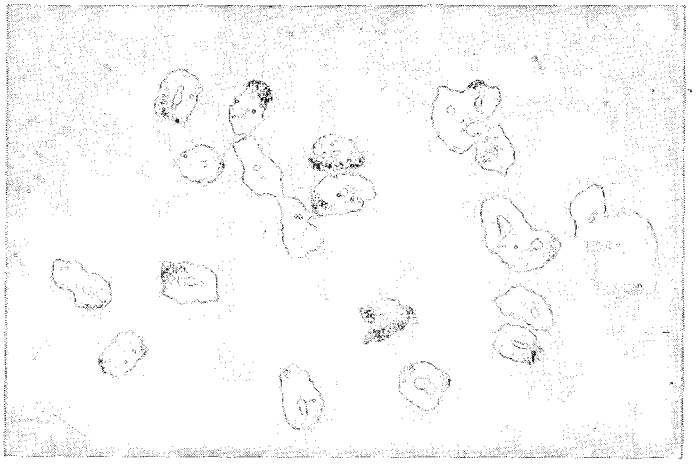
WHEAT INFORMATION SERVICE



No. 31 October, 1970

Wheat Information Service
Biological Laboratory, Kyoto University
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I. Research Notes

Callus formation in wheat anthers[1)]

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Anthers containing pollen grains at tetrad stage in diploid, tetraploid and hexaploid wheats were used as the materials. They were planted on modified White's medium supplemented with 20 mg/l of 2, 4-D and solidified with 0.9% agar in a test tube. They were incubated under dark condition and constant temperature of 25°C. The pH of medium was adjusted to 5.8. Callus formations started about 4 weeks after planting. Differences in the production of callus among the species were observed and the results are given in Table 1. Among diploid species, about 3% of explants formed callus in the wild *T. aegilopoides,* while the tendency to callus formation was very low in the cultivated *T. monococcum.* A similar tendency was also observed in tetraploid species, namely, wild *T. dicoccoides* showed a relatively high callus production of about 18%, and no callus at all was found in about 600 explants of cultivated *T. durum.* It is interesting that no callus was observed in two cultivated hexaploid wheats, *T. aestivum* and *T. spelta,* so far examined. Callus tissues obtained from the above diploid and tetraploid species could be successfully subcultured with the same or other kinds of synthetic medium and have been maintained over several passages up to present. Although the ability to form callus is lower in diploid than in tetraploid species, its growth was better in the former. The use of haploid or polyhaploid callus cells for mutation experiments is under way. In spite of the very slow growth, modified White's medium supplemented with 2,4-D was the best for wheat anthers, among three types of medium, namely, Erickson's, and Murashige and Skoog's.

Callus induction was also tried in roots of diploid wheats, maize and *Arabidopsis* which are our materials for mutation experiments. Calli were formed easily in these materials, and their growth was more vigorous than of those obtained from anthers. Roots were

1) Presented at 5 minutes communication of the 2nd International Conference of Plant Tissue Culture held in Strasbourg, 9 July, 1970.

Table 1. Ability to form callus in di-, tetra- and hexaploid wheats

Strain	Number of explants	Number of anthers with callus (%)
Diploid wheats		
T. aegilopoides	698	23 (3.3)
T. monococcum	2410	0
〃 (5030)*	979	0
〃 (5031)*	1733	2 ?
〃 (5074)*	509	0
〃 (5075)*	1001	0
Tetraploid wheats		
T. dicoccoides	492	86 (17.5)
T. durum	592	0
Hexaploid wheats		
T. spelta	638	0
T. aestivum	631	0

* Homozygotic strain of X-ray induced recessive mutant.

formed from *Arabidopsis* callus on modified White's medium while wheat and maize did not form roots on the same medium. Requirements for callus formation and differentiation must be different by different materials. (The guidance in culture techniques of Dr. Hiroo NITZEKI is gratefully acknowledged.)

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Aneuploid analysis of chromosome pairing in *Triticum timopheevi*

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In a comparative study of the meiosis in 41- and 42-chromosome hybrids between Chinese Spring monosomic for chromosome 5B and *Triticum zhukovskyi*, UPADHYA and SWAMINATHAN (1965) found that the number of chromosomes entering into associations increased in 41-chromosome hybrids where 5B of Chinese Spring was absent. On the basis of these findings it was suggested that the genetic mechanism, similar to that found on the chromosome 5B of Chinese Spring (*Triticum aestivum*), might not be present in *T. zhukovskyi*. It was also suggested that *T. zhukovskyi*, a natural autoallohexaploid, which presumably arose from the cross *T. timopheevi* × *T. monococcum* (UPADHYA and SWAMINATHAN 1963), *T. timopheevi* also lacks the gene system of 5B of *T. aestivum*. This paper deals with a comparative study of meiosis in the 34- and 35-chromosome hybrids of the

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cross between mono-5B of chinese Spring and *T. timopheevi*.

Triticum aestivum sub sp. *vulgare* var. Chinese Spring, monosomic for chromosome 5B (2n=41) was crossed with *T. timopheevi* ZHUK. (2n=28) and in the F_1 meiotic metaphase I was studied in the 34- and 35-chromosome hybrids. It was observed that the chromosomes which entered associations as trivalents, quadrivalents and pentavalents were more in the 34-chromosome hybrid than in the 35-chromosome one. These differences in the multivalent associations were found to be statistically significant. This shows that chromosome 5B of *T. timopheevi*, equivalent to 5B of Chinese Spring is unable to supress pairing of homoeologous chromosomes to the degree controlled by 5B of Chinese. This, therefore, indicates that chromosome 5B of *timopheevi* does not possess a gene system similar to that located on 5B of *T. aestivum*.

FELDMAN (1966 a) studied chromosome pairing in the 41- and 42-chromosome hybrids between Chinese Spring mono-5B and amphidiploid of the cross *T. timopheevi* × *Ae. squarrosa* and suggested that since the mean pairing values were similar in the two types of hybrids, the *timopheevi* chromosome which corresponds to 5B of Chinese Spring compensates completely for the nullisomic condition of 5B of Chinese Spring and, therefore, *timopheevi* contains a gene system on this chromosome identical with that found in chromosome 5B of *aestivum*. Since the present data support the findings of UPADHYA and SWAMINATHAN (1965), it is worth while re-examining the evidence presented by FELDMAN (1966 a).

The genomic constitutions of *T. zhukovskyi*, *timopheevi-squarrosa* amphidiploid and the two types of 41-chromosome hybrids of these with mono-5B of Chinese Spring, with respect to the homoeologous group 5, are tabulated below.

Material	2n	Genome	Homoeologous group 5
T. zhukovskyi	42	AAAABB	5A *tim*+5B *tim*+5A *mono*, each in two doses.
timopheevi-squarrosa amphidiploid	42	AABBDD	5A *tim*+5B *tim*+5D *squa*, each in two doses.
Mono-5B × *timopheevi-squarrosa* amphidiploid	41	〃	2 of 5A+1 of 5B *tim*+2 of 5D
〃 × *zhukovskyi*	41	AAAABB	3 of 5A+1 of 5B *tim*+1 of 5D

tim : *T. timopheevi*, *mono* : *T. monococcum*, *squa* : *Ae. squarrosa*.

FELDMAN (1966 b) has shown that with respect to pairing, four doses of 5A compensate for the nullisomic condition of 5D in the presence of two doses of 5B in Chinese Spring. Further, according to him, tri-5A mono-5D along with atleast one dose of 5B of *aestivum* (since 5B is haplo sufficeint) should, therefore, have normal synapsis. But the 41-chromosome hybrid between monc-5B and *T. zykovskyi* (Table) having one dose of 5B from *T. timopheevi* with tri-5A+mono-5D, had shown increased chromosome associations; whereas 41-chromosome hybrid between mono-5B × *timopheevi-squarrosa* amphidiploid having one dose of 5B from *timopheevi* with di-5A+di-5D, had shown normal pairing. It is thus clear

that one dose of 5D was unable to complement the 5B of *timopheevi*, but two doses of 5D were able to complement 5B of *timopheevi* to bring about normal pairing.

On the basis of these data the following inferences can be drawn.

