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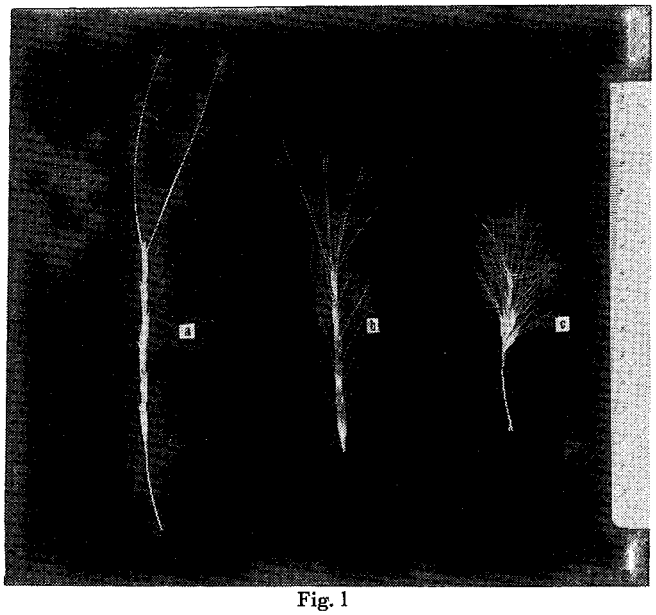

Fig. 1

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I. Research Notes

Structural heterozygosity and male sterility in *Triticum aestivum* L.[1)]

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Abstract

Male-sterile and partially male fertile common wheat (*Triticum aestivum* L.) plants were selected from crosses of Chinese Spring×Nebraska 542437-Lee and ×2 Selkirk[2]. All $F_3 \sim F_5$ plants were male sterile or partially male fertile, and most of these plants had 2n=42 (21_{II} or $19_{II}\ 1_{IV}$ or $19_{II}\ ⊙_4$).

Progeny of male steriles included plants with one or two multivalents ($16_{II}1_{IV}1_{VI}$, $17_{II}1_{III}1_{IV}$), and one plant had 2n=37 ($15_{II}1_{III}4_I$). Apparently, selection for male sterility resulted in plants with heterozygous chromosomal interchanges and aneuploidy.

Introduction

Several workers (1, 2, 3, 4) have reported male sterile plants among progenies from intervarietal crosses of common wheat. These genetic male sterile stocks were developed by selfing the partially male fertile plants or by crossing the male sterile plants with pollen from the fertile plants. In one report (2), transmission of the male sterility effect through the pollen and the F_2 segregation ratios indicated that the male sterile plants had one homozygous recessive gene for male sterility.

In this paper, we report the development of a male sterile hard red spring wheat with chromosome-structural heterozygosity.

Experimental results

One male-sterile F_1 plant (No. 64–952) was obtained from a cross between Chinese Spring mono-iso-6B and Rl-Lee (Nebraska No. 542437/Lee). This male sterile plant

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($2n=20_{II}+1_{I}$) was crossed with pollen from common wheat varieties Chinese Spring, Chris and Selkirk. One or more male sterile plants were obtained from crosses with each of the three varieties. One male sterile BCF_1 (65–1816) plant ($2n=21_{II}$, $19_{II}1_{IV}$) from the second cross with Selkirk (No. 64–952×2 Selkirk) set five seeds and produced five F_2 plants, four male sterile and one partially fertile (Tables 1 and 2). The F_3, F_4 and F_5 plants from crosses with Selkirk were examined for the percentage of seed set on bagged heads and for the chromosome number and chromosome pairing at metaphase I of meiosis in the pollen mother cells (Table 2). Of the five partially fertile F_3 plants, two were examined cytologically and both had $2n=21_{II}$ or $19_{II}\odot_4$. Of the 39 F_4 and F_5 plants, 13 were completely male sterile, 15 set 5% or less seed on the bagged heads. Of the remaining 11 F_4~F_5 plants, 7 set 10%, 1 set 20%, and 3 set 50% or more seeds. The classification of the 15 plants with 5% or less seeds in the sterile class would give a segrega-

Table 1. Segregation for male sterility among plants from crosses of Chinese Spring mono-iso-6B×R1-Lee and Selkirk

Cross	F_1 plant No.	% seed set	Number of F_2 plants				
			grown	sterile	part-fertile	fertile	unclassified
64–1265L× 64–1337–4*	64–951	50					
	64–952	0					
	64–953	40	32	2	0	30	0
	64–954	100	37	4	0	33	0
64–952× Selkirk	64–2399A	100	15	0	3	9	3
	64–2399B	100	14	0	2	8	4
	64–2400A	20	15	0	7	8	0
	64–2400B	1	2	1	0	1	0
	64–2440B	1	3**	0	1	2	0
64–2400B× Selkirk	65–1810	0	5**	3	2	0	0
	65–1811	10	4	0	2	2	0
	65–1812	10					
	65–1813	25					
	65–1814	80					
	65–1815	50					
	65–1816	1	2	2	0	0	0
	65–1816	1	3**	3	0	0	0
	65–1817	5					
	65–1818	25					
	65–1819	10					
	65–1820	50					
	65–1823	50					

*: 64–1265L×64–1337–4=Chinese Spring mono-iso 6B×Nebraska 542437-Lee.

**: Seed from unbagged heads.

Table 2. Association of structural heterozygosity of chromosomes and male sterility in common wheat

Pedigree	Plant No.	% seed set	Chromosome pairing
1265L × 1337-4* F_1	64-952	0	$20_{II}+1_I$
64-952 × Selkirk F_1	64-2440B	1	21_{II}, $19_{II}1_{IV}$
64-2400B × Selkirk F_1	65-1816	1	—
65-1816 (selfed) F_2	66-4455	0	—
	66-4456	0	—
	66-4457	0	—
	66-4458	5	—
	66-4459	0	—
66-4455 × Selkirk F_1	67-1143	90	21_{II}, $19_{II}1_{III}1_I$
	67-1144	50	21_{II}, $19_{II}1_{IV}$
	67-1145	20	$17_{II}1_{III}1_{IV}$
	67-1148	90	$16_{II}1_{IV}1_{VI}$
	67-1150	20	21_{II}, $19_{II}1_{IV}$
66-4458 (selfed) F_3	67-1136	10	21_{II}, $19_{II}\odot_4$
	67-1137	10	21_{II}, $19_{II}\odot_4$
67-1137 (selfed) F_4	67-3006	10	—
	67-3007	2	21_{II}, $19_{II}\odot_4$
	67-3008	1	—
	67-3009	2	—
	67-3010	50	21_{II}, $19_{II}\odot_4$
67-3006 (selfed) F_5	67-3701	0	21_{II}, $19_{II}1_{IV}$
	67-3702	0	21_{II}, $19_{II}\odot_4$
	67-3703	0	21_{II}, $19_{II}\odot_4$
	67-3704	10	21_{II}, $19_{II}\odot_4$
	67-3705	10	21_{II}, $19_{II}\odot_4$
	67-3706	0	21_{II}, $19_{II}\odot_4$
	67-3707	0	$2n=37$, $15_{II}1_{III}4_I$
	67-3708	5	21_{II}, $19_{II}\odot_4$
	67-3709	5	21_{II}, $18_{II}1_V1_I$
	67-3710	5	21_{II}, $19_{II}\odot_4$
67-3007 (selfed) F_5	67-3711	0	21_{II}
	67-3712	5	21_{II}
	67-3713	0	21_{II}, $19_{II}1_{IV}$
	67-3714	2	21_{II}, $19_{II}\odot_4$
	67-3715	2	21_{II}, $19_{II}\odot_4$
67-3008 (selfed) F_5	67-3716	0	21_{II}, $19_{II}\odot_4$
	67-3717	0	21_{II}, $19_{II}\odot_4$

Table 2. (continued)

Pedigree	Plant No.	% seed set	Chromosome pairing
67-3009 (selfed) F_5	67-3718	1	21_{II}, $19_{II}1_{IV}$
	67-3719	1	21_{II}, $19_{II}1_{IV}$
	67-3720	75	21_{II}, $19_{II}1_{IV}$
	67-3721	1	21_{II}, $19_{II}1_{IV}$
	67-3722	0	21_{II}, $19_{II}1_{IV}$
	67-3723	5	21_{II}, $19_{II}1_{IV}$
	67-3724	50	21_{II}, $19_{II}\odot_4$
67-3010 (selfed) F_5	67-3725	5	21_{II}, $19_{II}\odot_4$
	67-3726	10	21_{II}, $19_{II}1_{IV}$
	67-3727	10	21_{II}, $19_{II}\odot_4$
	67-3728	10	21_{II}
	67-3729	20	21_{II}, $19_{II}1_{IV}$
	67-3730	0	21_{II}, $19_{II}\odot_4$
	67-3731	0	21_{II}, $19_{II}1_{IV}$
	67-3732	2	21_{II}, $19_{II}1_{IV}$
	67-3733	10	21_{II}, $19_{II}1_{IV}$
	67-3734	1	21_{II}

* 1265L × 1337-4 = Chinese Spring mono-iso-6B × Nebraska 542437-Lee.

tion ratio of 28 sterile: 11 partially fertile, a single-gene segregation?

