
Identification of a Substituted Chromosome Pair in a Triticum-Agropyron Line

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The genus *Agropyron*, although itself having no agricultural forms, has a number of useful characters such as drought resistance, winterhardiness and disease resistance that would be of value if transferred to wheat. The first successful attempt to cross *Agropyron* and *Triticum* was made by Tzitzin in 1930 (Schmidt et al. 1953) and since that time considerable work has been done by various workers to incorporate these characters into common wheat. At the Oklahoma Agricultural Experiment Station a wheatlike, stable line, resistant to leaf rust *(Puccinia recondita* Rob. ex Desm.) from the cross involving *Agropyron elongatum* (Host) Beauv. ($2n = 70$) and *Triticum aestivum* L. has been developed. The resistance in this line, besides being of a high degree, is also effective against a large number of rust races. This line shows normal vigor and fertility and yields moderately well. However, from the quality standpoint, it is not as desirable as Pawnee, a variety of common wheat commercially grown in Oklahoma and adjacent states.

Marshall and Schmidt (1954) from their studies on the advanced generation *Agropyron-Triticum* hybrids observed that, in certain of the Agrotricums, meiotic instability persisted, although they had become fairly well stabilized for disease reactions and morphological characters. Swarup et al. (1956) studied F_1, F_2, F_3 and backcross generations of a cross between an Agrotricum with chromosome number $2n = 56$ and *Triticum aestivum* cv. Pawnee. They found that the genes for resistance against wheat streak-mosaic virus were located on more than one *Agropyron* chromosome belonging to genome X or Y. Knott (1958) reported the results of a backcrossing program for the purpose of incorporating rust resistance from a *Triticum-Agropyron* hybrid [*Triticum aestivum* cv. Chinese X (Chinese X *Agropyron elongatum)*] into the wheat variety Thatcher. In the late backcross generations, the rust-resistant plants were selfed and homozygous resistant lines were obtained. These lines proved to be either substitution lines in which a pair of *Agropyron* chromosomes had replaced a wheat pair, or addition lines in which an *Agropyron* pair had been added to the wheat complement.

The main purpose of the present investigation, therefore, was to make a detailed cytological analysis of this *Triticum-Agropyron* line and its various F_1 hybrids with other wheats. It was expected that the information thus obtained would be useful in designing an appropriate breeding procedure for combining high quality as well as the *Agropyron* rust resistance into a single variety.

MATERIALS AND METHODS

The *Triticum-Agropyron* line (C.I.[1] 13020) reported here is the result of a selection from the cross *(Triticum aestivum* X *Agropyron elongatum)* X Pawnee. The *Triticum-Agropyron* hybrid in advanced generation was received from Kansas State College. This line has been designated as TAP 67 (derived from its particular parentage, i.e. *Triticum, Agropyron,* and Pawnee; and 67 being the selection number) and will be referred to as such in the following pages.

Meiotic behavior in TAP 67 was investigated. Also it was crossed with common wheat varieties Chinese Spring, Pawnee, Wichita, and Cheyenne and to the entire series (21) of monosomic lines in the variety Chinese Spring. The F_1 progenies also were examined cytologically.

Sporocytes were fixed in 6:3:1 Carnoy solution and stored in a refrigerator until used. For making smears one anther was used to find the appropriate meiotic stages and the other two anthers were put in 4% solution of iron alum (ferric ammonium sulfate) for 30-45 minutes. After washing in water for approximately 1-2 minutes, these anthers were transferred to acetocarmine where they were left for approximately 8 hours[2]. The anthers were smeared with a bent needle in 45% acetic acid. The chromosomes were destained in the acetic acid until the desired condition was reached, at which time pressure with the thumb was applied to the slide to remove the excess of acetic acid and to flatten the cells. To get good spreading of chromosomes, it was often helpful to tap the cells with the handle of the needle before applying the pressure.

EXPERIMENTAL RESULTS

Meiosis in TAP 67 - Since there was no information available on the chromosome number and meiotic behavior of this line, it was considered necessary to analyze the line cytologically before proceeding to study the

[1] C. I. refers to accession number of Field Crops Research Division, ARS, USDA (formerly Cereal Investigation).

[2] Oral communication from M. Muramatsu, at present doing graduate work in the Department of Genetics, University of Missouri, Columbia, Missouri.