1. That chromosome 5A of *T. monococcum* present in *T. zhukovskyi* is not identical to the 5A of Chinese Spring (*T. aestivum*) or 5A of *T. timopheevi*, with respect to the genes controlling chromosome pairing.

2. That UPADHYA and SWAMINATHAN (1967) observed that the absence of chromosome 3D in the 27-chromosome hybrid between Chinese mono-3D and rye showed significant increase in the homoeologous pairing among wheat chromosomes. This has been shown by MELLO-SAMPAYO (1968) to be due to the presence of an inhibitor of homoeologous chromosome pairing on chromosome 3D of Chinese Spring. With respect to 3D, the chromosome complement of the 41-chromosome hybrid between mono-5B and *timopheevi-squarrosa* amphidiploid is: 1 of 3D Chinese+1 of 3D *squarrosa*, whereas in the case of 41-chromosome hybrid of mono-5B×*zhukovskyi*, there is only one dose of 3D of Chinese. It, therefore, appears that one extra dose of 3D from *squarrosa* in the first case was able to complement further the action of 5B from *timopheevi*.

3. That the potency of chromosome 5B of *T. timopheevi* appears to be of much lower order than the potency of 5B of *T. aestivum*, and that 5B of *timopheevi* does not therefore, compensate fully for 5B of Chinese Spring.

4. That chromosomes 3D and 5D present in the hexaploid wheats and carrying genes controlling homoeologous chromosome pairing were originally carried by the donor of the D genome, *Ae. squarrosa* and that present day *squarrosa* also carries them.

5. That the corresponding chromosome 5A of *T. monococcum* in *T. zhukovskyi* does not carry the gene system identical to that located on 5A of *T. aestivum*; as such the 5A system of *aestivum* very likely appeared after the incorporation of the A genome in tetraploid wheats.

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Genetic variability for different physical characters in wheat kernels

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Introduction

Quality of wheat is an important consideration which determines its use in any one of the several kinds of products made from it. Hard wheats which are high in protein are used for bread making, whereas soft low protein wheats are good for making cakes and cookies. Kernel texture is related to specific gravity of the grains which is associated with milling quality (SHOLLENBERGER and COLEMAN 1926). Similarly, the hardness and test weight of the grains are other important factors which may affect the flour return.

Although evironmental conditions have been found to alter the quality characters of wheat kernels, considerable varietal differences have also been observed.[2)] Little information is avialable in the literature regarding the specific gravity and hardness of wheat kernels. The present investigation was undertaken to study the extent of genetic variability present for various kernel characters and determine the extent of correlation between them. To include diverse wheat stocks, strains from India, Mexico, U.S.A., Australia and Canada were included in the present study.

Material and Methods

Eighty strains comprising of important varieties and other strains from diverse source origin were picked from the wheat collection maintained at Punjab Agricultural University, Ludhiana. These were planted in a randomized block design with 4 replications. Each strain was represented in every block by two rows 3 meter long. The experiment was conducted at Ludhiana during the winter season of 1967~68. The entire row was harvested at maturity and the grain yield was recorded in grams. The test weight was determined for 1000 kernel weight. The specific gravity of the kernels was determined as weight of 1000 kernels in gm/volume of water displaced by them in ml. Kernel hardness was measured with the help of Hardness Tester, manufactured by Kiya Seisakusho Ltd., Tokyo, Japan. The data were analysed by analysis of variance. Heritability estimates in broad sense, genetic advance and correlation coefficients were calculated in the usual manner.

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2) From Wheat Flour Institute, Chicago, Illinois, U.S.A. 1965.

Results

The range of variability, heritability estimates and genetic advance for different characters are given in Table 1 and the correlations among different characters are given in Table 2.

Table 1. Range of variability, heritability estimates and genetic advance for various kernel characters in wheat

Character	Range of variability	Mean	C.D. at 5%	Heritability estimates	Genetic advance (%)
1000 kernel weight	22.10～54.20gm	39.10	10.44	23.48	10.69
Specific gravity of kernels	1.04～ 1.73	1.21	0.15	79.76	20.75
Kernel hardness	6.50～14.40kg	11.48	0.89	84.52	24.65

Table 2. Phenotypic correlations between different kernel characters and grain yield in wheat

Character	1000 kernel weight	Kernel hardness	Specific gravity of kernels
Kernel hardness	−0.038		
Specific gravity of kernels	+0.056	−0.272*	
Grain yield	+0.223*	−0.220*	−0.192

* Significant at 5%.

There were considerable differences among strains for 1000 kernel weight which varied from 22.10 to 54.20 gm with a mean of 39.10 gm. The heritability estimate for 1000 kernel weight was quite low (23.48) and its expected genetic advance was 10.69% of the mean. The specific gravity of the kernels differed markedly, the range being 1.04 to 1.73. The heritability estimate for this character was high (79.76). The expected genetic advance for specific gravity of the kernels was 20.75% of the mean. The hardness (breaking strength) of the kernels varied in different strains. The softest kernels had a breaking strength of 6.5 kg and the hardest had 14.4 kg. The heritability estimate and expected genetic advance for kernal hardness were found to be 84.5% and 24.65%, respectively.

Grain yield was positively correlated with test weight whereas it had negative correlation with kernel hardness. The relationship of grain yield with specific gravity of the kernels was negative but non-significant. Kernel hardness was also negatively associated with specific gravity of the grains. The relationship of test wieght, with grain hardness and specific gravity were very weak and insignificant.

Discussion

The present study reveals that among the kernel characters studies specific gravity and hardness of the kernels possessed high heritability with high expected genetic advance.

Thus genetic improvement could be achieved with ease in these characters. Their negative correlation with each other indicated that with the increase in specific gravity, the hardness of the kernels would decrease. The test weight of the kernels was not associated with either the hardness of the kernels or their specific gravity. Therefore, this character is supposed to be inherited independent of the other two characters. A significant positive correlation between kernal weight and grain yield revealed the importance of the character in our breeding programme. SIKKA and JAIN (1958) and ANAND *et al.* (1969), also emphasized that kernel weight was an important factor contributing towards yield. Significant negative correlation between kernel hardness and grain yield indicated that the kernels of the higher yielding varieties were softer. Similar results were obtained by GUPTA and ATHWAL (1966) in Indian inbred lines of pearl millet. A non-significant relationship between specific gravity of the kernels and grain yield revealed that specific gravity had no bearing on yield.

Summary

Eighty strains from Wheat World Collection were tested for kernel weight, specific gravity and hardness of the kernels and grain yield. 1000 kernel weight had low heritability, whereas, kernel hardness and specific gravity had high heritability and high genetic advance. Test weight was positively correlated with grain yield whereas kernel hardness had negative relationship with grain yield. Specific gravity of the kernel had no association with grain yield. Kernel specific gravity and hardness were inversely related with each other.

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Red gene associated with faster growth of roots in hexaploid wheat

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SWAMINATHAN *et al.* (1968) reported the development of a complete series of monosomic lines in an Indian amber grained variety, Pb C591 of hexaploid wheat. This series was developed with the help of monosomic series of Chinese Spring which is red grained. Mono-5A of Pb C591 was observed to be red grained in which the gene responsible for the red color of the grain, located on chromosome 3D of Chinese, got translocated on to some chromosome of Mono-5A of Pb C591.

VERUGHESE and SWAMINATHAN (1966) mutated the red gene of Sonora-64, a Mexican wheat, with gamma rays and produced amber grained "Sharbati Sonora" which resembled Sonora-64 in all the morphological traits except the grain color.

In the seed material of Mono-5A of Pb C591 and the parent variety Pb C591 and that of Sonora-64 and Sharbati Sonora, the genetic background is the same except for the gene governing red color of the grain.

Following three sets of replicated experiments with 100 seeds of each of the varieties and strains were sown in petri plates and the length of the main root was measured in mm. after 7 days of sowing. Identical conditions of temperature (25°C) and watering were provided to all the germinating seeds.

Experiment 1: Mono-5A of Pb C591 and Pb C591.

Experiment 2: Sonora-64 and Sharbati Sonora.

Experiment 3: Mono-2A of Pb C591 and Pb C591.

