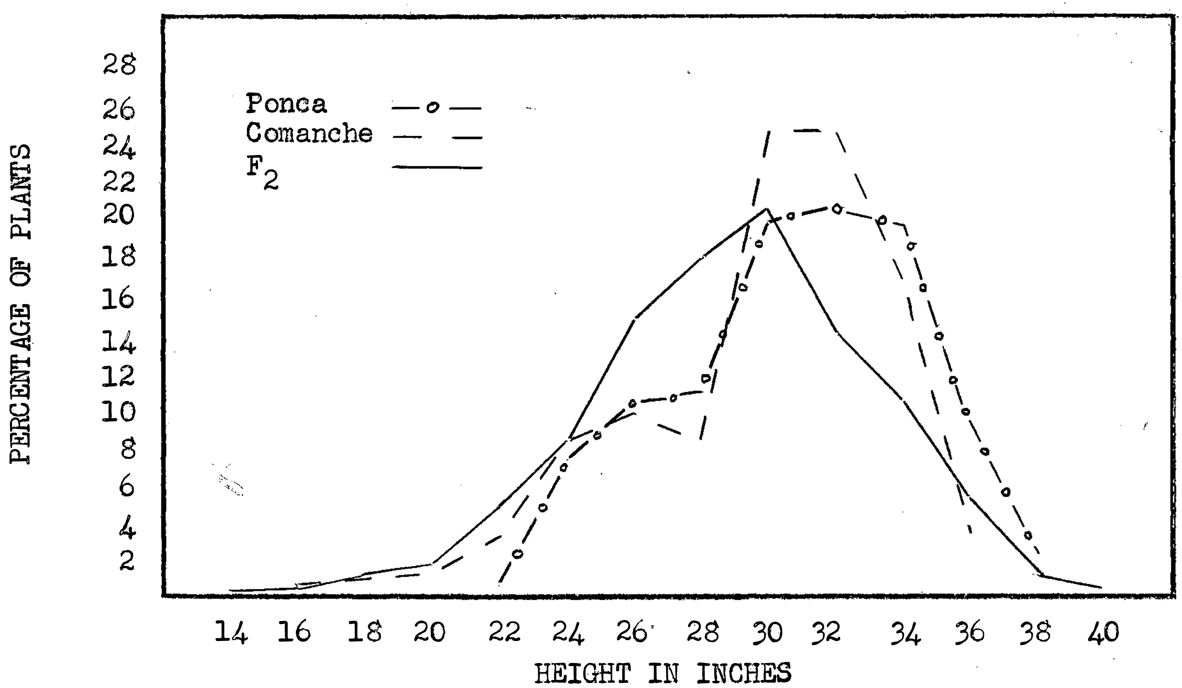

Fig. 16.--Distribution of height of plants of Concho X Triticum spp. - Agropyron elongatum F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

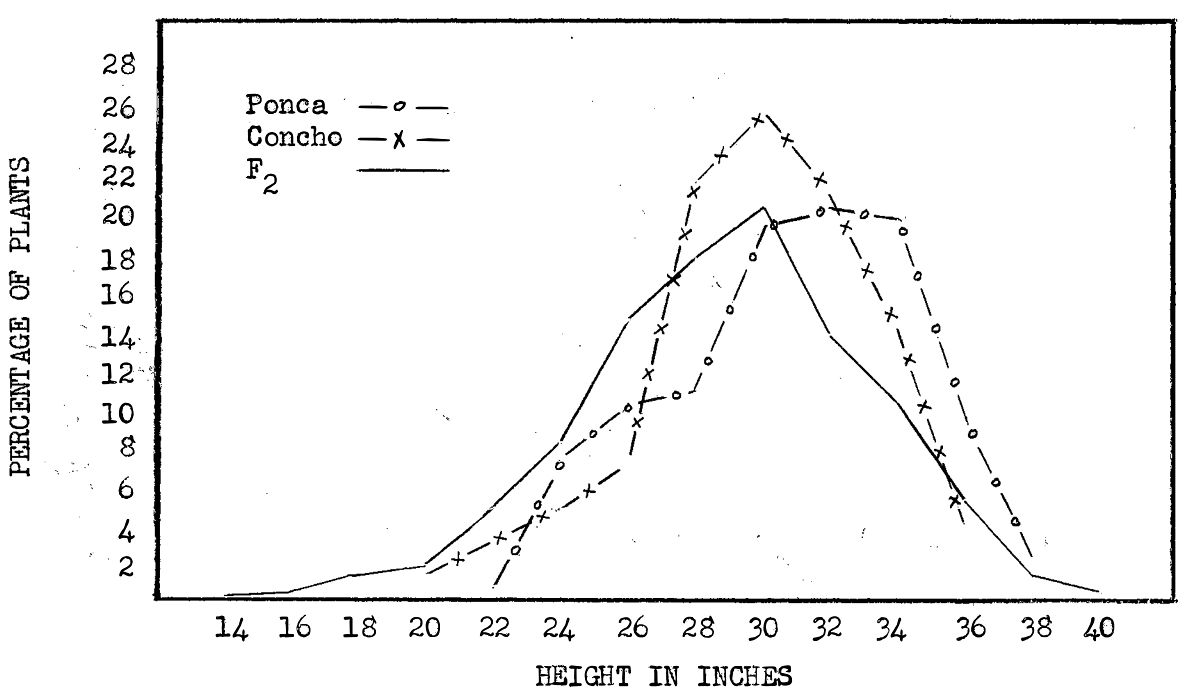

Fig. 17.--Distribution of height of plants of Concho X Triticum spp. - Agropyron elongatum F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