Of the 39 F_4~F_5 plants, 37 were examined cytologically; 35 had $2n=42=21_{II}$ or $19_{II}1_{IV}$ (a chain or a ring or both), 1 had $2n=42=21_{II}$ or $19_{II}1_V1_I$, and 1 had $2n=37=15_{II}1_{III}4_I$.

Most F_5 plants had a chain-of-four or a ring-of-four. Only four F_5 plants had $2n=21_{II}$. These four male sterile plants with normal 21 chromosome pairs were from two F_4 plants with $2n=42$ (21_{II}, $19_{II}\odot_4$). A critical examination might have shown the presence of a multivalent in these F_5 plants.

A cross of one male sterile F_2 plant (No. 66-4455) with Selkirk pollen produced plants with different percentages of seed set and with different chromosome pairing configurations (Table 2). Of five plants from the cross of No. 66-4455 × Selkirk, two plants, Nos. 67-1145 and 67-1146, had some of the pollen mother cells with two multivalents, $17_{II}1_{III}1_{IV}$ and $16_{II}1_{IV}1_{VI}$, respectively. The occurrence of more than one multivalent in these plants, and various frequencies of a multivalent among the F_5 plants, indicated that all these male sterile plants did not have the same chromosome interchange—also that some of the plants had more than one chromosome interchange.

Discussion

Most F_5 plants had complete or nearly complete male sterility and had a ring-of-four or a chain-of-four at metaphase 1 of meiosis in some of the pollen mother cells.

Of the 34 F_5 plants, one had $2n=37$ ($15_{II}1_{III}4_I$) and another had $2n=42$ ($18_{II}1_V1_I$). These plants would produce complex aneuploids. If the genetic male sterile stocks reported by other workers have structural heterozygosity, then those male sterile stocks may show cytological instability. WANINGE and ZEVEN reported PUGSLEY's genetic male-sterile had aneuploids. Our male-sterile wheat plants had chromosome-structural heterozygosity and some of these produced aneuploids or plants with one or two multivalents of three, four, five or six chromosomes. Apparently, selection for male sterility resulted in selection for chromosomal interchanges. Because frequency of a multivalent between plants was different, all male-sterile plants may not have an identical chromosome interchange.

Literature cited

1. ATHWAL, D. S., P. S. PHUL and J. L. MINOCHA 1967. Genetic male sterility in wheat. Euphytica **16** : 354~360.
2. BRIGGLE, L. W. 1968. Genetic male sterility in hexaploid wheat. Proc. 11th Hard Red Winter and Hard Red Spring Wheat Workers Conference. Feb. 6–8, 1968, p. 100~101.
3. GILL, B. S. and S. C. ANAND 1970. Genetic male sterility for hybrid seed production in wheat. Crop Science **10** : 385~386.
4. PUGSLEY, A. T. and R. N. ORAM 1959. Genetic male sterility in wheat. Australian Plant Breeding and Genetics Newsletter **14**.
5. WANINGE, J. and A. C. ZEVEN 1968. Chromosome numbers in Pugsley's male sterile wheat. Euphytica **17** : 378~380.

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Spontaneous speltoid and compactoid mutants in male sterile lines of *T. aestivum* and *T. sphaerococcum* carrying *T. timopheevi* cytoplasma

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In our studies on hybrid wheat with *T. timopheevi* system of cytoplasmic-genetic male sterility and fertility restoration involving conversion programme of male sterile (A-line) and fertility restorer (R-line) lines in more than hundred spring wheat varieties, we have noticed a few spontaneous mutants for ear characters and likewise, also in *T. sphaerococcum* in which *timopheevi* cytoplasm was incorporated. Segregating Selkirk and Pembina stocks carrying *T. timopheevi* cytoplasm and genes for fertility restoration used in our investigation were kindly supplied by Dr. A. B. CAMPBELL, Canada Department of Agriculture, Winnipeg, Manitoba, Canada.

Four speltoid plants found in male sterile selfed BC_1 (partially fertile plants from BC_1) progenies of C 306, PV 18, Kalyansona and S 310 varieties in a population of 2412 plants were partially fertile, most of the spikelets in a ear produced abnormal anthers which did not shed viable pollen, whereas none was found in a population of more than one million plants from male fertile, selfed BC_1 progenies carring *timopheevi* cytoplasm and fertility restorer genes. The ears of these plants showed elongation of rachillae with varying degrees of laxness with maximum being more than double the ear length of that of the original wheat variety and had strongly keeled, tight glumes. From male sterile selfed BC_2 (Partially fertile plants from BC_2) progenies of Sherbati Sonora in a population of 3181 plants three partially fertile plants were found, two had lax ears and tight glumes resembling those of *T. spelta* and one was like *T. compactum*, while in more than one million plants from male fertile selfed BC_2 progenies not a single such plant was found. Seeds from these three plants when grown produced plants with ears resembling with those of *T. spelta* and *T. compactum*. Such plants were not found in BC_1, BC_2 and selfed BC_3 male sterile progenies. One speltoid was found in F_2 population of 210 plants of *T. sphaerococcum* male sterile line. This plant was highly male sterile but set few seeds which when grown in the following season produced plants with *spelta* like ears. All these eight mutants were recovered from a population of more than two and half a million plants.

Cytoplasmic effects may cause reduction in plant height and shortening of internodes, as our observations show that dwarf plants arise occasionally in early generation materials during conversion programme of A-line and R-line in wheat varieties. Such cytoplasmic effects have been reported by DUVICK (1965) in corn.

Since the frequency of speltoid and compactoid heads in male sterile plant population is considerably lower than that of dwarf plants and since the progeny of these ear types show *spelta* and *compactum* type ear characters the possibility of cytoplasmic effects can be ruled out and presumably here mutation at the *Q* locus is involved. Only after hybridization of these mutants with normal wheat varieties and their genetic analysis, which we have under way now, it will be possible to ascertain their exact nature. SWAMINATHAN (1965) has provided experimental evidence that speltoid and compactoid mutants arise following induced mutations at the *Q* locus situated at the long arm of chromosome 5A in the sub-species *vulgare, compactum* and *sphaerococcum*. He suggested that spontaneous speltoid and compactoid mutants may occur frequently in populations of these three subspecies following unequal crossing over within the locus. MASSON and ANDERSON (1962) have reported spontaneous occurrence of speltoid mutants in populations of Selkirk, Pembina, Thatcher, Redman and Regent, commercially grown wheat varieties in Western Canada.

Due to inadequate development of vascular bundles in the anthers of male sterile plants transmission of some substances, DNA and RNA, from tapetal cells to the develop-

ing microspores is restricted (JOPPA *et al.* 1966 and DUVICK 1965). Hence, it is quite likely that the male sterility inducing *timopheevi* cytoplasm which affects the microgametogenesis adversely in *T. aestivum* and *T. sphaerococcum* might have provided the environment which perhaps enhanced the possibility of occurrence of mutation at the *Q* locus resulting in the alteration of the sequence of developmental processes controlling the spikelet density in ears and consequently, phenotypic variations in ear characters arise up to subspecific level.

Literature cited

DUVICK, D. N. 1965. Cytoplasmic pollen sterility in corn. Advan. Genet. **13** : 1～56.

JOPPA, L. R., F. H. MCNEAL and J. R. WELSH 1966. Pollen and anther development in cytoplasmic male sterile wheat. Crop Sci. **6** : 296～297.

MASSON, A. B. and R. G. ANDERSON 1962. Speltoids in wheat. Seed Scoop **8**(6) : 4～5.