The mean length of main root of amber and red grained strains in the 3 experiments

Table 1. Mean length of main roots of amber and red grained strains of wheat varieties Pb C591 and Sonora-64

Experiment	Material	Grain color	Length of root (mm.)	t value
1	Mono-5A of Pb C591	Red	17.4	4.6*
	Pb C591	Amber	10.5	
2	Sonora-64	Red	18.1	9.4*
	Sharbati Sonora	Amber	12.8	
3	Mono-2A of Pb C591	〃	8.7	1.3
	Pb C591	〃	10.4	

* Significant at 1 percent level.

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is given in Table 1. "Students T test" was applied to the mean differences in the root length in the 3 sets of experiments to test their significance.

It was observed that the mean differences in the root length in the experiment 1 and 2 were statistically significant at 1 per cent level. This means that in experiment 1 and 2 in which the strains are genetically identical but for the gene responsible for the red grains, this gene is correlated with the faster rate of growth of the root.

Experiment 3 is non significant showing that in the amber seeds of a monosomic line of Pb C591 (2A) and that of Pb C591 the rate of growth of the main root is the same.

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NP839, NP883 and NP880: new sources of fertility restoration in male sterile wheat

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The pioneering work of KIHARA (1951, 1963), FUKASAWA (1958), WILSON and ROSS (1962) and SCHMIDT, JOHNSON and MAAN (1962) on cytoplasmic-nuclear interactions in wheat has opened up possibilities of commercial exploitation of heterosis in this important cereal crop. A stable cytoplasmic-genetic male sterility and fertility restoration system whereby the pollen production in breeding lines can be switched "off" or "on" at will is one of the pre-requisites for successful production of hybrid wheat. Our extensive studies on the mechanism of *T. timopheevi* system of cytoplasmic male sterility and fertility restoration with ten varieties of wheat including C303, C306, Sharbati Sonora, Lerma Rojo, S310, Kalyansona, PV18, NP830, NP875 and Sonalika involving more than two thousand lines, F_1 plants and backcross progenies led us to the conclusion that these varieties can be classified into three categories: varieties carrying modifiers (fertility restoring) of strong action, those carrying such modifiers of weak action and varieties without such modifiers (MIRI 1966, 1968, MIRI *et al.* 1970).

OEHLER and INGOLD (1966) reported a commercial variety "Primepi" carrying a dominant gene for fertility restoration and PORTER and MERKLE (1967) found fertility restoring

genes in a composite population of world collection of common wheat. Our recent findings reported here show that the Indian wheat varieties NP 839, NP 883 and NP 880 carry genes which fully restore fertility and support the hypothesis proposed by us earlier (MIRI *et al.* 1970) It is now suggested that a systematic study should be undertaken of the so far identified hexaploid wheat varieties, carrying fertility restorer genes, to find how many different loci are involved, which may then be numbered as R_1, R_2, R_3 etc. as has already been done by wheat rust geneticists for black, brown and yellow rusts. The most promising of the fertility restorer genes can then be used for the development of hybrid wheat.

Twenty-nine varieties (Table 1) were crossed as pollen parents with completely male sterile Kalyansona lines W-12-67-4, W-12-67-2, W-12-67-25, W-11-67-31 and W-11-67-25, carrying *T. timopheevi* cytoplasm, during the 1968 crop season. The F_1 progenies from these crosses were grown in pots in the 1969 season and plants were classified for male fertility on the basis of the development of anthers and seed set on bagged ears. Sixteen F_1 plants obtained from the cross W-12-67-4×NP839, twenty-three F_1 plants from the cross W-12-67-2×NP883 and five F_1 plants from the cross W-12-67-4×NP880, were completely fertile. Kalyansona is a dwarf (Norin) wheat selected from breeding material developed initially in Mexico by BORLAUG and his colleagues. It is ten to fifteen days later in maturity compared with NP839, NP883 and NP880, all of which are tall Indian varieties. All the F_1 plants were tall and early maturing and the head type of Kalyansona appeared to be partially dominant. The complete fertility observed in the F_1 plants sug-

Table 1. Fertility restoring ability of thirty-nine varieties of wheat

Class I	Class II	Class III	Class IV	Class V
no restoration activity	modifiers of weak action	modifiers of strong action	partial fertility restoring genes	full fertility restoring genes
NP718	NP890	NP876	RS31-1	NP839
NP852-12	NP891	K64	NI-747-19	NP883
NP884	Hyb 65	C273	NP52	NP880
NP888	D144	C286	NP801	
NP846	C281	NP4	NP825	
NP858	PV18*	NP830*	NP860	
NP836	Kalyansona*	NP875*	Niphad 4	
NP810		Sonalika*		
C591				
C306*				
C303*				
Sharbati Sonora*				
Lerma Rojo*				
S310*				

* These varieties have been reported earlier (MIRI, AMAWATA and JAIN 1970).

gests that these three varieties carry fertility restoring genes. The F_1 progenies derived from the crosses with twenty-six other varieties showed varying degrees of male fertility (Table 1).

Our studies including those reported earlier show that the different wheat varieties can be grouped into five classes on the basis of their fertility restoring ability in male sterile wheat carrying *T. timopheevi* cytoplasm. The wheat varieties may carry full fertility restoring gene or genes, partial fertility restoring genes, modifiers of strong action, modifiers of weak action or no modifiers at all (Table 1). Modifiers appear to be complementary to the fertility restoring genes from *T. timopheevi*; therefore, the varieties carrying modifiers are useful and their conversion to fertility restorer line (R-line) is easy, whereas, the varieties lacking modifiers may not be so suitable for the development of fertility restorer lines. Conversely, varieties without modifiers are most suitable for the development of male sterile lines (A-line). Our data will support the model developed by WILSON (1968), if we assume dosage effect for the modifiers of strong and weak action.

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Protein electrophoretic patterns of Transcaucasian wheats

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Seeds of five separate, wild, collections of *Triticum araraticum* JAKUBZ. were provided by the All Union Institute of Plant Industry. The Leningrad accession numbers and their place of collection are as follows:

K-28132; *T. araraticum* var. *thumaniani* JAKUBZ. Near Erevan, Armenia.
K-28244; *T. araraticum* var. *thumaniani* and var. *nachitschevanicum* JAKUBZ. Nakhichevan Republic.
K-30210; *T. araraticum* var. *thumaniani*. Nakhichevan Republic.
K-30216; *T. araraticum* var. *nachitschevanicum*. Nakhichevan Republic.
K-39098; *T. araraticum* var. *thumaniani*. Azerbaijan.

Alcohol extracts of single seeds were electrophoresed following the technique of JOHNSON (Science 158: 131~132, 1967) and the whole experiment repeated several times. Accessions K-28244 and K-30210 gave protein spectra similar to that exhibited for *T. dicoccum* by JOHNSON in the above paper, while the other three accessions gave spectra similar to that exhibited for *T. timopheevi*, as expected.

Triticum dicoccum has the same protein spectrum as the wild Syrio-Palestinian *T. dicoccoides* (JOHNSON 1967). Although these accessions have yet to be crossed and the meiotic chromosome behaviour of their hybrids investigated, these results indicate that plants with a protein pattern similar to the Syrio-Palestinian *T. dicoccoides* are native to the Transcaucasus region and that they are morphologically similar to *T. araraticum*.

Recently, TANAKA and ISHIKAWA (Genetics 60: 229, 1968) identified two types of *T. araraticum*. The first type formed fertile hybrids with *T. timopheevi*, while the second type did not. NISHIKAWA and SAWAI (W.I.S. No. 29: 2~3, 1969) measured the relative amounts of nuclear DNA in these two types and found that the first type had an amount of DNA similar to *T. timopheevi*, while the second type approached the DNA content of *T. dicoccum*-type wheats. Thus, the tetraploid wheats of the Transcacasus area appear to be a heterogeneous group, and there is the possibility that the Syrio-Palestinian race of *T. dicoccoides* is native there also.

A single collection of *T. ururtu* TUM., (K-33870, Armenia) was investigated using the same techniques. Its protein pattern was similar to Fig. 1 (E) of JOHNSON's above paper, except that it had three dense fast moving bands, migrating between 7 and 10 cm, rather than one.