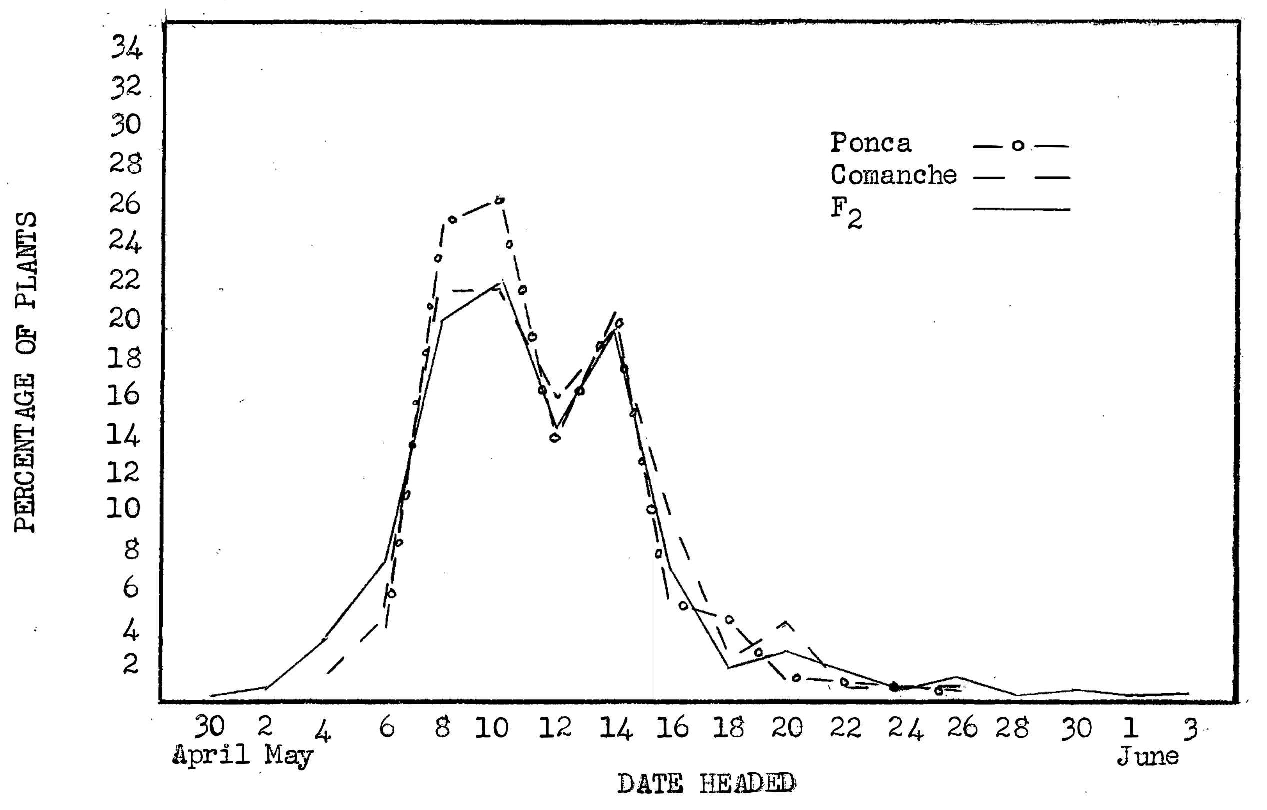

Fig. 18.--Distribution of date of heading of Concho X Triticum spp. - Agropyron elongatum F_2, Comanche and Ponca at Stillwater, Oklahoma, 1951-52.