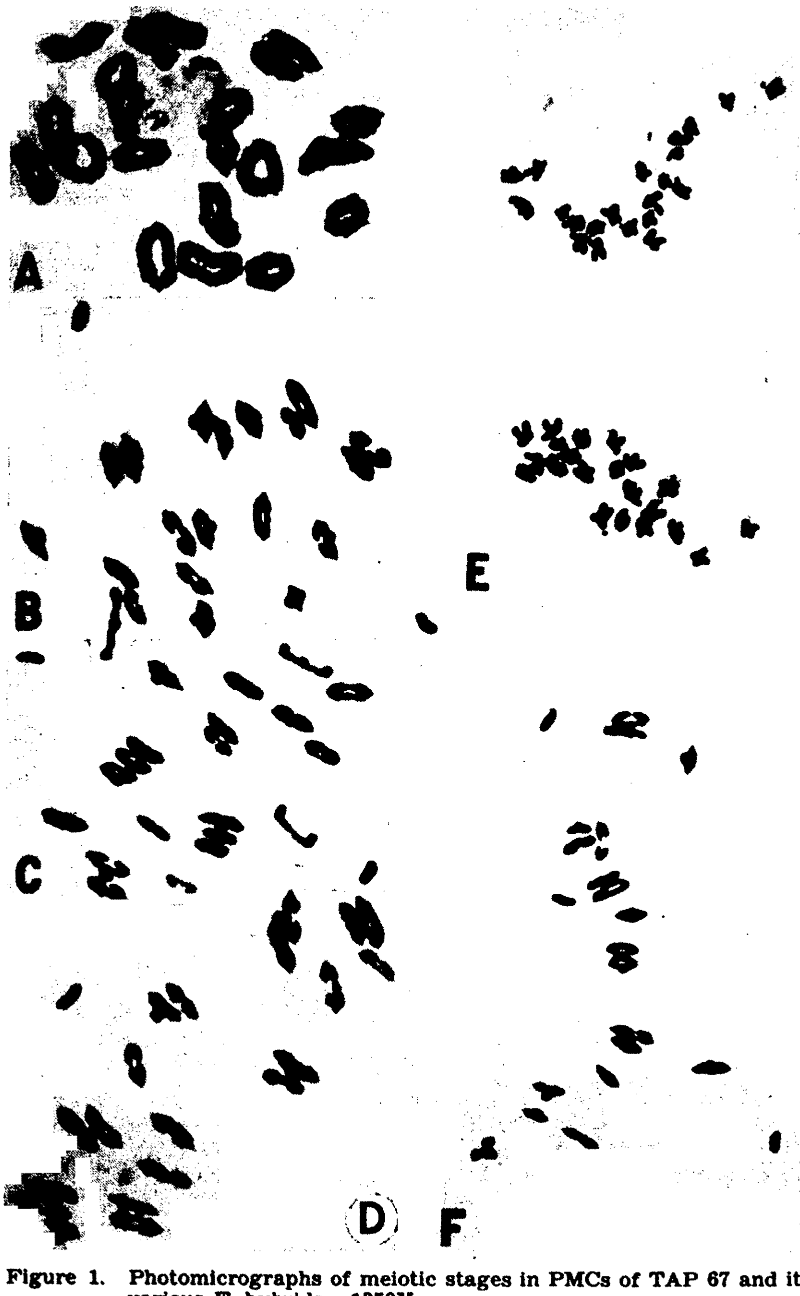

Figure 1. Photomicrographs of meiotic stages in PMCs of TAP 67 and its various F_1 hybrids. 1350X.

meiotic configurations in the various F_1 progenies.

The plants which were used for cytological analysis were picked at random. At metaphase I, regularly 21^{II} were obtained. Out of the 150 cells examined at diakinesis and metaphase I from 6 different plants, only 2 cells failed to show the normal configuration of 21^{II}. Both of these cells had 20^{II} and 2^{I}. The association between the homologous chromosomes appeared to be strong since most of the time they formed closed bivalents (chiasmata in both arms) (Fig. 1-A). The separation of the chromosomes at anaphase I also appeared to be normal (Fig. 1-E). Micronuclei both at the dyad and tetrad spore stages were rare. From these observations, it appears that the line is quite stable meiotically.

Meiosis in F_1 hybrids — Crosses were made between TAP 67 and the wheat varieties Chinese Spring, Pawnee, Wichita and Cheyenne, and all were analysed cytologically. In the microsporocytes of these F_1 hybrids at metaphase I, regularly 20^{II} and 2^{I} were formed (Fig. 1-B and C). This indicates that TAP 67 lacks a pair of wheat chromosomes and has instead a pair of chromosomes for which no homologue is available in common wheat. From these observations it can be concluded that in TAP 67 a pair of chromosomes from *Agropyron elongatum* has been substituted for a pair of wheat chromosomes.