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Effect of gamma rays on the expression of hybrid necrosis in wheat

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Hybrid necrosis: a phenomenon characterized by the gradual perishing of F_1 hybrid plants at one stage or the other, imposes serious limitation on the realization of desired recombinants in many cross-combinations involving indigenous wheat varieties, such as, N. P. 830, N. P. 839, N. P. 875, N. P. 883, C. 306 on one hand and Mexican dwarfs like Kalyan Sona, Chotti Lerma, Safed Lerma, Sonalika and many other European varieties, on the other. Hybrid necrosis which is based on two dominant complementary genes Ne_1 and Ne_2 (HERMSEN 1963, ANAND, GILL and JAIN 1969, NARULA, SRIVASTAVA and SRIVASTAVA 1970) each of which has multiple alleles controlling the degree of necrosis, is of wide spread occurrence (HERMSEN 1963, ZEVEN 1966, KIHARA and TSUNEWAKI 1962). It has been observed that indigenous varieties carry Ne_1 while there is a preponderance of Ne_2 in the Mexican dwarf varieties (NARULA, SRIVASTAVA and SRIVASTAVA 1970).

Mexican dwarf varieties, which have been widely acclaimed for their explosive yield potential, do not command consumer's popularity in India as these do not only lack the *chapati-making* qualities but also the grain lustre characteristic of the Indian varieties. It has, therefore, been felt necessary to transfer the grain quality from the indigenous varieties to the well-adapted Mexican introductions. Because of wide spread occurrence of the Ne^s_2 in the dwarf varieties and Ne^s_1 in some of the best Indian wheats, hybrid necrosis has imposed a ceiling on the choice of parental combinations. This also up-sets the programme of diallel cross-combinations.

HERMSEN (1963) suggested methods to preclude hybrid necrosis by using non-carrier varieties; exploiting varietal impurity; introducing non-carrier as a bridging host and irradiating parental varieties to obtain non-carrier mutants. But as these methods are either time-consuming or limit choice of parents, it was desired to see if radiations could be used to inactivate the necrotic genes present in the F_1 hybrids and foster recombinants in crosses which otherwise manifest severe necrosis at the seedling stage.

Ten F_1 seeds from the cross C. 306 (amber grained) × PV-18 (red grained) were subjected to 16 kr. gamma rays at the Division of Genetics, I.A.R.I., New Delhi and the treated seeds were grown in pots at Pusa five days after the treatment was given. Five untreated crossed seeds were sown separately as control. Plants from treated seeds were harvested and threshed separately. M_2 generation was space-planted in the field in the next rabi season and screened for hybrid necrosis.

All the five untreated seeds germinated normally but manifested severe necrosis three weeks after their emergence; only six out of ten treated seeds germinated. These plants

grew normally and did not show necrosis till the flag-leaf stage, when very sligh yellowing of leaves was observed. The hybrid nature of the plants was established by the seed color of M_1 plants which was red like the male parent. This indicates that either both the severe alleles present in these varieties were inactivated or changed from severe to very mild form. The latter hypothesis seems to be more plausible as the necrosis was observed when the M_2 generation material (five plants) was screened. The degree of necrosis varied from mild to moderate type.

Table 1. Segregation into necrotic and normal plants in M_2 generation

Cross	Number of plants		×2	P. value	Segretation pattern	
	necrotic	normal			necrotic	normal
C. 306×PV. 18-1	21	38	0.5338	0.3～0.5	5	11
-2	60	145	0.3990	0.5～0.7	〃	〃
-3	34	68	0.2011	0.5～0.7	〃	〃
-4	98	125	—	—	—	—
-5	60	200	—	—	—	—

Observations recorded on the number of plants showing necrosis (Table 1) indicated that a ratio fitting 5 Necrotic: 11 Normal in case of families from three plants while the other two gave abberant ratios. NARULA, SRIVASTAVA and SRIVASTAVA (1970) have shown that if the phenotype of the F_1 hybrid does not express necrosis, the segregation pattern in the F_2 generation conforms to 5 necrotic: 11 normal, because more than two dozes as against two of the F_1 are necessary for the manifestation of hybrid necrosis in certain weakly necrotic crosses. It, therefore, gives an indication that the severe alleles for necrosis present in these test varieties have been transformed through irradiation into weak types. SHARMA (1969) who followed the same approach of precluding hybrid necrosis and obtained chimeras at tiller and at leaf level, in addition to normal plants, which set adequate seeds for growing M_2 generation, also observed the same phenomenon of higher mutational rate. If these loci be really so highly mutable, it may be interesting to ascertain whether there is any spontaneous mutation in the natural population, which may account to some extent for varietal impurity mentioned by HERMSEN (1963).

This approach to preclude hybrid necrosis makes it feasible for the plant breeders to manipulate cross-combinations hitherto not possible without resorting to time-consuming and devious means.

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Wild tetraploid wheats from West Iran cytogenetically identical with Israeli *T. dicoccoides*

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Two samples of wild tetraploid wheats were collected by us in the western flanks of the Zagros Mountains, Iran (Ilam area, approx. 100 km S.W. of the town of Kermanshah). Morphologically and ecologically both collections fit very well the ranges described by HARLAN and ZOHARY (1966) for the "Turkish-Iraqui race" of *T. dicoccoides*.

The two Iranian forms were crossed with (i) an Israeli *dicoccoides* tester line as well as *T. durum*. (ii) a representative of the *T. timopheevi-T. araraticum* cytogenetic stock. The following lines were used in the crossing program and the results obtained on chromosome pairing and on fertility of the F_1 hybrids are set up in Table 1.

No. 6690: Wild tetraploid wheat, 50 km southeast of Shahabad on road to Ilam, Kermanshah District, Iran.

No. 6691: Wild tetraploid wheat, 40 km southeast of Shahabad on road to Ilam.

No. 6256: *T. dicoccoides*, Safad Rosh-Pinna road, Eastern Galilee, Israel.

No. N163: *T. durum* variety Nursit 163, A standard Israeli *durum* cultivar.

No. 6284: *T. dicoccoides* var. *nudiglumis*, Handren Dagh, North Iraq, Coll. J. B. GILLETT. This is the Iraqi line used by L. SAGHS (1953) in his crosses with *T. timopheevi*. It served as our representative of the *timopheevi-araraticum* stock.

It is clear from the data presented in Table 1 that the wild Iranian wheats are fully interfertile with the Israeli *dicoccoides* stock. Chromosome pairing is normal and the presence in some combination of one or two translocation quadrivalents resembles very much the inter-varietal chromosomal variation found among various Israeli *dicoccoides* lines or different *durum* cultivars. In contrast, hybrids between the two Iranian lines and the representative of the *timopheevi-araraticum* stock manifest a drastic reduction of chromosome

Table 1. Chromosome pairing and fertility of F_1 hybrids

Cross-combination	No. of P.M.C. studied	Chromosome association*					Chiasmata per cell	seed set %
		I	II	III	IV	V+VI		
6690 × 6691	30	—	11.93 (10~12)	—	1.03 (1~2)	—	28.33±1.35	69.0
6690 × 6256	30	0.27 (0~2)	11.87 (11~12)	—	1.00 (1)	—	27.03±2.50	69.0
6256 × 6690-1	30	0.57 (0~3)	9.90 (9~12)	0.23 (0~1)	1.63 (1~2)	0.07 (0~1)	27.00±1.88	55.0
6256 × 6690-2	30	0.33 (0~2)	11.83 (10~12)	—	1.00 (0~2)	—	27.70±2.53	65.0
6691 × 6256	30	0.20 (0~2)	13.90 (13~14)	—	—	—	26.87±2.31	76.0
6256 × 6691	30	—	14.00 (14)	—	—	—	27.47±2.22	79.0
6690 × N163	30	0.40 (0~2)	11.80 (11~12)	—	1.00 (1)	—	27.30±2.55	94.0
6691 × N163	30	0.5 (0~2)	13.63 (12~14)	0.03 (0~1)	0.03 (0~1)	—	25.77±1.57	90.0
6691 × 6284	30	8.1 (1~13)	7.27 (3~10)	1.3 (0~3)	0.33 (0~2)	—	13.70±1.93	1.8
6284 × 6691	30	7.43 (5~12)	7.30 (4~10)	1.33 (0~3)	0.43 (0~2)	0.03 (0~1)	14.57±1.94	0.5
6256 × 6284	30	13.70 (6~18)	5.40 (2~8)	1.10 (0~3)	0.07 (0~1)	—	9.43±2.09	0.0
6284 × 6256	30	11.37 (5~18)	5.40 (2~9)	1.63 (0~3)	0.23 (0~2)	—	11.47±2.32	0.0

* Note : Values given for chromosome associations indicate *means* per microsporocyte ; those in parentheses represent *ranges* observed.

pairing and strong sterility.