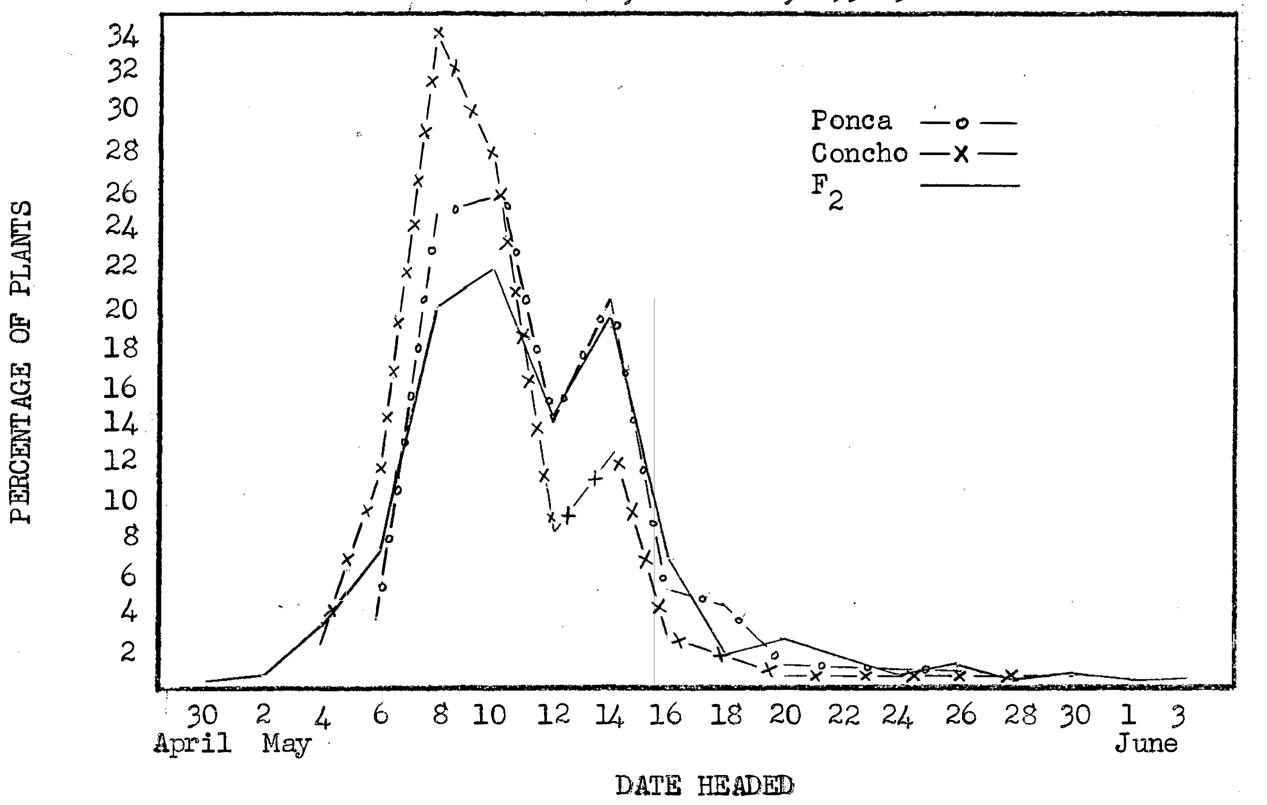

Fig. 19.--Distribution of date of heading of Concho X Triticum spp. - Agropyron elongatum F_2, Concho and Ponca at Stillwater, Oklahoma, 1951-52.

correlation study of the date of heading of the F_2 parent plants and their F_3 progenies gave a correlation coefficient of 0.509. This highly significant correlation coefficient suggests that date of heading could be selected in the material studied.

Disposal of Material

Ninety-eight F_4 lines, from seed of selected F_3 plants, were grown in a special nursery on the Agronomy Farm at Stillwater, Oklahoma, 1953-54. This number included the 75 F_4 lines tested for resistance to leaf rust race 105B in the greenhouse.

SUMMARY

F_2 and F_3 generations of (Timstein X Comanche F_1) X Concho and Concho X *Triticum* spp.- *Agropyron elongatum* were studied in the crop years 1952 and 1953 for the primary purposes of selecting more desirable breeding material and describing the populations.

Chaff color, awn condition and date of heading were studied in the F_2 and F_3 of both crosses while total number of tillers per plant, tillers with fertile heads per plant, height and leaf rust resistance were studied in the F_2 of both crosses. In addition to these characters the degree of clavateness, as measured by the clavateness index, was studied in the F_2 and F_3 of the cross Concho X *Triticum* spp.- *Agropyron elongatum*.

In the cross of (Timstein X Comanche F_1) X Concho, chaff color and awn condition appeared to be inherited on a monohybrid basis with white-chaff and fully awned being the recessive characters. Its average heading date was earlier than Comanche, Concho and Ponca which were grown for comparison. The distributions of total number of tillers per plant, tillers with fertile heads per plant and height were in normal curves.

The entire F_2 population of this cross appeared to be susceptible to leaf rust in the field, except for a few late plants which possibly escaped infection.

In the cross of Concho X *Triticum* spp.- *Agropyron elongatum*, chaff color appeared to be inherited on a monohybrid basis in the progenies of both F_1 plants included in this study. The fully awned condition appeared to be dominant in the F_2; however, in the F_3 breeding behavior, no genetic ratio could be fitted to the data. Spike density appeared to be inherited on a monohybrid basis with clavate spikes being the recessive character.

Resistance to leaf rust appeared to be recessive in character in the F_2 population. Greenhouse studies, carried on with 75 F_4 lines from selected F_3 plants, indicated that resistance to leaf rust was recessive in character with 9 resistant lines, 20 segregating lines and 46 susceptible lines being observed. Within the 20 segregating lines, the number of resistant and susceptible plants suggested that resistance to leaf rust race 105B was recessive in character and inherited on a 1-factor pair difference.

