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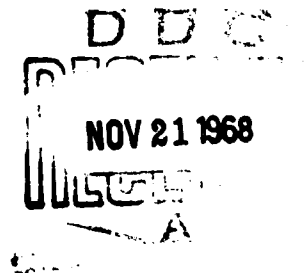
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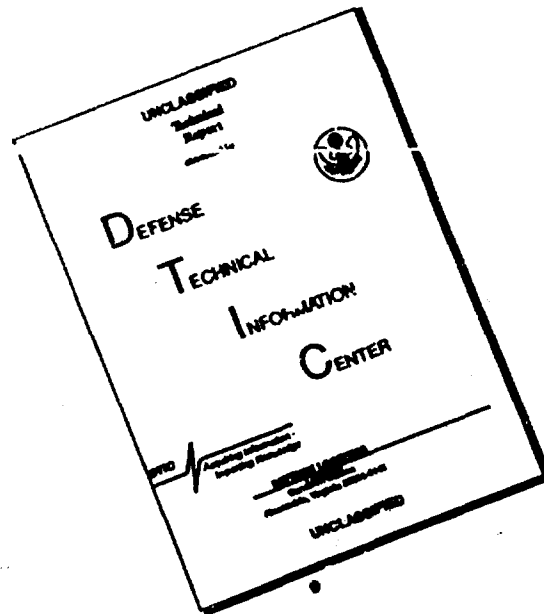
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**APPLICATION OF THE REMOTE HYBRIDIZATION METHOD
TO WINTER WHEAT BREEDING**

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In 1940 Academician N.V. Tsitsin organized the Laboratory of Wheat-Agropyron Hybrids at our institute. The task set forth was to use the economically valuable characters and properties of wild couch grass in developing new varieties of winter wheat.

In the course of the hybridization work it was established that of the many couch grass species (79) that grow in our country, those that can be readily crossed with all wheat species except triticum monococcum number only four, namely: grey, elongated, pubescent, and solonets couch grass.

The most interesting for practical breeding work, as shown by our experiments, is grey couch grass (*Agropyron glaucum*), which has a set of useful characters: very hardy in the winter (does well over a winter at temperatures of minus 40-45° with no snow), perennial life, resistance to fungus diseases, high protein content in the grain (20-22%), large productive tillering, multiflowered spikes (up to 13) and much grain (up to 5000 per plant).

Grey couch grass is the closest wild relative of wheat. This plant is widespread on all continents, which is indicative of its exceptional adaptability to various ecological conditions and endurance.

In spite of the difficulty of obtaining a hybrid

progeny from crosses between wheat and couch grass, which is related to overcoming the sterility of the first generation, extensive and valuable material has been obtained at the laboratory in a relatively short period of time, and it has enriched and advanced theoretical and practical remote hybridization.

Let us dwell briefly on the results and prospects of crossing soft winter wheat with grey couch grass.

Hybrids from crosses between 42-chromosome soft wheat and 42-chromosome couch grass (grey) are produced in accordance with the following system: (wheat x couch grass) x wheat. In the second, third and subsequent generations of hybrids from such a cross there is an extensive and complex form-producing process resulting in appearance of many diverse constant forms of plants. We have arbitrarily divided all these forms into three groups according to type of spike and number of chromosomes: 1) 42-chromosome hybrids with wheat type spike; 2) 56-chromosome hybrids with intermediate type spike, and 3) 42-chromosome and 56-chromosome hybrids with couch grass type spike.

The first group is of greatest interest for selection of economically valuable forms. As a rule the hybrids in this group do not differ from soft wheat with respect to morphological characters but, having *Agropyron* genes in their chromosome set, they are resistant to diseases, highly productive, nonlodging, hardy and have other valuable properties. Three such 42-chromosome winter hybrids, PFG 186, 599 and No 1, have been released to regions and are being cultivated in 18 oblasts and republics in our zone. They differ from other cultivars of winter wheat now in production by their high productivity, hardiness, early maturation, resistance to fungus diseases, to lodging, and along with this they have a large grain and good baking qualities.

Thus, the mean PFG harvest over a 20-year period of strain testing at the institute constituted 42.8 centners per hectare. Under production conditions in the nonchernozem zone it has produced record harvests in some years: up to 60-70 centners of grain per hectare.

During the last two years we transmitted two more wheat-*Agropyron* hybrids for state strain testing. One of them, PFG 99 (Figure 1) merits attention; during the strain testing period at the institute it surpassed the yield of

standard PFG 186 by 5.1 centners per hectare.