Our finds compliment the previous report of RAO and SMITH (1968) who discovered wild wheats cytogenetically similar to the Israeli *T. dicoccoides* among J. R. HARLAN collections from southern Turkey. This extend the geographic range of wild forms belonging to this stock to the southeast end of the Fertile Crescent arc.

It is clear from finds that both *dicoccoides* and *araraticum* cytogenetic types occur sympatrically in southern Turkey, northern Iraq and western Iran, and that ecologically both occupy the oak (*Quercus brantii*) park-forest belt of this region. Furthermore, morphologically these sympatric wheats are embarrassingly similar, and RAO and SMITH also found a cytogenetically bridging form, interfertile with testers of both stocks. Obviously, we need a further clarification of the spatial and genetic relationships between wild tetraploids in Armenia and Kurdistan. But the data available already make it necessary to revise the concept of the place of domestication of *dicoccum* wheats. Contrary to the earlier proposal of HARLAN and ZOHARY (1966), Palestine and southern Syria can not any more be regarded as the sole location in which emmer domestication took place. The north and the northeastern segments of the Fertile Crescent arc become candidates as well!

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Search for wheat genes on chromosome 2M of *Aegilops comosa* SIBTH. et SM.

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Introduction

There are several examples of isomeric genes located on homoeologous chromosomes of *Triticinae* species. Especially the much investigated chromosomes of the A-, B- and D-genomes have given nice examples.

It was considered interesting to investigate whether there are genes on chromosome 2M of *Aegilops comosa* SIBTH. et SM. isomeric to genes found on chromosomes of 2A, 2B and 2D of *Triticum aestivum* (L.) THELL.

The genes in question are:

chromosome	gene	literature
2A(II)	Ch_1/ch_1 (ssp. *macha*)	*vide* note below
2A(II)	Rf/rf (ssp. *vulgare*)	TALAAT 1969
2B(XIII)	Ne_2/ne_2 (〃)	TSUNEWAKI 1960
2B(XIII)	D_2/d_2 (*T. aestivum*)	HURD and MCGINNIS 1958
2D	D_1/d_2 (〃)	HERMSEN 1963b

N.B. : Dr. R. J. METZGER has provisionally localized Ch_1/ch_1 on chromosome 2A (II) of ssp. *macha*. Results from later investigations, however, did not fully confirm this decision. Therefore, he had rather regard the localization of Ch_1/ch_1 as yet unknown (personal communiciation, January 1970).

No attempts were made to determine whether any wheat gene localized on 2M also had a corresponding locus. Nor was it intended to settle whether there was a locus of an isomeric recessive wheat gene on 2M at all.

Material

RILEY *et al.* (1968) developed the following addition line and substitution lines of *Triticum aestivum* ssp. *vulgare* (VILL.) MK. cv Chinese Spring (genome formula AABBDD) and the chromosome 2M of *Aegilops comosa* SIBTH. *et* SM. (genome formula MM).

I.v.P. coll. No.	Artifact
87	Chinese Spring —di 2M
88	〃 —nulli 2A —di 2M
89	〃 —nulli 2B —di 2M
90	〃 —nulli 2D —di 2M

Chromosome 2M apparently completely compensate for the absence of the wheat chromosome because the substitation lines look healthy and resemble ssp. *vulgare*. It carries a gene for a broad spectre of yellow rust resistance now incorporated in the derivative Compair (RILEY *et al.* 1968). It is not known whether this gene is corresponding to the gene for yellow rust resistance localized on 2A(II) of Thatcher (WELSH *et al.* 1965).

This material was compared with Chinese Spring which was also received from Dr. R. RILEY, Cambridge, U. K. and was a derivative of the plants used to produce these artifacts.

Results

The haploid genotype of Chinese Spring was established as $ch_1Ch_2Ne_1{}^wne_2d_1d_2d_3$. This genotype is identical with the Chinese Spring line investigated by HERMSEN (1963a, 1963b, 1966, 1967). Ch_2/ch_2 has been located on 3D (TSUNEWAKI and KIHARA 1961) and D_3/d_3 on 4B (HURD and MCGINNIS 1958, HERMSEN 1963b).

If 2M carries Ch_1 all artifacts should have the genotype $Ch_1Ch_1Ch_2Ch_2$ and this would have led to chlorotic plants (HERMSEN 1966). This was not the case. So 2M does not carry Ch_1. The same holds good for the $Ne_2{}^s$-allele because plants having the genotype $Ne_1{}^wNe_1{}^wNe_2{}^sNe_2{}^s$ would be necrotic (HERMSEN 1963b). Artifacts 87, 88 and 89 were crossed with an $Ne_1{}^s$-carrier. If 2M carries a dominant Ne_2-allele necrotic plants would have been found in the F_1's and/or F_2's. They were not discovered so 2M does not carry Ne_2.

Artifact 90 was crossed with Amby ($d_1D_2D_3$, HERMSEN 1967), and artifacts 87 and 89 with Kenya Farmer ($D_1d_2D_3$, HERMSEN, 1963b, 1967) to try and find D_1 and D_2 genes. If artifact 90 had carried D_1 the F_1 would have been dwarfed. The same is true if artifacts 87 and 89 had carried D_2. No dwarf plants were observed neither in any F_1 normal in any F_2 so 2M does not carry D_1 and D_2.

All artifacts were crossed with *T. timopheevi*-cytoplasmic male sterile plants. No F_1 plant produced seeds and this indicates that 2M does not carry an *Rf* gene.

It may be concluded that 2M of the *Ae. comosa*-source investigated does not carry Ch_1, Ne_2, D_1, D_2 and *Rf*. It is not known whether there are loci for the recessive alleles. The only similarity is the presence of genes for yellow rust resistance on 2A (II) of Thatcher and on 2M. Of course, the compensation for the loss of a pair of wheat chromosomes by a pair of 2M chromosomes suggests that there are genes common to 2M and the wheat chromosomes.

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Genetic pistillody in New Zealand wheat

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When anthers of the wheat flower show various degrees of transformation towards the form of the gynoecium the phenomenon has been called pistillody (LEIGHTY and SANDO 1924) carpellody (CALDER 1930) and multiple-carpel (BHATIA and SWAMINATHAN

1963). It has been reported, and abundantly illustrated, from apparently normal wheat (LEIGHTY and SANDO 1924), in nuclear substitution lines incorporating cytoplasmic male sterility (KIHARA 1951, 1966, 1967, KIHARA and TSUNEWAKI 1961, 1967), in progenies from irradiated seed (BHATIA and SWAMINATHAN 1963), in two hybrid generations of New Zealand wheat (CALDER 1930), and in *Triticum-Agropyron* hybrids (TSITSIN and LUBIMOVA 1959). In nulli-6B and nulli-7A lines of cv. Chinese Spring, SEARS (1954) found pistillody fairly common but this character was suppressed in the monotelo- and mono-isosomics. No simple genetic ratios were obtained in any experiments, but CALDER, and BHATIA *et al.* concluded that pistillody was a heritable recessive character.

Pistillody was recently seen in one of 10 families involving repeated backcrossing of a standard New Zealand wheat cultivar-Aotea[1]. Nine plants in this family of 31 displayed pistilloid anthers varying from a few stigmatic hairs on an anterior anther to the complete transformation of all stamens into gynoecia. Not all florets in a spike bore pistilloid anthers. Such variability in expression within florets, spikelets, and spikes of the same plant has been detailed by most of the authors cited above. In the records presented here plants were classified as pistilloid if any anther displayed pistilloid characteristics.