Eighty-seven F_4 lines grown from selected F_3 plants of the cross (Timstein X Comanche F_1) X Concho and 98 F_4 lines of the cross Concho X *Triticum* spp. - *Agropyron elongatum* from selected F_3 plants, including the 75 lines which were tested in the greenhouse for resistance to leaf rust race 105B, were included in the wheat breeding program at the Oklahoma Experiment Station in 1953-54.

LITERATURE CITED

1. Armstrong, J. M. Investigations in Triticum Agropyron by hybridization. The Empire Jour. of Expt. Agri. 13:41-53. 1945.

2. Ausemus, E. R. Correlated inheritance of reaction to diseases and of certain botanical characters in triangular wheat crosses. Jour. Agr. Res. 48:31-57. 1934.

3. Biffen, R. H. Mendel's laws of inheritance and wheat breeding. Jour. Agr. Sci. 1:1-48. 1905.

4. Boshnakian, S. The genetics of square-headedness and of density in wheat and the relation of these to other characters. Cornell Mem. 53:801-822. 1922.

5. Chester, K. S. The nature and prevention of the cereal rusts as exemplified in the leaf rust of wheat. Chronica Botanica Co., Waltham, Mass. 1946.

6. Cicin, N. V. Problems of winter and perennial wheat. Herbage Abs. 7:203-204. 1937.

7. Clark, J. A. Segregation and correlated inheritance in crosses between Kota and Hard Federation wheats for rust and drought resistance. Jour. Agr. Res. 29:1-47. 1924.

8. ___________, J. R. Hooker. Segregation and correlated inheritance in Marquis and Hard Federation crosses with factors for yield and quality of spring wheat in Montana. U.S.D.A. Bul., 1403. 1926.

9. ___________, V. H. Florell and J. R. Hooker. Inheritance of Awnedness, Yield, and Quality in crosses between Bobs, Hard Federation and Propo wheats at Davis, California. U.S.D.A. Tech. Bul. 39:4-16. 1928.

10. ___________, K. S. Quisenberry and L. Powers. Inheritance of bunt reaction and other characters in Hope wheat crosses. Jour. Agr. Res. 46:413-425. 1933.

11. Gaines, E. F. and H. P. Singleton. Genetics of Marquis X Turkey wheat in respect to bunt resistance, winter habit and awnlessness. Jour. Agr. Res. 32:165-181. 1926.

12. Gfeller, F. Inheritance of earliness of heading and other characters in Garnet X Red Fife. Sci. Agr. 17:482-491. 1937.

13. Hayes, H. K. and R. J. Garber. Breeding crop plants. McGraw-Hill Book Co. Inc. New York and London. 1927.

14. Hayes, H. K., J. H. Parker and C. Kurtzweil. Genetics of rust resistance in crosses of *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*. Jour. Agr. Res. 19:523-542. 1920.

15. Howard, A. and G. L. C. Howard. On the inheritance of some characters in wheat II. Mem. Dept. Agr. India, Bot. Ser. 5:1-47, 7:273-285. 1912, 1915.

16. Johnston, C. O. Some species of *Triticum* and related grasses as hosts for the leaf rust of wheat, *Puccinia triticina* Eriks. Trans. Kansas Acad. Sci. 43:121-132. 1940.

17. Kezer, A. and B. Boyack. Mendelian inheritance in wheat and barley crosses. Colorado Expt. Sta. Bul. 249. 1918.

18. Lapchenko, G. D. Hybrids between Agropyrum and wheat. Plant Breed. Abs. 1034. 1941.

19. Mains, E. B., C. E. Leighty and C. O. Johnston. Inheritance of resistance to leaf rust in crosses of common wheat. Jour. Agr. Res. 32:931-972. 1926.

20. O'Mara, J. G. Awn inheritance in *Triticum vulgare*. Genetics. 33:119. 1948.

21. Percival, J. The wheat plant. Duckworth and Company, London 463 pp. 1921.

22. Reitz, L. P., C. O. Johnston and K. L. Anderson. New combinations of genes in wheat X wheat grass hybrids. Trans. Kansas Acad. Sci. 48:151-159. 1945.

23. Sax, K. The relationship between chromosome number, morphological characters and rust resistance in segregates of partially sterile wheat hybrids. Genetics 8:301-321. 1923.

24. Schlehuber, A. M. Wheat inheritance: Reaction of four bunt biotypes spike density and seed color. Wash. Agr. Expt. Sta. Bul. 323. 1935.

25. ____________. Reaction of varieties and inheritance of resistance to races of leaf rust, *Puccinia rubigo-vera tritici* (Eriks.) Carlton in hard red winter wheat. Zeitschrift f. Pflanzenzuchtung 29:193-208. 1950.

26. Schmidt, J. W. Disease reaction and agronomic characters of certain *Triticum-Agropyron* crosses. Unpublished Master's Thesis. Kansas State College Library. 119 pp. 1949.

27. Schmidt, J. W., E. G. Heyne, C. O. Johnston and E. D. Hansing. Progress of Agrotricum breeding in Kansas. Trans. Kansas Acad. Sci. 56:29-45. 1953.

28. Sebesta, E. E. Cytological observations in wheat (Triticum aesativum L.) and in wheat X wheat grass (Agropyron elongatum (Host Beauv.) hybrids. Unpublished Master's Thesis. Oklahoma Agricultural and Mechanical College Library. 42 pp. 1953.