Identification of the substituted wheat chromosome — To identify the pair of wheat chromosomes lacking in TAP 67, it was crossed with all the 21 monosomic lines in the variety Chinese Spring. In the deficient gametes, from each of these monosomic lines, one particular chromosome was lacking. Therefore, PMCs in all the monosomic F_1 plants are expected to show 19^{II} and 3^{I} at metaphase I (Fig. 1-F), except in the case of the F_1 with the critical monosome, which lacks the same wheat chromosome that has been replaced in TAP 67. Therefore, the cells of such F_1 plants at metaphase I will have 20^{II} and 1^{I}, with the univalent being from *Agropyron*. Such meiotic configuration was observed only in the F_1s involving monosome XVI as seen in Fif. 1-D. This indicates that in this line chromosome XVI from wheat has been replaced by the *Agropyron* chromosome. Knott (1958) also used monosomic lines to identify the substituted chromosome in his stem-rust resistant substitution lines. He found chromosome VI to be lacking in these lines.

DISCUSSION

The substitution line TAP 67, as mentioned before, is normal for vigor and fertility and compares favorably with Pawnee with regard to these characters. Nullisomic plants for chromosome XVI in the variety Chinese Spring are reported to be weak and almost entirely lacking in fertility (Sears, 1954). This indicates that the *Agropyron* chromosome is able to furnish considerable genetic compensation for the loss of chromosome XVI of wheat, as far as these characters are concerned. However, it has been observed in TAP 67 as well as in some other lines having *Agropyron* resistance (evolved by backcrossing and deriving *Agropyron* resistance from TAP 67) that they are quite inferior in quality to the agronomically desirable susceptible varieties used as recurrent parents.

Figure 1

A. Diakinesis in TAP 67, 21^{II}.
B. MI in an F_1 of Pawnee X TAP 67, 20^{II} 2^{I}.
C. MI in an F_1 of Chinese Spring X TAP 67, 20^{II} 2^{I}.
D. MI in an F_1 of Monosome XVI X TAP 67, 20^{II} 1^{I}, the univalent being an *Agropyron elongatum* chromosome.
E. AI in TAP 67, 21 chromosomes at each pole.
F. MI in an F_1 of Monosome I X TAP 67, 19^{II} 3^{I}. (930 X)

This poor quality could be due either to a lack of compensation for all the genes for quality on the lost chromosome, resulting in the net loss of certain quality genes or to the actual presence of certain deleterious genes for quality on the *Agropyron* chromosome. It could also be due to the unfavorable interactions between the genes on this chrmosome and the genetic backgrounds. Further studies are in progress to determine specifically the effects of this chromosome on quality.

Several methods could be followed for improving the quality while still retaining the *Agropyron* chromosome for the high degree of leaf-rust resistance. However, the choice of a particular method would be determined by the factor or factors which alone or in combination are responsible for lowering the quality. One method would be to substitute the *Agropyron* chromosome for chromosome XVI of wheat in different wheat varieties of high quality. By this method, it could be possible to find a genetic background with which the interaction of the genes on the *Agropyron* chromosome might be more favorable and also probably where the quality genes with additive effect might be more numerous. A large number of crosses with different varieties may have to be attempted before a suitable genetic background is found.

Another method would be to substitute the *Agropyron* chromosome for wheat chromosomes other than XVI and produce substitution lines for all other 20 chromosomes in Pawnee as well as in other agronomically desirable high-quality wheats. If the wheat chromosome that is absent in any particular substitution line is less important than chromosome XVI, the line will show better bread-making quality and, therefore, would be more desirable.

Since the *Agropyron* chromosome does not pair with any of the wheat chromosomes, a third method would be the use of radiation or some other mutagenic agent. This method might be useful in transferring, through translocation, the resistance without the undesirable genes from the *Agropyron* chromosome to that of wheat as suggested by Sears (1956). This would be particularly promising if the resistance is due to a single gene or due to two or more closely-linked genes, since it is desirable to transfer only a small segment of the chromosome so that along with the resistant gene or genes few deleterious genes are transferred.

SUMMARY

Cytological studies of a *Triticum-Agropyron* line (TAP 67), along with its F_1 hybrids with common wheat, were made. It was observed that this line was regular in its meiotic behavior and had an *Agropyron* chromosome substituted for one of wheat. Monosomic analysis revealed that this line lacked the wheat chromosome XVI.

The genetic factors which might be responsible for the poor quality in this line, in spite of its being normal in vigor and yield, and in other similar lines are pointed out. Also certain methods are suggested which could be used for improving the quality while still retaining the high resistance to leaf rust contributed by *Agropyron*.

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