This new cultivar is notable for early maturation, it is hardier in the winter, totally insusceptible to powdery and kernel smut when artificially infected, does not shed, is easily threshed, resists lodging, and has good baking qualities.

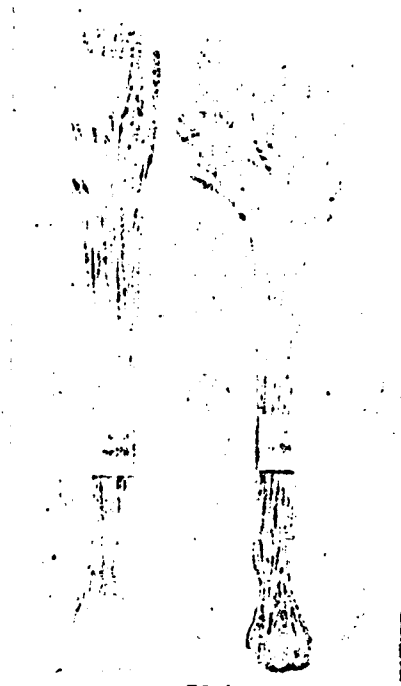
According to the data of the Moscow Oblast Inspection Offices of the State Commission, during the two years of testing PFG 99 yielded 3.1 centners more per hectare than the standard.

At present there are many new promising specimens and strains at the Laboratory of Wheat-Agropyron Hybrids. In 1966 a study was made of 20 new specimens in a competitive strain test, 14 of which surpassed the productivity of standard variety, PFG 186. In three of the most promising specimens (260, 99/8 and 258), the harvest increment constituted 5-7.6 centners per hectare. In addition, 73 specimens underwent preliminary strain testing and 41 of these surpassed the standard harvest. Eleven specimens stood out among these new breeding materials, and their yield was higher than both the standard PFG 186 and Mironovskaya 808.

In contrast to the first group of hybrids, those in the second group (56 chromosomes) had 14 couch grass chromosomes rather than genes and consequently they have more of the couch grass characters and properties.

With respect to appearance and, first of all, spike type, these hybrids occupy an intermediate place between wheat and couch grass. Among them are forms that have inherited from wheat the annual form of life, self-pollination, lobular root system, large size and color of grain, structure of ear husk, and forms that inherited from couch grass resistance to diseases, hardness, perennial form of life, maturation of the plants from top to bottom, cross pollination, green grain color and other characters.

The hybrid plants also present new characters absent from the initial forms. The spike is of an intermediate type, spike ramification is usual and tassellate, there are typical multiple flowers (up to 18), presence of two ears on one level of the spike stem and high protein content in the grain (over 25%).



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Figure 1. Sheaves of winter wheat. On the right -- promising PFG 99; on the left -- standard PFG 186.

The cytogenetic studies performed at our laboratory recently have indicated that the constant forms of intermediate 56-chromosome hybrids vary with respect to genotype. It is known that the chromosome set of soft wheat consists of genomes A, B, D and that of grey couch grass -- genomes B, D, X. The additional 14 couch grass chromosomes in these hybrids are referable to different genomes: in some forms they belong to couch grass genome D, in others to genome X. Therefore there is different manifestation of couch grass and wheat characters in intermediate hybrids.

The presence of constant forms of intermediate

hybrids with different genomes of couch grass indicates that the breeder has new and valuable forms of plants at his disposal. Earlier we considered this type of plants merely as a side product obtained in hybridizing wheat and couch grass and of no interest to the breeder because of the low yield. Further studies revealed that it is possible to obtain plants with the appearance and spike of wheat not only from a direct hybridization of wheat and couch grass as had been done heretofore, but also by crossing intermediate 56-chromosome hybrids with different genome composition with one another. This results in highly productive hardy wheat plants with good grain and many economically useful couch grass characters.

It may be that in the future wheat and couch grass hybridization will proceed in the direction of creating mediators, intermediate 56-chromosome forms of hybrids which, when crossed with one another or with wheat, can produce better forms and varieties of wheat. Thus the structure of the genome composition of constant intermediate wheat-Agropyron hybrids which we have determined permits an utterly new approach to the problem of their future use.

On the basis of laboratory studies on hybridization of many varieties of winter wheat with grey couch grass, the following conclusions can be drawn:

1. Grey couch grass, like the other widely distributed natural Agropyron species, represents a very heterozygous population. Therefore before undertaking hybridization of wheat and couch grass a thorough study must be made and initial couch grass material must be selected.