29. Shebeski, L. H. and Y. S. Wu. Inheritance in wheat of stem rust resistance derived from Agropyron elongatum. Sci. Agr. 32:26-35. 1952.

30. Shen, T. H. The inheritance of resistance to flag smut (Urocystis Tritici Koern) in ten wheat crosses. Nanking Univ. Co. Agr. and Forestry Bul. 17:1-16. 1934.

31. Snedecor, G. W. Statistical methods applied to experiments in agriculture and biology. Iowa State College Press. Ames. 1948.

32. Stewart, G. Correlated inheritance in Kanred X Sevier varieties of wheat. Jour. Agr. Res. 36:873-896. 1928.

33. ___________. Inheritance of awns in crosses involving Sevier and Federation wheats. Jour. Amer. Soc. Agron. 20:160-170. 1928.

34. ___________. Inheritance in a wheat cross between Ridit and a segregate of Federation X Sevier (14-85). Jour. Amer. Soc. Agron. 23:964-976. 1931.

35. ___________. Correlated inheritance in a cross between Dicklow X Sevier wheat. Jour. Amer. Soc. Agron. 23:916-928. 1931.

36. ___________. Miscellaneous genetic data from wheat crosses. Jour. Amer. Soc. Agron. 26:249-250. 1934.

37. ___________ and D. E. Heywood. Correlated inheritance in a wheat cross between Federation and a hybrid of Sevier X Dicklow. Jour. Agr. Res. 39:367-392. 1929.

38. ___________ and B. I. Judd. Inheritance of awns in a Kota X Hard Federation cross. Jour. Amer. Soc. Agron. 23:455-464. 1931.

39. ___________ and L. W. Nelson. Recurrence of a peculiar genetic recombination in the spike density of wheat. Amer Nat. 66:207-222. 1932.

40. ___________ and D. C. Tingey. A genetic recombination for the expression of awns in wheat. Amer. Nat. 62:532-539. 1928.

41. ___________ and R. W. Woodward. Inheritance in a wheat cross between hybrid 128 X White Odessa and Kanred. Jour. Agr. Res. 42:507-520. 1931.

42. Suneson, C. A. and W. K. Pope. Progress with Triticum X Agropyron crosses in California. Jour. Amer. Soc. Agron. 38:739-749. 1946.

43. Swenson, S. P., W. F. Buchholtz and J. E. Grafius. Complementary genes for leaf rust resistance and the inheritance of stem rust reaction and awnedness in a spring wheat cross. Agron. Jour. 39:739-749. 1947.

44. Tingey, D. C. and D. Tolman. Inheritance of resistance to loose smut in certain wheat crosses. Jour. Agr. Res. 48:631-655. 1934.

45. Tzitzin, N. V. What does crossing wheat with Agropyrum give? Plant Breed. Abs. 8:1156. 1937.

46. Quisenberry, K. S. and J. A. Clark. Inheritance of awn development in Sonora wheat crosses. Jour. Amer. Soc. Agron. 25:482-492. 1933.

47. Unrau, J. The use of monosomics and nullisomics in cytogenetic studies of common wheat. Sci. Agr. 30:66-89. 1950.

48. Watkins, A. E. and S. Ellerton. Variation and genetics of the awn in Triticum. Jour. Genet. 40:243-270. 1940.

49. White, W. J. Intergeneric crosses between Triticum and Agropyron. Sci. Agr. 21:198-232. 1940.

50. Worzella, W. W. Inheritance and interrelationship of components of quality, cold resistance and morphological characters in wheat hybrids. Jour. Agr. Res. 65:501-522. 1942.

51. Wismer, C. A. Inheritance of resistance to bunt and leaf rust in the wheat cross Oro X Tenmarq. Phytopath. 24:762-779. 1934.

APPENDIX

TABLE OF CONTENTS

App. Table 1.--Total number of tillers per plant of (Timstein X Comanche F_1) X Concho F_2, Comanche, Ponca and Concho at Stillwater, Oklahoma, 1951-52.

Number of Tillers per Plant	(Tim. X Com. F_1) X Concho F_2	Comanche	Ponca	Concho
	(Number of Plants)			
1	11	2	-	2
2	17	2	-	-
3	16	1	2	2
4	10	3	1	3
5	18	2	2	3
6	27	6	1	5
7	34	6	2	8
8	51	5	4	11
9	54	6	5	10
10	58	7	5	7
11	56	4	7	6
12	43	5	4	7
13	39	5	7	3
14	37	6	4	7
15	37	5	5	2
16	22	1	7	3
17	18	1	7	1
18	19	3	5	1
19	8	1	3	-
20	6	2	3	-
21	6	1	1	1
22	4	-	-	3
23	6	-	2	-
24	1	1	1	-
25	3	-	1	-
28	2	1	-	1
30	-	-	1	-
31	1	-	-	-
34	-	-	-	1
36	-	-	1	-

App. Table 2.--Number of tillers with fertile heads per plant of (Timstein X Comanche F_1) X Concho F_2, Comanche, Ponca, and Concho at Stillwater, Oklahoma, 1951-52.