SWAMINATHAN, M. S. 1965. The origin of macro- from micro-mutations and factors governing the direction of micro-mutational changes. Proceed. 3rd Inter. Symp. The Impact of Mendelism on Agriculture Biology and Medicine. Ind. Jour. Genet. Pl. Breed. **26A** : 29～41.

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Dwarf and semi-dwarf mutation induced in *T. aestivum* (L.) THELL. ssp. *vulgare* (VILL.) MK. with X-rays and EMS

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Dry seeds of the sorts Bezostaya 1 and Mironovska 808 were irradiated with X-rays with doses of 10, 15 and 20 kr, and a part of the seeds in M_1 were treated with EMS using concentrations of 0.2 and 0.4 at 25°C during 24 hours. In M_2 after the treatment low-stem mutant forms were chosen, in M_3 their inheritance was checked and in M_4 and M_5 reproduction was carried out of the more potentially valuable forms. Well equalized lines of M_5 were checked for productivity and the indices showing the character and quality of the grains as well as the resistance to cold. Table 1 shows that the induced mutation lines are characterized with stems, low in height and resistant to down-beating. The average height of the mutation lines of Bezostaya varies from 19.3 to 53.6 cm. while that of the initial sort was 76.8 cm.; the average heit of the mutation lines of Mironovska 808 varies from 31.2 to 55.2 cm., while that of the initial sort was 93.0 cm. A definite correlation has been found between height of stem and length of ear. The form of the ear of the dwarfs is compact and of the semi-dwarfs is square-headed or normal. The short ears are compact and the number of spikelets approach the original sorts. Nearly all short-stem lines have more protein and sedimentation value. All have smaller

Table 1. Characteristic of initial sorts and low-stem mutational lines

Initial sort and mutation line	Height of plant	Main ear			Weight of 1000 grains	Proteins of absolute dry matter	Sedimentary value
		Length cm.	Spikelets No.	Grains No.			
Bezostaya	76.8	10.1	20.5	44.6	39	13.51	54
M 197/322	53.6	7.6	20.3	46.1	32	15.37	70
M 169	40.6	6.7	16.7	27.7	28	17.69	70
M 98/21	53.2	9.2	18.0	35.2	35	13.83	70
M 51/112	44.3	9.1	21.4	45.2	26	16.40	73
M 20/127	19.3	4.8	18.3	35.0	31	17.78	66
Mironovska 808	93.0	11.6	19.8	44.0	44	14.03	57
M 161/322	55.2	6.5	18.2	41.0	36	14.42	60
M 204/36	51.3	9.3	18.7	42.0	44	14.68	69
M 36/61	47.0	7.8	15.8	37.4	27	15.93	45
M 8/24	40.6	6.1	16.0	40.7	31	17.67	80
M 295/206	31.2	5.7	17.4	22.0	21	17.62	82

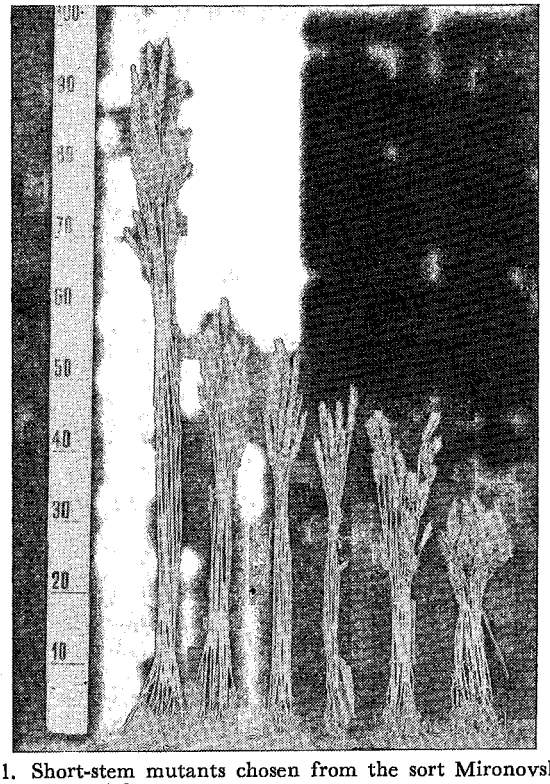

Figure 1. Short-stem mutants chosen from the sort Mironovska 808; From left to right: Mironovska 808—initial sort, M 161/322, M 204/36, M 36/61, M 8/24 and M 296/206

grain, lesser germination and assure lower yield of grain per plant. The latter is due mainly to the smaller grain.

For this reason the wheat short-stem sorts used in the selection being predominantly spring varieties it is of utmost importance that the investigated sorts should be mutants resistant to cold. Four of them originated from the sort Bezostaya 1 have a higher resistance to cold than Benzostaya 1 and have shown 12, 18, 33 and 72% of the plants resistant at −15°C. A high resistance to cold is shown also by the lines of the sort Mironovska 808 being lower initially but higher than the resistance of Bezostaya 1. The higher resistance of some of the mutants coincides with the results obtained by SHKVARNICOV (1964), TAVCAR and KENDJELIC (1966) and by DOUBININ (1969) and collaborates the theory that the mutation is one of the methods to stiplate resistance to cold and winter-hardness genetically for wheat, through polymeric factors stipulating such qualities.

The advantageous combination of short stem and high resistance to cold, good technological and productivity characterizes the studied short-stem mutants as suitable components in the selection of short-stem wheat sorts.

Literature cited

DOUBININ, N. P. 1969. Genetics and Agriculture. Edited by "Znanie"

SHKVARNICOV, P. K. 1964. Izv. Sib. Otd. AN USSR. Seria Biol. Med. Sci. 4(1) : 64～73.

TAVCAR, A. and V. KENDJELIC 1966. Mechanism and induc. factors. Prague, 101～111.

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Identification of chromosomes carrying factors for seed storage proteins

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The necessity and feasibility of improving the protein content and its quality in wheat have been stressed by SWAMINATHAN[1] and BORLAUG[2]. As high as 20% protein has been recorded in wheat (JOHNSON *et al.*[3] and AUSTIN *et al.*[4]). BORLAUG[2] and JOHNSON *et al.*[3] have shown that higher protein quantity of superior quality can easily be incorporated in high yielding strains of wheat through hybridization in widely divergent genotypes. Since a knowledge of the genetics of protein characters would be helpful in breeding, an attempt was made to identify the genes associated with high protein content and to locate the same on specific chromosomes through monosomic analysis.

Each of the twenty-one monosomic lines of the wheat variety Chinese Spring was crossed with the dwarf varieties Sonora-64 and Lerma Rojo-64A. As against a 12% protein content in the disomic variety Chinese Spring, Sonora-64 and Lerma Rojo contained about 15% protein at the same soil fertility level. The monosomic Chinese Spring

lines were used as female parents and Sonora-64 and Lerma Rojo as male parents in the two separate sets of crosses. The protein content was determined for 42 chromosome and 41 chromosome plants in all the 21 monosomic lines in the F_1 generation. The F_2 populations derived from the monosomic F_1 plants, for each monosomic line, were harvested in bulk. Seeds from some randomly chosen single plants from each of the 21 lines were harvested separately. The F_3 progenies of twenty single F_2 plants for critical monosomics were raised and their grain protein content was also determined. The Dye binding capacity technique (UDY[6] and KAUL *et al.*[6]) was used to determine the protein quality in the 1968~69 material. Tryptophan content of the critical chromosome lines showing high protein content, was also determined along with their parental lines (SPIES and CHAMBERS 1949).

The 21 monosomic lines of Chinese Spring did not differ significantly in protein content among themselves. However, in comparison to the disomic the grain protein content in each of the 21 monosomic lines was slightly higher (Table 1).

The monosomic F_1 plants of eight chromosome lines namely 1D, 2A, 3A, 3B, 5A, 6B, 7A and 7B in Chinese Spring × Sonora-64 showed a significantly higher grain protein content in comparison to their disomic counterpart (Table 2). Similar significant increases in grain protein content were observed in the monosomic F_1's of five chromosomes—1D, 3A, 3B, 6B and 7D in Chinese Spring × Lerma Rojo.