Small F_3 families were raised from 19 of the 22 normal F_2 plants. Fourteen of these families contained plants classified as pistilloid while 5 families contained no abnormal plants (Table 1).

Table 1. Frequencies of normal and pistilloid plants in F_2 and F_3 generations

Generation	Normal	Pistilloid	Total
F_2	22	9	31 (1 family)
F_3	196	56	252 (14 families)
〃	87	0	87 (5 families)

These results would fit the action of an autosomic pair of alleles with the homozygous recessive permitting the development of pistilloid anthers. The F_2 would fit a 3: 1 segregation ($\chi_1^2=0.24$); two thirds of the normal F_2 plants segregated both normal and pistilloid types in F_3 ($\chi_1^2=0.4$) indicating heterozygous F_2 genotypes. Among the 14 segregating F_3 families there was non-significant heterogeneity ($\chi_{13}^2=8.38$), and a good fit to a 3: 1 ratio ($\chi_1^2=1.04$).

This genetic solution may be an over simplification. The expression of pistillody was rarely complete—as few as 10% in some spikes—and would fit BHATIA and SWAMINATHAN's suggestion that pistillody is a character of low expressivity and low penetrance. KIHARA (1951), and KIHARA and TSUNEWAKI (1961) are emphatic that environmental effects, especially day length, are important in the expression of the pistilloid potentiality. Here,

1) Aotea^7 × A Federation 2 × Aotea^7 × 1066/1 3 × Aotea^8 × Hilgendorf 61.

all F_2 and F_3 families were raised in growth chambers with temperature and light control. No other wheat lines, of similar or dissimilar genetic origins not even the 9 other F_2 families of identical genetic origin, grown under the same conditions were affected. Neither were pistilloid anthers present in cv. Aotea[1] incorporated into *T. timopheevi* cytoplasm through cv. Bison; they were typically indehiscent, flared or curled at the base as in most CMS lines. The pistillody recorded by CALDER in Solid Strawn Tuscan × (F_4 White Fife × Benefactor) occurred in a line closely related to the New Zealand cv. Cross 7 (Tuscan × White Fife) which is half of the genetic background of cv. Aotea (COPP 1958). The material reported on here will differ in only very few chromosome segments from cv. Aotea. Is it possible that anther pistillody in New Zealand wheat is an infrequent mutation of a gene derived from Tuscan or White Fife associated with chromosome 6B or 7A?

At the same time as observations were being made on cv. Aotea we examined for pistillody field grown plants of spring sown hexaploid wheat raised from the open-pollination of lines incorporating cytoplasmic male sterility through cv. Bison. Very slightly or slightly pistilloid anthers were present in 44 plants of the 70 examined, and this character was expressed in 39% of the anthers checked in those plants. In none of them did pistillody approach the condition seen in the cv. Aotea material described above. *T. timopheevi* cytoplasm may, therefore, be associated with very slight pistillody in hexaploid wheat, though KIHARA (1966) did not find it so.

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Chromosome pairing at diakinesis in hexaploid *Triticale*[1)]

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Previous studies of chromosome association were made almost exclusively at metaphase I of microsporocytes in hexaploid *Triticale* (NAKAJIMA 1952, 1956, 1963, NAKAJIMA and ZENNYOZI 1966, SANCHEZ-MONGE 1959). The present author, during the study of meiosis in some hexaploid *Triticale*, was able to make excellent preparations of diakinesis cells. These preparations of chromosome configurations at diakinesis were found to be the source of valuable information on the nature of chromosome pairing in the hexaploid *Triticale*.

The materials were plants of the primary *Triticale* (6A 190) from the following cross: *T. durum* var. Stewart × *S. cereale* var. Prolific.

Table 1. Chromosome configurations at diakinesis and metaphase I of hexaploid *Triticale*, 6A 190

Chromosome association	Percent of sporocytes at	
	diakinesis	MI
21_{II}	87	59
$20_{II}+2_{I}$	10	29
$19_{II}+4_{I}$	2	8
$18_{II}+6_{I}$	1	3
$17_{II}+8_{I}$	0	1
Number of sporocytes	100	100

Experimental materials were grown in the growth cabinet with the temperature of about 20°C and 16 hr. daylight time. Table 1 shows chromosome configurations at

1) This work was supported by research grants from the Rockefeller Foundation (RF 65019) and the National Research Council of Canada.

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diakinesis and metaphase I. From this table it was shown that 87% of the sporocytes had 21 bivalents at diakinesis while it was 59% at MI. The number of bivalents per sporocyte was 20.83 at diakinesis and 20.42 at MI. The number of univalents per sporocyte was 0.34 at diakinesis and 1.16 at MI. At diakinesis more closed bivalents were observed than at MI as shown in Table 2.

Table 2. Number of bivalents and univalents per sporocyte at diakinesis and metaphase I of a hexaploid *Triticale*, 6A 190

Meiotic stage	Number of bivalents per PMC			Number of univalents per PMC	Percent PMC with 21_{II}
	closed	open	Total		
Diakinesis	19.7 (11～21)	1.1 (0～8)	20.83	0.34 (0～6)	87.0
MI	15.6 (8～21)	4.8 (0～9)	20.42	1.16 (0～8)	59.0

As is clearly seen in the Figure on the cover, most of the bivalents were closed ones associated by two chiasmata. Some bivalents, however, were not tightly associated; the homologous chromosomes seemed to be laid side by side without connection by true chiasma. Usually one nucleolus was observed which was tightly attached by two bivalents. Occasionally two nucleoli were observed at this stage.

At metaphase I the frequency of sporocytes with 21 bivalents, the number of bivalents per sporocyte, and the number of closed bivalents were reduced to 59%, 20.4, and 15.6, respectively. The number of univalents per sporocyte and open bivalents per sporocyte was increased (Table 2).

Mean number of chromosomes consisting of open bivalents and univalents was about 12.0 at metaphase I, while the corresponding figure was only 3.0 at diakinesis.

These results show that most of the open bivalents and univalents at metaphase I of hexaploid *Triticale* resulted from desynapsis or terminalization of chiasmata occuring in most rye chromosome bivalents after diakinesis.

Since most univalents at metaphase I of octoploid *Triticale* were also originated from rye chromosomes (MÜNTZING 1957, SANCHEZ-MONGE 1959), it would be reasonable to assume that the chromosome associations at diakinesis would be better than at metaphase I in octoploid *Triticale*.

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Spontaneous crossing between hexaploid *Triticale* Rosner and *Triticale* No. 64.

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Triticales are in general self-pollinating, but cross pollination may occur in 61~0%. When cultivating *Triticale* No. 64 (2n=6x=42) and *Triticale* Rosner (2n=6x=42) of Canadian origin close together in 1968 and 1969 we found even more spontaneous crossing *Triticale* Rosner was first sown in the nursery of the Experimental Institute of Kecskemet on 7. February 1968. The grains harvested were sown in a sheltered plot on 8. October of the same year. Five rows of the Canadian *Triticale* were margined on both sides by five rows of *Triticale* No. 64. Vegetation period for both of them is as follows:

Triticale	Date of					Vegetation period day
	sowing	germination	heading	flowering	maturing	
1968						
Rosner	7.2	21.3	22.5	27.5	21.6	136
No. 64	7.2	21.3	1.6	4.6	30.6	145
1969						
Rosner	8.10	15.10	15.5	20.5	30.6	265
No. 64	8.10	15.10	24.5	29.5	9.7	274

When analysing growth stages it appears that *Triticale* Rosner flowers 8~9 days earlier than the Hungarian winter type (half-winter type) *Triticale*. For all that *Triticale* No. 64 begins to flower when *Triticale* Rosner is in full bloom and has its main flowering period at the second bloom of *Triticale* Rosner (flowering of tillers).