No. Fertile Tillers per Plant	(Tim. X Com. F_1) X Concho F_2	Comanche	Ponca	Concho
	(Number of Plants)			
1	11	2	-	2
2	20	3	2	1
3	16	2	-	3
4	13	2	1	2
5	21	3	2	3
6	27	6	1	5
7	34	4	3	8
8	47	5	4	10
9	54	7	5	12
10	59	7	4	6
11	55	3	8	9
12	44	6	6	4
13	35	5	4	4
14	44	5	8	5
15	34	6	7	2
16	23	1	3	3
17	19	1	6	1
18	14	2	5	1
19	6	2	2	-
20	10	1	4	-
21	4	1	1	3
22	3	-	1	1
23	4	-	1	-
24	1	1	1	-
25	3	-	-	-
26	1	-	-	-
28	1	1	-	1
29	-	-	1	-
30	1	-	-	1
31	-	-	-	-
35	-	-	1	-

App. Table 3.—Height of plants of Concho, Comanche, Ponca, and (Timstein X Comanche F_1) X Concho F_2 at Stillwater, Oklahoma, 1951-52.

Height of Plants in Inches	(Tim. X Com. F_1) X Concho F_2	Comanche	Ponca	Concho
	(Number of Plants)			
15	1	-	-	-
18	1	1	-	-
19	-	2	-	-
20	2	-	-	1
21	-	-	1	1
22	2	-	-	-
23	3	2	-	1
24	3	1	2	-
25	7	5	2	3
26	8	3	2	5
27	4	2	1	2
28	12	3	8	7
29	17	2	6	5
30	22	8	10	9
31	24	10	11	9
32	49	5	6	9
33	74	11	8	11
34	64	10	5	11
35	68	5	10	3
36	85	4	2	8
37	59	2	6	2
38	51	-	1	-
39	29	-	-	-
40	13	-	-	-
41	4	-	-	-
43	2	-	-	-

App. Table 4.--Date of heading in May of (Timstein X Comanche F_1) X Concho F_2, Comanche, Ponca, and Concho at Stillwater, Oklahoma, 1951-52.

May	(Tim. X Com. F_1) X Concho F_2	Comanche	Ponca	Concho
	(Number of Plants)			
1	1	-	-	-
2	1	-	-	-
3	18	-	-	-
4	33	-	-	-
5	66	-	-	3
6	116	-	1	8
7	98	8	3	12
8	73	8	8	15
9	46	12	13	10
10	22	4	3	7
11	23	9	9	10
12	27	7	10	4
13	16	8	5	7
14	16	2	8	3
15	9	2	6	3
16	7	1	2	-
17	-	1	-	2
18	12	4	5	-
19	4	2	1	1
20	5	3	1	-
21	2	1	-	1
23	1	1	-	-
24	2	2	2	-
25	2	-	-	1
26	3	-	3	-
29	-	1	-	-

App. Table 5.—Classification of awns of F_1 plant 5731-2 in the cross of Concho X Triticum spp.- Agropyron elongatum F_3.

F_3 Family No.	F_2 Classification	F_3 Classification 2	3	4	5	Total Plants
		(Number of Lines)				
———	Aa/1	1	-	-	-	21
———	Aa	-	1	-	-	18
———	Aa	-	-	5	-	99
———	Aa	-	-	-	5	56
———	aa/2	-	-	2	-	18
———	aa	-	-	-	27	450
———	aa? Aa /3	-	-	-	1	18
		(Number of Plants)				
7120	Aa	8	16	-	-	24
7170	Aa	2	6	-	-	8
7127	Aa	-	3	21	-	24
7157	Aa	-	4	6	-	10
7160	Aa	-	1	13	-	14
7183	Aa	-	20	1	-	21
7206	Aa	-	2	6	-	8
7121	Aa	-	-	5	10	15
7106	Aa	-	-	8	15	23
7108	Aa	-	-	12	8	20
7138	Aa	-	-	11	10	21
7149	Aa	-	-	10	8	18
7173	Aa	-	-	3	22	25
7174	Aa	-	-	3	2	5
7179	Aa	-	-	2	1	3
7190	Aa	-	-	12	5	17
7191	Aa	-	-	9	5	14
7192	Aa	-	-	16	4	20
7205	Aa	-	-	14	10	24
7216	Aa	-	-	7	10	17
7223	Aa	-	-	10	11	21
7128	Aa	23	4	3	-	30
7109	Aa	-	1	5	14	20
7114	Aa	-	2	8	10	20
7116	Aa	-	15	5	2	22
7133	Aa	-	1	5	25	31
7153	Aa	-	5	20	4	29
7162	Aa	-	1	7	4	12
7172	Aa	-	2	12	6	20
7178	Aa	-	1	8	3	12
7193	Aa	-	5	2	7	14

Continued
App. Table 5.