Table 1. Protein content in 21 monosomic lines of wheat variety Chinese Spring

Chromosome	Genome		
	A	B	D
1	12.2	14.0	14.0
2	13.5	13.7	14.0
3	13.6	14.0	14.2
4	14.2	13.5	13.0
5	14.0	14.2	14.0
6	14.3	14.0	13.2
7	12.6	13.2	12.8
Disomic control	12.0		

The F_2 data for two seasons (1967~68 and 1968~69) showed a significant increase in grain protein content in the F_2 progenies of 41-chromosome F_2 plants for six chromosomes, namely 1D, 3A, 3B, 5A, 7A and 7B in Chinese Spring × Sonora-64. In two chromosome lines involving 2A and 6B, an increase had been observed in the F_1 monosomics, but no corresponding increase in grain protein content could be obtained in the F_1 progenies. In Chinese Spring × Lerma Rojo, a highly significant increase in grain protein content was observed in the F_2 progenies of 41-chromosome F_1 plants involving

Table 2. Protein content in the parents, F_1 and F_2 of monosomic lines

Material	Grain protein content (%)		DBC (absorption units)
	F_1	F_2 (1967~68)	F_2 (1968~69)
Chinese Spring × Sonora-64			
1D (2n=41)	19.6	16.5	0.26
2A (2n=41)	18.0	15.1	0.25
3A (2n=41)	18.6	18.0	0.26
3B (2n=41)	20.0	17.2	0.26
5A (2n=41)	21.0	17.4	0.27
6B (2n=41)	17.8	13.0	0.25
7A (2n=41)	19.9	16.6	0.26
7B (2n=41)	19.0	16.4	0.27
Disomic (2n=42)	14.6	14.0	0.24
Chinese Spring × Lerma Rojo			
1D (2n=41)	18.6	16.8	0.28
2A (2n=41)	16.0	14.4	0.22
3A (2n=41)	19.0	16.7	0.26
3B (2n=41)	17.4	16.5	0.26
6B (2n=41)	17.7	13.4	0.22
7D (2n=41)	18.5	16.2	0.26
Disomic (2n=42)	15.0	14.6	0.24

Table 3. Tryptophan content in the F_2 (bulk) population in critical monosomic lines

Material	Tryptophan content gm/100 gm meal
Chinese Spring	0.085
Sonora-64	0.108
Lerma Rojo	0.114
Chinese Spring × Sonora-64 F_2	
Disomic (2n=42)	0.090
1D (2n=41)	0.118
3A (2n=41)	0.130
3B (2n=41)	0.122
5A (2n=41)	0.130
7A (2n=41)	0.130
7B (2n=41)	0.104
Chinese Spring × Lerma Rojo F_2	
Disomic (2n=42)	0.100
1D (2n=41)	0.110
3A (2n=41)	0.142
3B (2n=41)	0.118
7B (2n=41)	0.110

chromosomes 1D, 3A, 3B and 7D. The high grain protein noted in the 41-chromosome F_1 plants for 6B, however, was not maintained in the F_2 progenies. In monosomic F_1's of 2A and 6B in the Sonora-64 cross and 6B in the Lerma Rojo cross there was shrivelling of seeds and partial sterility and these could account for some of the enhanced protein content observed in them. In F_1, the grain protein content was higher than the mid-parent values in both the crosses. In the critical monosomic lines also, protein content was higher than that in the donor parent (Lerma Rojo and Sonora-64). This may be due to a heterosis effect for protein content.

Sonora-64 and Lerma Rojo showed a significantly higher tryptophan content in comparision with Chinese Spring. The data on the tryptophan analysis (Table 3) showed a significantly higher tryptophan content in all the critical lines possessing a higher protein content in both F_1 and F_2 (i.e., monosomics 1D, 3A, 3B, 5A, 7A and 7B; and 1D, 3A, 3B and 7D in Chinese Spring × Sonora-64 and Chinese Spring × Lerma Rojo respectively.

The data on protein content (Table 4) from the F_3 progenies of critical monosomic lines confirm the F_2 results in both the crosses. The average grain protein content in the F_3 progenies of each critical line was higher than that in their disomic control. Different F_3 families in each critical line showed very little variation. Differences between different F_3 families seldom exceeded more than 2 DBC units. The average protein con-

Table 4. Grain protein content in the F_3 progenies of critical monosomic lines

Material	DBC absorption units	
	Mean of 20 F_3 families	Range
Chinese Spring × Sonora-64		
Disomic (2n=42)	0.23	0.21～0.27
1D (2n=41)	0.25	0.24～0.27
3A (2n=41)	0.26	0.25～0.28
3B (2n=41)	0.26	0.25～0.28
5A (2n=41)	0.26	0.25～0.27
7A (2n=41)	0.25	0.24～0.26
7B (2n=41)	0.26	0.24～0.27
Chinese Spring × Lerma Rojo		
Disomic (2n=42)	0.23	0.20～0.26
1D (2n=41)	0.25	0.24～0.26
3A (2n=41)	0.26	0.25～0.28
3B (2n=41)	0.26	0.25～0.27
7D (2n=41)	0.26	0.25～0.27
Sonora-64	0.26	
Lerma Rojo	0.26	
Chinese Spring	0.22	

tent in different critical monosomic lines also did not show much variation. Taking all the critical monosomic lines together for each cross, the range of variation in protein content was lower in the F_3 of critical lines than in the disomic control. In the Sonora-64 cross, the protein content in DBC absorption units varied from 0.24 to 0.28 in the critical monosomics as against 0.21 to 0.27 units in the F_3 of disomic control. Similarly, in the Lerma Rojo cross it ranged from 0.24 to 0.27 units in the critical lines as against 0.20 to 0.26 in the F_3 of disomic control. The DBC absorption value for F_2 bulk was 0.24 in both the crosses, whereas in F_3 the DBC value was 0.23 units. In the critical monosomic lines also the average protein content in the F_3 was slightly less than that in their corresponding F_2 parent. This indicates that effects other than those caused by additive gene action for grain protein content persist in the F_2 generation. In the F_3 generation, a few families showed a protein content higher than that of the donor parent, more particularly in mono-3A, -3B and -5A in the Sonora-64 cross and in mono-3B and -3A of the Lerma Rojo cross. These chromosomes might have genes for protein synthesis with a better penetrance.

Wheat strains containing a high protein content have been developed in India and Mexico using Sonora-64 and Lerma Rojo as the base material. This suggests that Sonora-64 and Lerma Rojo might have a few non-identical factors controlling protein content, which is in agreement with the present findings. JHA[7] located the factors for grain color of Sonora-64 and Lerma Rojo on chromosomes 3B and 3A respectively. The present study shows that one of the factors for high grain protein content and grain color in Sonora-64 and Lerma Rojo are located on the same chromosome. This might explain why some amber grain mutants isolated from Sonora-64 had simultaneously a higher protein content. A similar situation might prevail in Lerma Rojo also and this is probably why Pusa Lerma, an induced amber-grain mutant from Lerma Rojo, has shown a higher protein content than the parent strain (AUSTIN, personal communication).

Literature

1. SWAMINATHAN, M. S. 1968. Five Years of Research on Dwarf Wheats. I.A.R.I., pp. 1～46.
2. BORLAUG, N. E. 1968. Proc. 11th Hard and Red Winter Joint Wheat Workers Conference. pp. 8～23.
3. JOHNSON, V. A., P. J. MATTEM and J. W. SCHMIDT 1968. Ibid., p-56.
4. AUSTIN, A., V. K. HANSLAL and H. D. SINGH 1968. J.P.G. School, I.A.R.I., 6 : 131～142.
5. UDY, D. C. 1956. Cereal Chem. 33 : 190.
6. KAUL, A. K., R. D. DHAR, M. S. SWAMINATHAN and G. AHNSTROM 1969. Curr. Sci., 14 : 330.
7. JHA, M. P. 1970. (In press).
8. SPIES, J. R. and D. C. CHAMBERS 1949. Analytical Chem. 21 : 514～523.

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Inheritance of dwarfness in Olesen's Dwarf (*T. aestivum* L.)

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Introduction

Dwarf wheat varieties are responsible for a major break through in wheat production in many parts of the world. This was because of their response to heavy doses of fertilization without lodging. The dwarfness in these varieties was derived from the Japanese Norin-10 source. It is controlled by two major independent recessive genes and several modifying factors (BRIGGLE and VOGEL 1968). Since the dwarfness in Norin-10 source is recessive, a large population is required to be grown to select plants with several dwarfing genes. Recently the authors came across another short variety Olesen's Dwarf. This variety was picked from the wheat material grown in Rhodesia and is of unknown genetic origin[1]. The inheritance of dwarfness in this strain has not yet been reported. The present paper deals with the mode of inheritance of dwarfness in Olesen's Dwarf as it is different from other sources of dwarfness in wheat.