2. It is best to use wheat as the maternal form. In this case more hybrid seeds (25-90%) germinate, first generation hybrid sterility is easier to overcome and the form-producing process proceeds in the direction of intermediate and wheat types. When couch grass is used as the maternal plant, the percentage of hybrid seed germination is very low and the first generation hybrids are sterile; it is almost impossible to overcome the sterility by repollination with wheat pollen. The form-producing process goes in the direction of couch grass type hybrids.

3. Not all winter wheat cultivars can be readily crossed with couch grass or yield equivalent hybrid breeding material. Best results are obtained from crosses

between couch grass and winter wheat of hybrid origin (RFG 46/131, RFG 434/154, Hostianum 237, Erythrospermum 648, Erythrospermum 118).

4. There is dominance of couch grass characters in first generation hybrids: perennial life, great winter hardiness and resistance to frost and fungal diseases, long friable spike, sturdy stalk.

5. The best method to overcome sterility in first generation hybrids is repollination with wheat pollen.

6. There is extensive form-producing activity in second, third and fourth generation hybrids with respect to such characters as type of spike, perenniality, winter hardiness, immunity, fertility, early maturation and others. Plants with a wheat-type spike begin to segregate in the second generation.

7. From the fourth generation on, the form-producing process begins to recede. Among the progeny of this generation of hybrids already about 70-80% of the forms are constant with respect to morphological characters and they are used as initial material for selection of economically valuable forms.

8. As a result of the form-producing process there emerge 42-chromosome wheat-Agroropyron hybrids with soft wheat type spike to which the following characters are the most readily transmitted: nonlodging, resistance to powdery and kernel smut, early maturation and productivity.

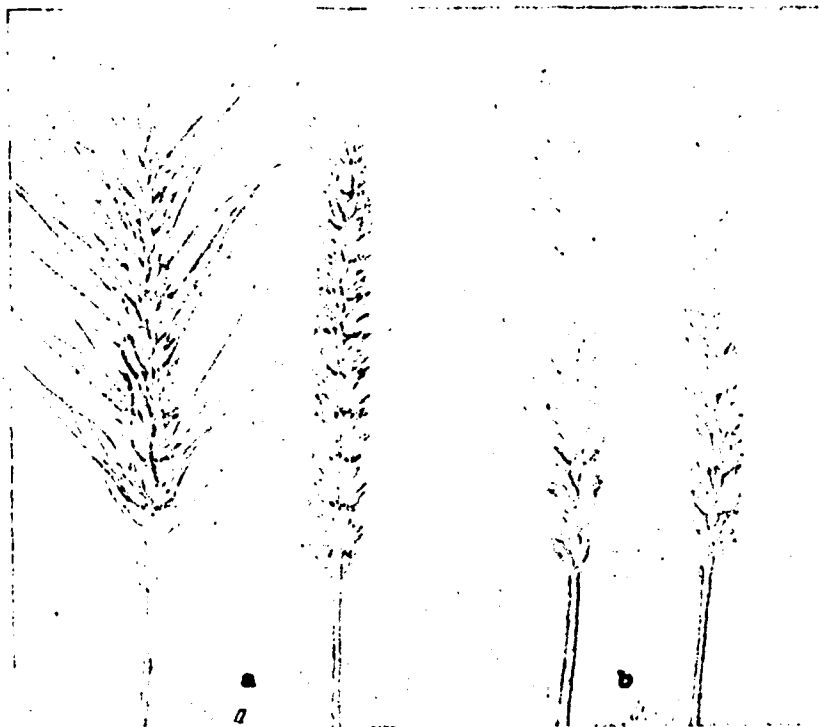
9. Involvement of couch grass in hybridization is one of the actual means of increasing frost resistance and hardiness of winter wheat. The intermediate 56-chromosome wheat-couch grass hybrids that we developed survive the winters even under the rigorous conditions of Siberia.

10. Cytological studies performed at our laboratory revealed that the supernumerary 14 couch grass chromosomes in the intermediate 56-chromosome hybrids are referable to different genomes. This reveals new directions in the use of intermediate forms of hybrids in breeding work.

Our experience in hybridization of wheat with couch grass and the vast experimental material we have accumulated make it possible to set forth new tasks in the field

of remote hybridization, the performance of which is of great theoretical and practical importance.