F_3 Family No.	F_2 Classification	F_3 Classification 2	3	4	5	Total Plants
		(Number of Plants)				
7196	Aa	-	1	5	5	11
7198	Aa	-	6	15	6	27
7208	Aa	-	1	6	3	10
7218	Aa	-	1	8	6	15
7155	Aa	1	6	3	3	13
7182	Aa	2	12	2	2	18
7140	aa? Aa	-	-	5	17	22
7145	aa? Aa	-	-	20	5	25
7209	aa? Aa	-	-	7	5	12
7125	aa? Aa	3	-	6	17	26
7146	aa? Aa	-	3	14	9	26
7154	aa? Aa	-	5	12	7	24
7137	aa? Aa	1	1	11	10	23
7129	Aa? aa ∠4	-	1	25	-	26
7122	Aa? aa	-	-	19	5	24
7142	Aa? aa	-	-	1	19	20
7144	Aa? aa	-	2	11	4	17
7161	aa	-	1	12	-	13
7110	aa	-	-	3	18	21
7112	aa	-	-	6	15	21
7147	aa	-	-	11	7	18
7158	aa	-	-	13	4	17
7163	aa	-	-	5	4	9
7166	aa	-	-	7	2	9
7171	aa	-	-	8	5	13
7177	aa	-	-	10	8	18
7180	aa	-	-	11	8	19
7184	aa	-	-	11	6	17
7185	aa	-	-	15	8	23
7194	aa	-	-	6	9	15

Concluded
App. Table 5.

F_3 Family No.	F_2 Classification	F_3 Classification 2	3	4	5	Total Plants
		(Number of Plants)				
7195	aa	-	-	14	6	20
7210	aa	-	-	11	5	16
7215	aa	-	-	7	3	10
7113	aa	-	3	4	14	21
7126	aa	-	5	4	21	30
7152	aa	-	1	19	10	30
7159	aa	-	1	6	11	18
7217	aa	-	1	2	21	24

/1 Aa was the incompletely awned class in the F_2.

/2 aa was the completely awned class in the F_2.

/3 aa?/Aa Questionable as to whether incompletely or completely awned in the F_2 but placed in the incompletely awned class.

/4 Aa?/aa Questionable as to whether incompletely or completely awned in the F_2 but placed in the completely awned class.

App. Table 6.--Classification of awns of F_1 Plants 5731-3 in the Cross of Concho X *Triticum* spp.- *Agropyron elongatum* F_3.

F_3 Family No.	F_2 Classification	F_3 Classification 3	4	5	Total Plants
		(Number of Lines)			
----	Aa	6	-	-	73
----	Aa	-	19	-	212
----	Aa	-	-	20	202
----	aa	-	11	-	74
----	aa	-	-	39	408
		(Number of Plants)			
7238	Aa	2	4	-	6
7279	Aa	1	8	-	9
7282	Aa	2	13	-	15
7297	Aa	7	6	-	13
7243	Aa	-	7	7	14
7252	Aa	-	6	3	9
7256	Aa	-	1	15	16
7265	Aa	-	9	5	14
7270	Aa	-	10	1	11
7275	Aa	-	7	4	11
7284	Aa	-	9	1	10
7289	Aa	-	3	2	5
7314	Aa	-	3	1	4
7320	Aa	-	17	4	21
7312	Aa	1	-	7	8
7232	Aa	4	10	8	22
7259	Aa	1	8	12	21
7261	Aa	2	6	5	13
7262	Aa	3	10	11	24
7266	Aa	9	4	6	19
7274	Aa	4	5	4	13
7278	Aa	3	8	3	14
7294	Aa	1	12	4	17
7303	Aa	3	6	8	17
7346	Aa	2	6	6	14
7225	aa	-	12	6	18
7226	aa	-	9	12	21
7242	aa	-	3	15	18
7251	aa	-	6	10	16
7253	aa	-	4	11	15
7264	aa	-	2	5	7
7280	aa	-	4	4	8
7286	aa	-	8	3	11
7293	aa	-	4	2	6

App. Table 7.--Clavateness index of Concho X *Triticum* spp.-*Agropyron elongatum* F_2, Comanche, Ponca and Concho at Stillwater, Oklahoma, 1951-52.

Clavateness Index	Concho X *T.*spp.-*A.el.* F_2	Comanche	Ponca	Concho
	(Number of Plants)			
1.47	1	-	-	-
1.50	2	-	-	-
1.51	1	-	-	-
1.53	4	-	-	-
1.54	3	-	-	-
1.57	6	-	-	-
1.58	3	-	-	-
1.60	2	-	-	-
1.62	3	-	-	-
1.63	2	-	-	-
1.64	12	-	-	-
1.67	18	-	-	-
1.69	29	-	-	-
1.70	2	-	-	-
1.71	11	-	-	-
1.73	18	-	-	-
1.75	47	-	-	-
1.77	28	-	-	-
1.78	5	-	-	-
1.79	3	-	-	-
1.80	13	-	-	-
1.82	56	-	-	1
1.83	58	-	-	-
1.85	20	-	-	-
1.86	8	-	-	-
1.88	7	-	-	2
1.89	20	3	-	2
1.90	64	1	5	8
1.91	117	-	2	-
1.92	65	-	-	1
2.00	219	30	23	29
2.09	18	-	-	1
2.10	36	1	13	6
2.11	52	22	40	22
2.13	20	26	12	15
2.14	8	7	4	3
2.15	1	-	-	-
2.17	1	2	-	-
2.19	1	-	-	-

Concluded
App. Table 7.