Material and method

Olesen's Dwarf wheat strain was crossed with the tall indigenous variety C 306. The F_1 was back crossed with both the parents. The two parents, the F_1, the two back crosses and the F_2 plants were grown in a compact block in 1969~70 at the Punjab Agricultural University, Ludhiana. The plants were spaced 15 cm apart with 42 cm distance between rows. Any gap which occurred between the plants was filled. The height of the plants was measured from the ground level to the tip of the spike (excluding awns) at maturity.

Results and discussion

The means and variances of parents and other generations are given in Table 1 and

Table 1. The mean and variance for plant height in different generations of the cross C 306×Olesen's Dwarf

Variety/Generation	No. of plants	(Height cm)	S^2
C306	15	132.2	
Olesen's Dwarf	14	50.6	
F_1	12	81.8	
F_2	188	86.9	7845
BC_1 (F_1×C306)	46	102.1	11049
BC_2 (F_1×Olesen's Dwarf)	48	64.2	7384

1) Personal communication, Dr. R.G. ANDERSON, The Rockefeller Foundation, New Delhi., India.

Table 2. Frequency distribution (percentage) of plants in different height categories in the F_2, BC_1 and BC_2 generations of the cross C306 × Olesen's Dwarf

Mean height (cm)	Range (cm)	F_2	BC_1	BC_2
48	45～51	1.6	—	12.5
55	52～58	3.7	—	6.2
62	59～65	6.9	—	37.5
69	66～72	8.0	—	25.0
76	73～79	14.9	—	12.5
83	80～86	12.2	4.3	6.2
90	87～93	12.2	13.0	—
97	94～100	11.7	34.8	—
104	101～107	16.0	17.4	—
111	108～114	7.4	8.7	—
118	115～121	2.1	13.0	—
125	122～128	2.1	4.3	—
132	129～135	1.1	4.3	—

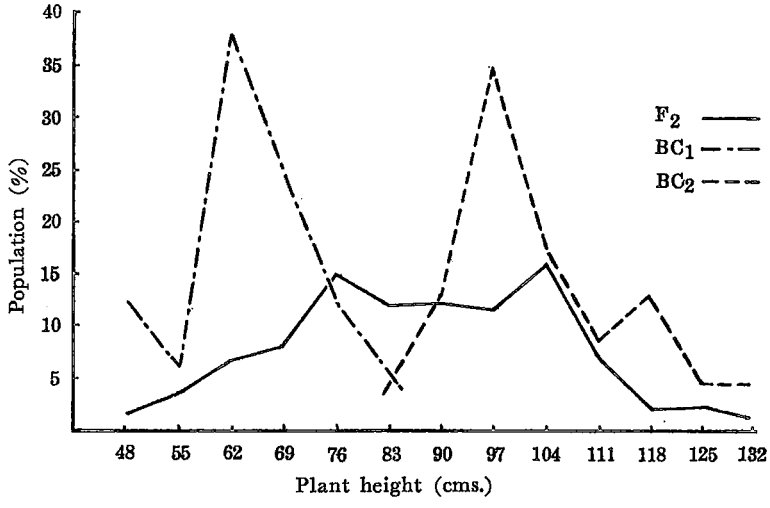

Figure 1. Frequency distribution of F_2, BC_1 and BC_2 generations for plant height in the Olesen's Dwarf × C 306

their frequency distribution is represented in Table 2 and Fig. 1.

The tall parent C 306 had a mean height of 132.2 cm and the Olesen's Dwarf was only 50.6 cm high. The height of F_1 plants was 81.8 cm which was lower than the mean of the parents, indicating partial dominance for dwarfness. The average height of the F_2 plants was 86.9 cm which further confirmed that the dominance for dwarfness was incomplete and some other gene action was also involved. The frequency distribution of the F_2 plants (Table 2 and Fig. 1) showed bimodal distribution with a larger number

Table 3. The plant heights in the F_2 and back cross generations, together with genotypes and frequencies

Generation	Theoretical frequency	Genotype	Height
F_2	1	*AABB*	dwarf
	2	*AABb*	〃
	1	*AAbb*	〃
	2	*AaBB*	〃
	4	*AaBb*	medium
	2	*Aabb*	〃
	1	*aaBB*	〃
	2	*aaBb*	〃
	1	*aabb*	tall
BC_1	1	*AaBb*	medium
	1	*Aabb*	〃
	1	*aaBb*	〃
	1	*aabb*	tall
BC_2	1	*AABB*	dwarf
	1	*AABb*	〃
	1	*AaBB*	〃
	1	*AaBb*	medium

of plants at 76 cm and fewer plant in between. This indicates the operation of two different genes controlling the expression of plant height in this cross. In the back cross generation, the plants segregated into dwarf or tall ones with approximately 5% overlapping only. This suggests that only few genes are involved. The frequency distribution in the F_2 and back cross generations further indicates that there are two major genes controlling height in Olesen's Dwarf. One of the genes has greater effect on plant height than the other. The plant height in the F_2 and back cross generations varied according to the following assumptions given in Table 3.

Dwarfness is partially dominant over tallness. The two genes have cumulative effect. If only one of them is present, the plant is semi-tall. The heterozygotes of both the genes are medium in height. The homozygotes are shorter than the heterozygotes. It is very likely that there are some modifying factors in addition to the two major factors controlling height. The authors have not come across in the literature such inheritance in wheat.

Summary

Olesen's Dwarf wheat variety was crossed with the tall variety C 306. The segregation of height in the F_2 and back cross generations indicated the existence of two major genes controlling this character. The dwarfness is partially dominant and the two genes

have cumulative effect. This variety has a different source of dwarfness and has not been reported so far.

Literature cited

BRIGGLE, L. W. and O. A. VOGEL 1968. Breeding short stature, disease resistant wheats in the United States. Euphytica 17 (1968 Suppl. 1) : 107~130.

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Development of secondary hexaploid *Triticales* by crossing *Triticale* with rye

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Under our conditions hexaploid *Triticale*-forms are more productive than octoploids. Hexaploids, however, incline to lodging, and characteristics concerning earliness, winter-hardiness and drought tolerance do not fill the requirements. These unfavourable qualities must be implicitely improved upon, in order to make them competetive with traditional fodder cereals. Protein content is satisfactory; but the lysine and triptophane content in *Triticale* protein has to be improved. For food purposes it is important to develop gluten of good quality and to improve the baking and technological qualities.

Feeding problems have been caused by spontaneous infections of ergot (*Claviceps purpurea*). Animals do like it as grain fodder. Its present nutrition value is slightly better than that of wheat or maize. In regions where rye is grown its quality surpasses that of rye-bread. As in Hungary bread made of wheat is preferred, *Triticale* as bread cereal, is not a primary question.

At the present stage of *Triticales* breeding we have to examine which way to follow in improving and how to enlarge variability. Crossing octoploids with hexaploid *Triticales* are highly adequate for this purpose. However, when developing secondary hexaploid *Triticales* the significance of the rye and wheat genome respectively has not been cleared up yet. In the present study the part of the rye genome was examined (Table 1.).