Of great interest, first of all, is the matter of creating wheat with a high protein content in the grain.



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Figure 2. Spikes of high protein hybrids obtained from crosses

Legend: a) PPG x winter wheat; b) PPG x Derzhavin RPA.

On the basis of the hybrid material available, the laboratory has already undertaken the creation of such winter

wheat varieties for the nonchernozem zone. Extensive and diverse initial material is used in the crosses: intermediate (PPFG) wheat-couch grass hybrids with high protein content in the grain (20-24%), high protein rye-wheat amphidiploids (RPA) from different zones of the USSR and other countries. Hybridization is performed as follows: PPFPG x PPFPG, PPFPG x wheat, and PPFPG x RPA. The morphologically constant hybrids of the wheat type obtained from these crosses are notable for high spike productivity (50-60 grains) and high protein content (18-20 or more percent) (Figure 2).

Thus, as indicated by the preliminary results of the studies, a new means of developing high-protein wheat has been outlined.

Wheat-couch grass hybrids, being complex with respect to their hereditary basis, are a valuable object to be exposed to ionizing radiations and chemical mutagens. It is known that ordinary wheats are not very mutable. The data from our studies indicate that ionizing radiations and chemical mutagens induce an extensive mutation process in wheat-couch grass hybrids, a large number of diverse mutants appears and they can be used either directly as cultivars or as valuable initial material for hybridization.

The mutants we produced were tested in 1965-1966 in preliminary and competitive strain tests. Five mutants were singled out whose yield is 5-8 centners per hectare higher than the standard; they have a short nonlodging stalk, a solid and well-grained spike and large grain.

Among the cultivated wheat cultivars there is not a single one, as we know, that is resistant to many species of fungi, including aggressive strains of stem rust. The efforts of many scientists and breeders are directed toward solving this very difficult and important problem. Our experience indicates that such forms can be quickly developed by crossing wheat with couch grass. Much initial material has been obtained at the laboratory which is resistant to powdery and kernel smut and various forms of rust. Experiments performed in 1965-1966 with artificial infection of the material in question revealed that 75% of the constant intermediate hybrids were resistant to stem rust. The material available to us permits us to hold the hope of developing winter wheat cultivars with group immunity.

Recently both here and abroad work has begun for the

use of cytoplasmic male sterility in wheat breeding. However, in creating hybrid wheat on the basis of CMS [cytoplasmic male sterility] some difficulties are encountered. This is related first of all to the fact that the existing fertility restorers do not provide normal fertility in the hybrids. In addition, when shifting to a sterile basis for wheat varieties, along with sterility undesirable characters are transmitted: brittleness of the spike, late maturation, irregular maturation of hybrid plants, and others. For this reason new sources of CMS have to be sought. In this respect wheat-couch grass hybrids will apparently be of great interest. Rather often plants with sterile pollen appear in the course of form-production in wheat and couch grass hybrids.

Previously no attention was paid to these forms. However the preliminary studies conducted in 1965-1966 indicated that they could be of value to obtain heterotic wheat.

In our work with wheat-couch grass hybrids, extensive cytogenetic studies enabled us to take a new direction, to use haploidy in developing new winter wheat varieties. This method is particularly valuable in remote hybridization since the latter itself induces haploidy.

Doubling the number of chromosomes in the haploids results in rapid production of totally homozygous strains (analogous to inbred strains) which permit creation of new initial material as the result of manifestation of recessive characters previously latent in the hybrid plants. This will permit the creation of new constant forms with a combination of the most useful characters of both genera: wheat and couch grass.

In order to create large-spiked, highly-productive and hardy winter wheat varieties our laboratory is performing more complex crosses, using wheat, rye and couch grass in hybridization. At the present time some original constant large-spiked forms with great hardiness, thick and sturdy stalk, resistance to fungal diseases have been obtained from such trigeneric crosses. Their spike is solid and long with 28 to 32 ears instead of 20-25 in ordinary wheat. Grain content is very high, the number of grains per spike reaches 120-150 versus 45-55 in ordinary wheat. The grain is large (weight per 1000 grains: 45-50 grams), it is well-filled and regularly shaped. Protein content of the grain is 17-19%.

Thus, remote hybridization reveals endless possibilities to the breeder with respect to improving existing varieties and developing new winter wheat cultivars.

Winter wheat breeding by the remote hybridization method is a complex problem and its future successful solution is related to the extensive application of modern advances in the field of genetics, cytology, biochemistry and other allied branches of biology.