As *Triticale* Rosner is 30 cm shorter than *Triticale* No. 64, at flowering time it was abundantly supplied with fresh pollen from the taller *Triticale*. The extent of crossing could not be determined by examining the grains, however, it was easy to detect spontaneous crossing in F_1 plants. Namely, when hand crossing, the F_1 hybrids of crosses between *Triticale* Rosner and *Triticale* No. 64 are easily recognizable by some dominant marker characteristics such as

	Plant height cm	Head length cm	Number of spikelets/head	Head type	Color of auricle
T. No. 64	130	14.2	28.6	awned at the top of ear	red
T. Rosner	100	11.1	21.0	awned	white
F_1 plants	130	14.5	28.8	awned at the top of ear	red

In 1968 about 7000 grains of *Triticale* Rosner were harvested, out of which 5 times 200 grains were sown on 8. October 1968. From these 710 plants were cultivated. From the 710 plants there were 146 which had the height, red auricles and head type of No. 64, that is, they were spontaneous F_1 plants (20.56%). The extent of spontaneous crossing is remarkably high, showing that *Triticale* Rosner flowers fairly open in Hungarian conditions. From hand pollination between *Triticale* Rosner and *Triticale* No. 64, made simultaneously, 24.3% seed set was obtained in 1968 and 18.1% in 1969. Reciprocal cross was only made in 1968 with a seed set of 16.6%.

The pedigree of *Triticale* Rosner is fairly complicated. Among its parents *Triticum durum* has a dominant part *Triticum* Rosner (*Triticum durum* cv. GHIZA × *Secale cereale*) × (*T. durum* cv. Carleton × *S. cereale*) × (*T. persicum* × *C. cereale*) × (a *Triticum-Secale* Introduction). The basic material of *Triticale* No. 64 is *Triticum turgidum*; the pedigree is shown in No. 31. of WIS, 1970.

It is to hope that due partly to the considerable extent of spontaneous crossing and partly to purposeful hand pollination and selection some new and more valuable types can be developed suitable for practical field production.

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Studies on the hybrids between *Triticale* and wheat

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1. The spontaneous crossing of the octoploid *Triticale* Rudorf (Heine VII. × *S. cereale* Inz. Linie Roggen) with the hexaploid *Triticale* No. 64.

KISS described a spontaneous crossing between the hexaploid spring *Triticale* Rosner of Canadian origin and the *Triticale* No. 64 of Hungarian origin. As according to KROLOW (1969) the proving of spontaneous crossing in *Triticales* is complicated it is perhaps worthwile to relate the phenomenon.

In this report I want to describe a spontaneous cross between an octoploid *Triticale* form of German origin—as indicated in the title—and the hexaploid *Triticale* No. 64. As we got the German *Triticale* from Professor RUDORF we registered it as *Triticale* Rudorf out of respect for him. This strain (Heine VII. × Inzucht Linie Roggen 2n=8x=56) was sown in our nursery in autumn 1967 for the first time. We received three strains; 1 row of each strain was sown and each row was bordered by 3 rows of *Triticale* No. 64.

Table 1. The vegetation period of tested *Triticales* in 1967~68 and 1968~69

Triticale	2n	Date of					Total vegetation period in days
		sowing	germination	heading	flowering	maturing	
1967~68 :							
Rudorf-1	56	4.10	11.10	25.5	28.5~19.6	8.7	278
// -2	//	4.10	11.10	26.5	30.5~15.6	8.7	278
// -3	//	4.10	11.10	27.5	1.6~17.6	8.7	278
No 64	42	4.10	11.10	10.5	14.5~ 4.6	26.6	266
1968~69 :							
Rudorf-1	56	23.9	29.9	3.6	8.6~24.6	12.7	292
// -2	//	23.9	29.9	3.6	8.6~24.6	12.7	292
// -3	//	23.9	29.9	3.6	8.6~24.6	12.7	292
No 64	42	23.9	29.9	24.5	29.5~18.6	5.7	285

Considering development stages it appears that in 1968 *Triticale* No. 64 flowered 14~18 days earlier than the octoploid *Triticale* Rudorf. However, the end of flowering of *Triticale* No. 64 coincided with the beginning of flowering in *Triticale* Rudorf and this is the only explanation for the appearance of individuals similar to F_1 hybrids from a spontaneous cross in the following year in the population of *Triticale* Rudorf next year. In hand pollination F_1 hybrids from *Triticale* Rudorf × *Triticale* No. 64 are easily recognisable due to dominant marker characters such as:

Table 2. Morphological characters on good sand soil in 1968

Triticale	Height cm	Chief ear cm	Number of spikelet/ear	Ear type	Color of auricle
No. 64	125	18.20	34.20	awned at the top	red
Rudorf-1	68	11.66	25.70	awnless	white
// -2	65	8.92	23.20	//	//
// -3	63	10.26	23.30	//	//

Table 3. Parents and spontaneous F_1 hybrids on dry poor sand soil in 1969

Triticale	Height cm	Chief ear cm	Number of spikelet/ear	Ear type	Color of auricle
No. 64	100	12.50	24.3	awned at the top	red
Rudorf-1	65	8.15	20.2	awnless	white
// -2	65	7.85	20.7	//	//
// -3	60	8.40	24.5	//	//
R.-1 × No. 64	95	11.50	27.5	//	red
R.-2 × No. 64	105	12.00	27.0	//	//
R.-3 × No. 64	97	11.00	31.0	//	//

In 1968~69, 100 seeds were sown of the three *Triticale* Rosner strains each and 76, 78 and 48 plants respectively were grown. From these plants 41 individuals were spontaneous F_1 hybrids (20.7%) having the height, red auricle, 11~12 cm ear size and 27~31 spikelet of No. 64. The extent of the spontaneous cross was even greater than the seed set in the hand pollination though contrary to the 12~16 percent known so far seed set from octoploid × hexaploid *Triticales* reached 30.9% in 1968.

The spontaneous cross of both *Triticale* Rosner and *Triticale* Rudorf with the taller *Triticale* No. 64 shows that *Triticale*-breeders have to pay greater attention to open flowering in *Triticales*. In this respect *Triticales* are intermediate between wheat and rye, standing closer to wheat. The trend towards selfpollination in varieties and strains known by us is similar to wheat, because they can set seed as weell as wheat when isolated.

2. Development of short secondary hexaploid *Triticales* by crossing *Triticale* with wheat

Amphiploids coming from crossing primary tetraploid wheat with rye are more difficult to develop than octoploid *Triticales*. Even if we succeed in turning the sterile hybrids amphiploid, the amphiploids thus obtained have poor fertility, very shrunken, shrivelled grain type and no variability at all, which is one of the most important phenomena in nature. It is highly improbable than in practical growing such primary hybrids will successfully compete with the classical cereals developed thousands of years ago (wheat, barley, rye and oats). Such primary hybrids have not developed yet. The Canadian and Hungarian *Triticales* now available are progenies of complex crosses.

At first Pissarev and Zsilkina (1967), Sanchez-Monge (1958), Mogileva (1969) and we ourselves as well, wanted to develop wheat forms with the quality characteristics of rye, with higher protein content, earlier maturity and stronger straw from crosses between *Triticale* and wheat. Only from 1962 onwards have we tried to select in the direction of *Triticale* and no more in the direction of wheat. *Triticale* and wheat crosses have been especially used for developing short *Triticales*. In the first years the following short wheat varieties were used as parents: Norin 50, Norin 16, Freccia, Ardito, San Pastore, Mara, Produttore 6, Produttore 13, Besostaja 4, 1, Shkorospelka 3b, Etoile de Choissy, Magdalena, Heine VII, etc.

These wheat varieties did not succeed in dwarfing rye and *Triticale* varieties. The F_1 hybrids obtained were in every case as high as the higher parent, and even if in advanced generations we did succeed in developing shorter hybrids they were practically without any value.

In 1965 we crossed our *Triticale* varieties No. 57 and No. 64 with the dwarf wheat variety Blé Tom Pouce, received from our colleague Lehman in Gatersleben. We heard

later that this wheat variety was brought to Europe and America by the Hindukush expedition. This was the first wheat in which dwarfness inherited dominantly. Dominance means that its hybrids with 130～180 cm tall rye and *Triticale* were 60～70 cm tall in the first year, thus very close to the height of the wheat Tom Pouce, which is 40 cm tall. The F_1 hybrid was twice, maximum three times, backcrossed with hexaploid *Triticale*; in the segregating progeny generations *Triticales* were selected from 20 cm up to 180 cm. Types higher than 110 cm were used to complete our collection. The short, constant types were divided into 4 groups:

A_1	80～100 cm
A_2	60～ 80 cm
A_3	40～ 60 cm
Dwarf type	20～ 40 cm

Fig. 1. Short A_2-type elite *Triticale*

Most of the short types had strong straw and good grain type, were winterhard and some lines were extraordinary fertile. The dwarf type alone has poor fertility. Cultural methods of today are, however, not yet suitable for growing dwarf plants, even if they were fertile.