In 1966 401 seeds (10.77%) were obtained from crossing 3720 flowers; in 1967, 10 seeds (1.09%) were obtained when crossing 922 flowers, and in 1968 two seeds (0.38%) were obtained from crossing 524 flowers. SULUNDIN and NAUMOVA (1965) obtained seed set of 16.5%, while in 1965~67 TARKOWSKI got 38.8~45.8%. TARKOWSKI doubled the chromosomes in a F_1 plant with 28 chromosomes and got a completely new alloautoocto-

Table 1. Studies of hexaploid *Triticale* × *Secale cereale* and reciprocal crosses in 1966~1968

Combination	Pollinated flowers	Grain set number (%)	Germinated grain number (%)	Pollen fertility of F_1 in %	Grain/ ear number of F_1 in %
1966. :					
T. No. 57 × *S. cereale*	491	7 (1.24)	5 (71.50)	51.0	7.9
T. No. 64 × 〃	1,172	44 (3.75)	33 (75.00)	49.3	4.2
T. Ko. × 〃	1,567	213 (13.59)	129 (60.57)	31.6	3.5
(T. Ko. × T. 30) × *S. cereale*	490	137 (27.96)	52 (37.96)	9.7	2.4
S. cereale × T. No. 57	1,570	0 (0)	— (—)	—	—
1967. :					
T. No. 57 × *S. cereale*	814	9 (1.11)	7 (77.80)	26.9	4.5
〃 × *S. vavilovi*	108	1 (0.92)	1 (100.00)	17.0	0.0
S. cereale × T. No. 57	530	0 (0)	— (—)	—	—
1968. :					
T. No. 64 × *S. cereale*	524	2 (0.38)	2 (100.00)	15.5	1.5
S. cereale × T. No. 64	112	0 (0)	— (—)	—	—
N.N.5. Summer Toluca(CIMMYT)*Triticale* 6x × Rye	2,055	344 (16.70)	— (20~30)	—	—
1968~1969					
N.N.5. Winter Ciano(CIMMYT)*Triticale* 6x × Rye	188	17 (9.0)	— (—)	—	—

ploid plant with genomes AABBSSSS. It is from this plant that he wants to develop a cross pollinating *Triticale*-form.

We had in mind to develop more secondary hexaploid *Triticales*. Thus, F_1 plants when in bloom were backcrossed with *Triticale* No. 57 and No. 64. While in the first generation of the hexaploid wheat × rye cross flowers are almost entirely sterile (out of 100 flowers 0.2 seeds are expected), F1 flowers of the hexaploid *Triticale* × rye cross are slightly more fertile, since we got an average of 1~2 seed out of a hundred flowers. In extreme cases seed set per plant can vary between 0~112.

When examining pollen in the first generation of the hexaploid wheat × rye, stained pollen grains represented 0~19%; in the first generation of hexaploid *Triticale* × rye the extreme values of stained pollen grains varied between 9.7~51.0%. All this can be explained by differences of the basic genomes. In the wheat rye cross the genome formula of the F_1 plants is ABDS, while the hexaploid *Triticale* × rye cross contains ABSS genomes, that is, beside the AB genomes of wheat there are two rye genomes. In meiosis rye chromosomes segregate normally, while wheat chromosomes form univalents, and it is very seldom that pairing occurs between homoeologous chromosomes (1~21%).

Crossing *Secale cereale* with *Triticale* has been unsuccessful in all three years. However, it is almost certain, if crosses were made with more rye varieties and in larger num-

bers in this direction seed set would occur.

In 1967, 218 plants were cultivated in the first generation of a hexaploid *Triticale* × *Secale* cereale cross. Out of them 104 plants were entirely sterile; 114 plants were slightly fertile. In case of a segregation of 1 : 1 the chi^2 value is 0.458 P% = 50~30.

In 1968, we only got 8 F_1 plants; 5 sterile and 3 slightly fertile ones.

F_1 hybrids were 2.9~25.0 cm taller than the taller parent. In maturity they stood between *Triticale* and rye. Ears were stirikingly similar to sterile ears of *Triticale*. The rye character asserted itself in the size of the auricle, while that of *Triticale* in its red color.

The meiosis of only 4 F_1 plants with 28 chromosomes was examined (1315 pollen mother cells). It appeared that univalent chromosomes varied between 6~18. The number of cells containing 7 bivalents varied individually, the smallest value being 30.6, the highest 37.5%. In two cases cells with 6 bivalents were present in the largest numbers (34.7~48.7%). Examination showed that there are much more bivalents in hybrids from hexaploid *Triticale* × *Secale cereale* crosses than in hybrids of hexaploid wheat × *Secale cereale*.

In 1968, 333 BCF_1 plants were grown; 38 plants were completely sterile, 168 plants yielded about 50 seeds, 110 plants had a grain yield between 100~500, 14 plants between 550~1000, and only 3 plants yielded more than 1,000 seeds.

Table 2. Grain yield and chief ear number of BCF_1 generations in a cross of hexaploid *Triticale*^{2} with *Secale cereale*

Number of seeds	0 ~ 10~20~30~40~50~60~70~80								$\bar{x}\pm sx$
Chief ear number	162	47	26	32	19	23	16	8	21.15±17.67

Seed set on the principal ear of the 333 plants was examined separately (Table 2). Data are not identical with the values obtained per plant, all the more as there are more sterile and at the same time more fertile ears among the chief ones. Grain yeild is surprisingly good; in earlier years we have never succeeded in propagating *Triticale* × rye hybrids beyond their second generation.

In 1969 BCF_2 generations of hexaploid *Triticale*^{2} × *Secale cereale* were divided into 3 groups: 1. *Triticale*-like individuals with moderate fertility, 2. rye-like plants with poor

Table 3. Grain yield and chief ear number of BCF_2 generation of hexaploid *Triticale*^{2} × *Secale cereale*, 1969

Materials	Number of seeds 0~10~20~30~40~50~60~70~80~90~100										$\bar{x}\pm sx$
Similar to rye	33	18	20	23	20	11	1	–	1	–	10.87±7.40
〃 to *Triticale*	30	18	20	23	20	12	1	3	2	1	28.98±3.54
〃 to F_1	4	–	1	–	–	–	–	–	–	–	9.00±4.80

fertility and 3. F_1-like, very sterile plants with intermediate type. Fertility per chief ear for each group is shown on Table 3.

Cytological studies are in progress. We hope selection will succeed in both directions (rye and *Triticale*). For the first time in our trials we could thus develop hexaploid. *Triticale* and *Secale cereale* respectively from *Triticale*^{2} × rye cross.

Literature cited

SMUTKUPT, S. 1968. Herstellung und Eigenschaften von *Secalotricum* im Vergleich mit *Triticale*. Angewandte Botanik 42(3/4) : 95～118.

SULÜNDIN, A. F. and L. M. NAUMOVA 1965. Amfidiploidi polucsennie ot Szkrescsivanyija ozimoj tverdoj psenyici sz rozsju. Szelekcija iszemenovodsztvo 1 : 52～55.

TARKOWSKI, C. 1966. Cytogenetica, hodowla i wartosc rolnicza prszenzyta (*Triticale*). Postepy Nauk Rolnych, Warszawa. 4 : 35～54.

TARKOWSKI, C. and D. OTLOWSKA 1968. Preliminary research on hexaploid *Triticale* × tetraploid and diploid rye hybrids. Genetica Polonica 9(1～2) : 49～58.

N. N. 1968～69. Cross-compatibilities among wheats, *Triticales* and rye. CIMMYT. Mexico. 82～97.

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Origin of the preliminary released Hungarian hexaploid *Triticale* varieties, Nos. 57 and 64

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In Hungary up to the present the secondary hexaploid *Triticale* varieties, Nos. 57 and 64, have been officially registered. Both varieties come from identical crossing combinations using *Triticale* No. 1 as basic material. This latter is an amphiploid (2n=6x=42) derived from crossing *Triticum turgidum* with *Secale cereale* developed by György REDEI (at present, Professor of Genetics at the University of Missouri, U.S.A.) and was sent to me in as far back as 1950. But it could not be taken into general cultivation because of its tall straw, poor winterhardiness, late maturing, poor fertility and shrunken and shrivelled grains. Though it showed some variability in fertility among certain individuals, neither its fertility nor the characteristics mentioned above have improved as years passed by. Neither did we succeed in getting more valuable types when crossing amphiploids of *Triticum turgidum* × *Secale cereale* developed by Professor NAKAJIMA. Simultaneously we have also developed octoploid *Triticales*, but their fertility was even lower than that of *Triticale* No. 1. Several octoploid *Triticales*, more fertile than our own hybrids, have been received from abroad, such as *Triticale* AD 20/1, *Triticale* Meister, *Triticale* Taylor

and quite recently the Swedish *Triticale* M×C×A and *Triticale* O×L. The Swedish *Triticales* arrived only in 1963, so they have no part in the pedigree of Nos. 57 and 64 but *Triticale* Rimpau, received from Gatersleben, was taken in.