Clavateness Index	Concho X *T*. spp.-*A*. *el*. F_2	Comanche	Ponca	Concho
	(Number of Plants)			
2.20	10	1	-	5
2.22	28	3	17	19
2.25	9	27	14	14
2.29	-	10	2	5
2.30	1	-	-	-
2.33	6	6	2	5
2.38	2	1	3	8
2.40	1	2	-	-
2.43	1	6	-	1
2.50	-	-	1	-

App. Table 8.--Number of tillers per plant of Concho X *Triticum* spp.-*Agropyron elongatum* F_2, Comanche, Ponca and Concho at Stillwater, Oklahoma, 1951-52.

Number of Tillers Per Plant	Concho X *T.*spp.-*A.el.* F_2	Comanche	Ponca	Concho
	(Number of Plants)			
1	17	3	-	3
2	16	3	-	2
3	19	4	-	-
4	33	6	2	6
5	65	10	1	11
6	54	12	6	14
7	88	11	6	19
8	105	14	7	8
9	99	9	10	13
10	103	16	3	13
11	98	14	9	17
12	72	14	10	7
13	77	9	8	6
14	51	4	13	7
15	27	2	10	3
16	40	5	10	11
17	17	4	15	3
18	15	1	6	2
19	15	1	6	2
20	11	3	2	-
21	4	-	1	-
22	3	-	3	-
23	4	1	4	-
24	2	-	2	-
25	2	1	2	-
26	1	-	-	-
27	1	1	1	-
28	1	-	-	-
29	1	-	1	-
30	1	-	-	-

App. Table 9.—Number of tillers with fertile heads per plant of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Comanche, Ponca and Concho at Stillwater, Oklahoma, 1951-52.

No. Fertile Tillers per Plant	Concho X *T.* spp.-*A.el.* F_2	Comanche	Ponca	Concho
		(Number of Plants)		
1	21	4	-	4
2	19	3	1	1
3	22	6	-	-
4	36	9	1	6
5	68	11	3	12
6	62	10	7	14
7	97	15	5	19
8	97	9	12	9
9	109	15	8	14
10	112	15	5	13
11	78	15	12	17
12	79	9	4	7
13	63	6	8	4
14	44	6	15	8
15	26	2	17	7
16	42	3	11	5
17	16	3	7	3
18	13	1	4	2
19	10	2	5	2
20	10	1	1	-
21	5	1	2	-
22	2	-	2	-
23	3	-	4	-
24	2	-	1	-
25	3	1	2	-
27	1	1	-	-
29	2	-	1	-

App. Table 10.--Height of plants of Concho X *Triticum* spp.- *Agropyron elongatum* F_2, Comanche, Ponca and Concho at Stillwater, Oklahoma, 1951-52.

Height in Inches	Concho X *T.* spp.-*A.el.* F_2	Comanche	Ponca	Concho
	(Number of Plants)			
14	1	-	-	-
15	2	-	-	-
16	2	1	-	-
17	5	-	-	-
18	6	-	-	-
19	3	-	-	-
20	16	2	-	2
21	19	1	-	-
22	32	4	1	-
23	38	4	2	1
24	47	8	8	6
25	66	5	8	6
26	85	9	6	5
27	90	5	8	13
28	95	7	7	19
29	90	11	10	15
30	122	25	17	22
31	75	17	13	15
32	68	19	15	16
33	59	15	14	14
34	48	10	13	7
35	39	3	10	3
36	15	2	3	3
37	9	-	3	-
38	4	-	-	-
39	4	-	-	-

App. Table 11.--Heading dates of Concho X *Triticum* spp. - *Agropyron elongatum* F_2, Comanche, Ponca, and Concho at Stillwater, Oklahoma, 1951-52.

Date Headed	Concho X *T.*spp.-*A.el.* F_2	Comanche	Ponca	Concho
	(Number of Plants)			
April				
30	1	-	-	-
May				
1	2	-	-	-
2	4	-	-	-
3	11	1	-	-
4	22	1	-	3
5	30	2	1	7
6	44	4	4	9
7	100	10	8	18
8	106	21	26	32
9	133	25	21	24
10	94	6	15	17
11	54	14	11	7
12	91	9	8	5
13	111	14	21	9
14	87	14	7	9
15	35	5	3	4
16	36	9	4	-
17	4	2	2	-
18	14	1	4	-
19	13	1	-	1
20	13	5	2	-
21	-	1	-	-
23	1	-	-	-
24	4	1	-	-
25	6	-	1	1
26	6	1	-	-
28	2	-	-	-
29	4	-	-	1
30	1	-	-	-
June				
1	1	-	-	-
2	1	-	-	-
3	2	-	-	-

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Thesis: DESCRIPTIONS AND AGRONOMIC EVALUATIONS OF F_2 AND F_3 POPULATIONS OF TWO WHEAT CROSSES

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