It is mainly from wheat and not from rye that variability with special regard to dwarfness—can be introduced to *Triticale*. When selecting we have only to take care of fixing ear productivity inherited from rye in the advanced generations, too.

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Homoeologous relationships between two *Agropyron intermedium* chromosomes and wheat

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Certain chromosomes of *Agropyron elongatum* and *Ag. intermedium* have been found to compensate in genetic activity for wheat chromosomes. An *Ag. elongatum* chromosome conditioning stem rust resistance substituted effectively for homoeologous group 6 wheat chromosomes (Knott 1964, Johnson 1966, Anderson and Driscoll 1967). Two chromosomes from the same species each conferring leaf rust resistance were found to substitute for wheat chromosomes—one for 3D (Bakshi and Schlehuber 1958) and the other for 7D (Sharma and Knott 1966, Quinn and Driscoll 1967) and 7A (Nanda 1968). An *Ag. elongatum* chromosome conditioning blue endosperm substituted for a specific wheat chromosome (Knott 1958). Weique is a commercial wheat cultivar in which a pair of wheat chromosomes is replaced by an *Ag. intermedium* pair conditioning stem rust resistance (Wienhues 1965). A second chromosome conditioning rust resistance also substitutes for a specific wheat chromosome (Wienhues 1966).

Seed of two disomic *Ag. intermedium* addition lines to Vilmorin 27 wheat were kindly supplied by Dr. Y. Cauderon, Institut National de la Recherche Agronomique, Versailles, France. TAF_1 possesses resistance to leaf rust and TAF_2 resistance to stem rust due to the alien chromosomes. During maintenance of these lines root-tip chromosome counts revealed that certain resistant lines in both accessions possessed 42 chromosomes and had presumably arisen through alien chromosome substitution. Resistance of TAF_1 to Australian leaf rust strains is of the adult plant type and is difficult to recognise in the Vilmorin background since the latter possesses a measure of this type of resistance. However, when 42 chromosomes plants in each accession were crossed with *T. aestivum,* hybrid plants invariably exhibited $20_{II}+2_I$ at meiosis thus verifying their alien chromosome substitution constitution. Meiotic configurations observed are described according to the system suggested by Kimber and Sears (1968).

A TAF_2 substitution line was crossed with Chinese Spring stocks monosomic, monotelosomic or monoisosomic for members of the D genome. Except for crosses involving 7D, hybrids with 41 chromosomes consistently exhibited $1_{IV}+17_{II}+3_I$ and those with 42 chromosomes $1_{IV}+18_{II}+2_I$ in the case of monosomic crosses and $1_{IV}+17_{II}+tl_{II}$ (or il_{II}) $+2_I$ where monotelosomics (or monoisosomics) were implicated. The 41 chromosome hybrids in crosses involving monoiso-7D consistently showed $1_{IV}+18_{II}+1_I$ whilst those

with 42 chromosomes exhibited $1_{IV}+18_{II}+1_{I}+i$, thus indicating that the *Ag. intermedium* chromosome in TAF_2 had spontaneously substituted for wheat chromosome 7D. The quadrivalent observed in all crosses indicated a translocation difference in Vilmorin 27 relative to Chinese Spring involving chromosomes in the A or B genomes. A 42-chromosome plant in the "critical" cross involving monoiso-7D proved to be exceptional, exhibiting a modal pairing of $1_{IV}+1_{III}+17_{II}+1_{I}$. One explanation is that the trivalent arose through non-disjunction of a wheat chromosome either during mega- or microsporogenesis, or in an early somatic division.

Crosses between a TAF_1 substitution line and the complete Chinese Spring monosomic, monotelosomic or monoisosomic stocks used as female parents indicated that the *Ag. intermedium* chromosome in this case replaced wheat chromosome pair 3A and that chromosomes 5B and 7B were involved in the translocation difference between Vilmorin and Chinese Spring. Hybrids with 41 chromosomes in all crosses excepting those involving monotelo-3A, monoiso-5B or monoiso-7B showed $1_{IV}+17_{II}+3_{I}$ at meiotic metaphase I, whilst the corresponding 42-chromosome plants exhibited $1_{IV}+17_{II}+t1_{II}$ (or $i1_{II}$)$+2_{I}$. Two hybrids with 41 chromosomes from the cross with monotelo-3A exhibited $1_{IV}+18_{II}+1_{I}$ whilst the meiotic configuration in three 42-chromosome plants was $1_{IV}+18_{II}+1_{I}+t_{I}$. Forty-one chromosome hybrids in crosses involving monoiso-5B or -7B showed $1_{III}+18_{II}+2_{I}$. Certain exceptional F_1 plants were observed in this series of crosses. One plant from the monotelo-2D cross possessed 40 chromosomes without a moniososome, with a $1_{IV}+16_{II}+4_{I}$ meiotic configuration, indicating probably spontaneous loss of a wheat chromosome other than 3A, 5B, 7B or 2D. A forty chromosome plant in the cross involving monoiso-5B exhibiting $1_{III}+17_{II}+3_{I}$ can be explained in like manner. Two exceptional plants occurred in the cross involving monotelo-3A. The first showed $1_{IV}+17_{II}+2_{I}+t_{I}$, presumably due to loss of a wheat chromosome other than 5B or 7B, the unpaired telocentric being 3A from Chinese Spring. The second plant possessed 63 chromosomes including a telocentric. This triploid plant apparently arose from the fertilization of a $20+t_{I}$ egg by an unreduced male gamete with 42 chromosomes lacking the 3A wheat pair (40 wheat and two *Ag. intermedium* chromosomes). The modal meiotic pairing in this plant was $1_{IV}+14_{III}+6_{II}+4_{I}+t_{I}$.

The translocation in Vilmorin 27 involves the same two chromosomes as in Poso (Sears 1953). Driscoll and Quinn (1968) have suggested the possibility of producing from such material a translocation aneuploid stock deficient for the long arm of 5B which might be expected to encourage wheat-alien homoeologous pairing. Hybrids involving TAF_1 and TAF_2 substitution lines may have direct application in this proposal.

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II. Editorial Remarks

Corrections

WIS No. 30, p. 12: In an article "On the location of the asynaptic gene in wheat" by T. MAKINO, the following corrections should be noted.

Table 1. 4th column: Read "10.74" for "10.72"; Read "13.32" for "14.42";
Read "11.20" for " 9.50"; Read "13.28" for " 7.30"
5th column: Read " 2.72" for " 2.60"; Read " 3.66" for " 3.92"
6th column: Read " 1.82" for " 1.86"; Read " 1.08" for " 1.06"
7th column: Read " 4.54" for " 4.46"; Read " 4.74" for " 4.98"
12th column: Read "11.70" for " 9.44"; Read " 9.18" for " 9.40"

Announcement for future issues

WIS No. 32 will be planned for publication in March 1971. Manuscripts for this issue are accepted any time, not later than January 31, 1971.

WIS is open to all contributions regarding methods, materials and stocks, ideas and research results related to genetics and cytology of *Triticum, Aegilops, Secale, Haynaldia* and related genera. Manuscripts should be typewritten in English, and submitted with duplicates. One article should not exceed five printed pages, including one textfigure (smaller than 7×7 cm^2). Lists of stocks are exempted from this page limit. Authors receive 50 reprints of their contributions free of charge. Extra copies are printed by order at cost prince. Communications regarding editorial matters should be addressed to:

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The Managing Editor

Explanation of the Figure on the Cover

Chromosome pairing at diakinsis in hexaploid *Triticale* (cf. T. TSUCHIYA, pp. 22~23 in the present issue).