The succession of crossings and selections is as follows:

1954 : *Triticale* AD 20/1×*Triticale* Taylor
1955 : (*T.* AD 20)1×T.T./ F_1×*Triticale* Meister
1956 : (T. AD 20/1×T.T.×T.M.) F_1×*Triticale* Rimpau
1957 : propagation of F_1 hybrids
1958 : F_2 selected élites×*Triticale* No. 1 (2n=6x=42)
1959 : propagation of F_1
1960 : propagation of F_2 and selection of élites
1961 : F_3 good yielding élites×*Triticale* No. 30 (2n=6x=42) (*Triticum aestivum* F481×*Secale cereale* 2n=56)×*T.* No. 1-1952
1962 : BC F_1 propagation
1963 : BC F_2 propagation and selection of élites
1964 : BC F_3 〃 〃 〃
1965 : BC F_4 〃 and drilling trial
1966 : BC F_5 〃 and farm trial, state variety trial
1967 : BC F_6 state variety trial and farm propagation
1968 : BC F_7 〃 〃 〃 registered and farm propagation
1969 : BC F_8 〃 〃 〃 and farm trials and propagations
1970 : BC F_9 〃 〃 〃 〃 〃 〃 〃

In every case crossings and backcrossings were also made in the reciprocal direction. According to experiences if the octoploid *Triticale* (2n=8x=56) is used as mother, seed set is more satisfactory (12～16%) when compared to the reciprocal 0.6～1.8%.

F_1 hybrid grains from 56×42 chromosomes crossings have germinated in 62～80%; while those of 42×56 chromosomes crossings only in 30～63%. F_1 grains with 56×42 chromosomes are fuller; heptaploids with 42×56 chromosomes have more shrunken and shrivelled grains. The 2n=7x=49 chromosome plants were very sterile, some 0～7 very shrunken, wrinkled grains were set per head. In the F_2 generation some individuals are already fertile, these having always 42 chromosomes, or 40, 41, 43 chromosomes approaching euploids. These segregating hybrids have been named secondary hexaploids. It was mainly the fertility of these hexaploids segregating from crossings with different polyploid levels that made us suppose that such *Triticale* forms would prove more valuable in general cultivation than octoploids.

Triticales, Nos. 57 and 64 have proved more prolific in Hungarian state trials than any other rye variety. In wheat comparison trials their value was equal to that of the wheat variety Bezostaya 1.

In 1968 and 1969 yield slightly decreased, but in several farms it remained extra-

ordinary high. That accounts for their explosion-like spread.

According to national statistical data of 1969 the grain yield of *Triticale* was 15.30 q/ha on about 10,000 ha, and that of rye 12.8 q/ha. Experiences show that *Triticale* is more particular than rye; its winterhardiness is behind that of rye and its drought-resistance is still to be improved. On good wheat soil, with adequate cultural methods it can have a maximum yield of 43~54 q/ha, while on very poor, barren sand it yields 5.2~6.9 q/ha. Both *Triticale* varieties are cultivated for fodder (seed or green). Both are prefered by animals to rye. The protein content is 3~6% higher than in rye (rye has 10~11%, *Triticale* 14~17%) and 1~2% higher than in wheat (13~16%). In feeding trials with mice, rats, poultry and pigs it competed well with other cereals; in several trials its feeding value was even higher. Feeding trials with cattle have no satisfactory results yet.

Baking trials have showed that using technology for rye flour it can be well mixed with wheat flour in 50%. It gives excellent, tasteful, brown bread even when made of 100% *Triticale* flour.

For trials we exported 13 q seed in 1967, 280 q in 1968 and 625 q in 1969. In Hungary we had about 16,000 ha under *Triticale* in autumn 1969.

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New protein bands in an amphiploid of *Aegilops caudata* and *Ae. umbellulata*

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The principle of additivity of protein patterns in hybrids of known parcentage was demonstrated for *Stipa* × *Oryzopsis* (HALL & JOHNSON 1963), for hybrids between *Solanum* species (DESBOROUGH & PELOQUIN 1966) and for *Aegilops bicornis* × *Ae. squarrosa* (BERWER, SING & SEARS 1969). For both seed and tuber storage proteins and for *Aegilops* enzyme proteins the pattern of the hybrid was a simple addition of the two parental patterns. Moreover, the hybrid pattern could be simulated by an *in vitro* mixture of the parental proteins (JOHNSON, BARNHART & HALL 1967). DESBOROUGH and PELOQUIN (1966) reported some *Solanum* hybrids which had extra protein bands not present in the parents and we wish to report the same phenomenon in *Aegilops*.

A seed of *Aegilops caudata* G 593 (2n=14) × *Ae. umbellulata* G 494 (2n=14) was obtained and germinated. Tillers of the hybrid plant were separated, established as independent plants and colchicine solution applied after the method of BELL (1950). Some

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of the treated plants produced seed. The spike morphology of the fertile hybrid (2n=28) is intermediate between the two parents *Ae. caudata* and *Ae. umbellulata* (Figure 1 on the Cover) and closely resembles the morphology of *Ae. triuncialis* (2n=28) as previously reported for a hybrid of similar parentage (KIHARA 1954). This supports KIHARA's hypothesis that *Ae. triuncialis* arose as a natural allopolyploid from a hybrid of *Ae. caudata* and *Ae. umbellulata.*

Enough seed was gathered from the fertile hybrids to make a protein extraction with 70% ethanol. A protein sample was electrophoresed on acrylamide gel following the method of JOHNSON (1967). The electrophoretic spectra of both parents, of the amphiploid and of a mixture of parental protein in a ratio of 1 : 1 are illustrated in Fig. 2.

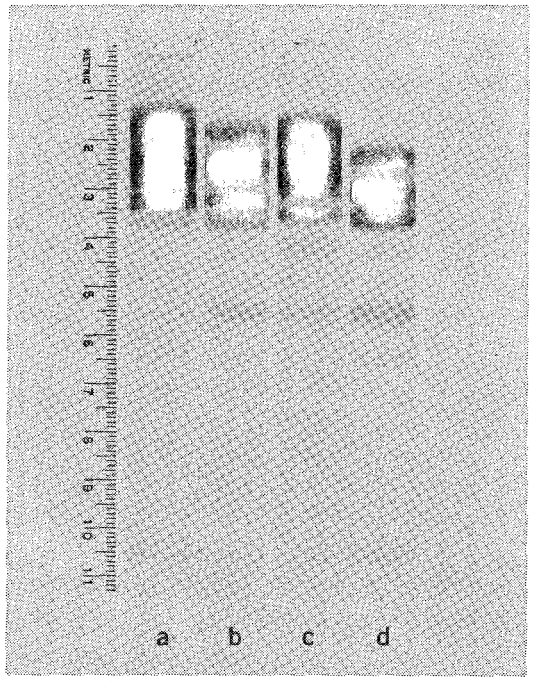

Figure 2. Comparison of the protein spectra of an amphiploid and a mixture
a. *Ae. caudata* G 593 × *Ae. umbellulata* G 494 (C 4x)
b. *Ae. caudata* G 593 and *Ae. umbellulata* G 494 1 : 1 mixture
c. *Ae. caudata* G 593, d. *Ae. umbellulata* G 494.

There appear to be two slow mooing bands at 1.0 cm. and 1.4 cm. from the origin of the amphiploid spectrum (Fig. 2a) which are not present in the parents (Fig. 2c-d) or the mixture (Fig. 2b). Apart from these amphiploid bands, all bands present in the parents are present in the amphiploid and in the mixture. The density of bands in the amphiploid compared with bands in the mixture is not the same, particularly the band at 5.5 cm. from the origin. Nevertheless, the electrophoretic pattern of this amphiploid

is very similar to those of *Ae. triuncialis* biotypes (WAINES 1969) again supporting KIHARA's original hypothesis.

The two new slow moving bands present in the amphiploid of *Ae. caudata* G 593 × *Ae. umbellulata* G 494, but not in the parents, nor in a mixture of their proteins, may be examples of hybrid protein bands formed by the combination of two genomes (IRWIN 1932, SCHWARTZ 1960). However, because the original hybrid was made tetraploid using colchicine, other explanations must be entertained. Spontaneous autotetraploids of *Rubus* showed new chromatographic patterns, as did colchiploids of the same plant (HASKELL 1968). The extra *Aegilops* bands may be due to the act of tetraploidy or to gene mutation by colchicine (FOSTER, ROSS & FRANZKE 1955). It is also possible that the amphiploid seed was at a stage of development different from that of the two parents; the proteins responsible for these two new bands may have been already broken down, or may have not yet been formed in the seed tissues of the diploid parents. These possibilities are being investigated further.

Literature cited

BELL, G. D. H. 1950. Investigations of the *Triticinae* I, Colchicine techniques for chromosome doubling in interspecific and intergeneric hybridisation. J. Agric. Sci. **40** : 9～18.

BREWER, G., C. F. SING and E. R. SEARS 1969. Studies of isozyme patterns in nullisomic-tetrasomic combinations of hexaploid wheat. Proc. Nat. Acad. Sci. U.S. **64** : 1224～1229.

DESBOROUGH, S. and S. J. PELOQUIN 1966. Disc electrophoresis of tuber proteins from *Solanum* species and interspecific hybrids. Phytochemistry **5** : 727～733.

FOSTER, A. E., J. G. ROSS and C. J. FRANZKE 1955. Genetic analysis of F_2 populations from crosses involving colchicine induced mutants in *Sorghum*. Proc. S. Dakota Acad. Sci. **34** : 21～22.

HALL, O. and B. L. JOHNSON 1963. Electrophoretic analysis of the amphiploid of *Stipa viridula* × *Oryzopsis hymenoides* and its parental species. Hereditas **48** : 530～535.

HASKELL, G. 1968. Biochemical differences between spontaneous and colchicine induced autotetraploids. Heredity **23** : 139～141.

IRWIN, M. R. 1932. Dissimilarities between the antigenic properties of red blood cells of dove hybrids and parental genera. Proc. Soc. Exp. Biol. & Med. **29** : 850～851.

JOHNSON, B. L. 1967. Confirmation of the genome donors of *Aegilops cylindrica*. Nature **216** : 859～862.

——, D. BARNHART and O. HALL 1967. Analysis of genome and species relationships in the polyploid wheats by protein electrophoresis. Amer. Jour. Bot. **54** : 1089～1098.

KIHARA, H. 1954. Considerations on the evolution and distribution of *Aegilops* species based on the analyser method. Cytologia **19** : 336～357.

SCHWARTZ, D. 1960. Genetic studies on mutant enzymes in maize : synthesis of hybrid enzymes by heterozygotes. Proc. Natl. Acad. Sci. U.S. **46** : 1210～1215.

WAINES, J. G. 1969. Electrophoretic-systematic studies in *Aegilops*. Ph.D. thesis, University of California, Riverside, California, pp. 223.

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II. Genetic Stock

Norin 10, a Japanese semi-dwarf wheat variety

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Norin 10 a recommended variety for northern prefectures registered at the Ministry of Agriculture and Forestry of Japan in 1935, was a semi-dwarf winter wheat, which was released for farmers in Iwate and Yamagata Prefectures. In recent years, *Norin 10* became known in the world as a breeding material mainly for its dwarfness.

At the Third International Wheat Genetics Symposium held in Australia in August of the year 1968, it was reported that semi-dwarf wheat varieties which were bred from the *Norin 10* crosses have become popular in America, Mexico, India and West Pakistan etc. This news was rather a delightful surprise to the present writer who had taken part in the breeding work of *Norin 10*.

In the present paper therefore the author wishes to report an outline of its origin, history and some of the important characters.

This paper has been completed according to the old records with advices and suggestions by Professer Kosuke YAMASHITA, Kyoto University, for which the author wishes to express his sincerest thanks.

1) Parental varieties of *Norin 10*:

Norin 10 was obtained from an artificial cross of *Turkey red* as mother and *Fultz-Daruma* as father. According to the old records, *Fultz* and *Turkey red* were introduced from the U.S.A., *Fultz* around 1892 and *Turkey red* later. *Fultz-Daruma* was a line from a cross of *Daruma* as mother and *Glassy Fultz* as father. This cross was made at the Central Agricultural Experiment Station in 1917, and a pedigree culture was continued up to F_6 (1923). *Daruma* is believed to have been a representative variety of the Kanto district, known as *Shiro-Daruma*, while *Glassy Fultz* is believed to have been a glassy derivative from *Fultz* with mealy grain.

Between 1924 and 1925, the projects of the field experiments at the Central Agricultural Experiment Station at Nishigahara, Tokyo, were transfered to the Konosu Branch Station, Saitama Prefecture. That was when systematic breeding of wheat through artificial crossing had just started in Japan. The F_2 seeds of *Turkey red* × *Fultz-Daruma*, along with several other combinations, were obtained from the Ehime Prefectural Agricultural

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Experiment Station and a selection of an initial stage was made during the period from 1926 to 1929. In the years up to 1930, 29 pedigrees of F_3～F_6 were handed over to the Iwata Prefectural Agricultural Experiment Station for local experiments.

2) Breeding purposes:

The cross, *Turkey red*×*Fultz-Daruma* at the Ehime Prefectural Agricultural Experiment Station was originally made for the purpose of obtaining a line with rust resistance, early maturity and a short stem. Since Iwate Prefectural Agricultural Experiment Station was the local center of the northern regions of Honshu (main island of Japan), further emphasis was put on a higher cold and snow resistance. In the course of the breeding work, however, there appeared a special dwarf type, and therefore, efforts were made to select this dwarf type for practical purposes.

3) The experiments carried out during the early stages at the Konosu Agricultural Experiment Branch Station:

The project leaders in wheat experiment at the Konosu Branch Station at that time were Dr. Morimasa YAMAZAKI, and Mr. Susumu HATANO. The F_2 breeds of *Turkey red*× *Fultz-Daruma* received from the Ehime Agricultural Experiment Station were cultured from 1926 and the selection was made in the following years. Consequently, from the selections, 7 strains of F_3 (Kokei 881～887) in 1927, 12 strains of F_4 (Kokei 1884～1895) in 1928, 9 strains of F_5 (Kokei 3642～3600) in 1929, and 1 strain of F_6 (Kokei 1892) in 1930 were sent to the Iwate Agricultural Experiment Station for local experiments.

4) Pedigree culture and further selection at the Iwate Agricultural Experiment Station:

The results are summarized in the following tables.

Table 1. The progress of culture and selection for *Turkey red*×*Fultz-Daruma*

Crop year	Generation	Culture		Selection		
		Strain groups	Strains	Strain groups	Strains	Individuals
1927～28	F_3	1	7	1	1	5
1928～29	F_4	4	17	4	4	23
1929～30	F_5	5	32	4	5	41
1930～31	F_6	5	42	4	7	31
1931～32	F_7	7	31	7	8	48
1932～33	F_8	8	48	6	6	60
1933～34	F_9	6	60	6	8	90
1934～35	F_{10}	8	90	8	15	130
1935～36	F_{11}	15	130	12	15	170

From 3 strains in the 12 Kokei[1] strains of F_4 received in 1928, dwarf plants segregated at about 10%. From Kokei 1895 were selected 5 individuals with a relatively high

1) Strains from Konosu Branch Station.

quality of cold and snow resistance (winter killing) including long (normal) and short (dwarf) stem plants. A dwarf strain of F_5 showed small spike and poor filling of the grain, and therefore from a strain segregating for long, semi-dwarf and dwarf (Kokei 1895–8) were selected 35 individuals. Among 35 strains of F_6 there were 5 strains of dwarf types, while from Kokei 1895–8–2 with longer spikes and better quality were selected 5 individuals. These 5 individuals became F_7 and all 5 strains were of seim-dwarf types.

In 1932 the strain of F_7 was named as Tohoku 34, and productivity as well as adaptability tests of this variety were then conducted not only in Iwate prefecture but also in neighboring Prefectures. The pedigree culture was continued until Kokei 1895–8–2–6–4 was selected from 5 strains of the F_9. In 1935 this breed was named *Norin 10* and registered at the Ministry of Agriculture and Forestry, as a recommended variety for the two northern Prefectures, Iwate and Yamagata. Since, however, there still appeared a small number of long stem plants (normal type), 50 strains were used for further experiments.

5) Productivity test at Iwate Agricultural Experiment Station

Over the three successive crop years, 1931～32, 1932～33 and 1933～34 precision cultivation tests to ascertain the productivity of *Norin 10* were carried out.

According to the practice of farmers, the rows were made at a width of 60 cm and seeds were sown at a distance of 13 cm. For this experiment, a field lot with uniform soil condition was selected, and the fertilizer was given for each row equally. A seed plate with holes at a distance of 2 cm was used for making the spacing regular. Two seeds were sown in each hole, and the desired density of stands was maintained by thinning or additional planting. In this way all care was taken for the uniform growth of individual plants.

Table 2. Yield under standard fertilizer and standard spacing conditions

Variety	Grain weights (kg/ga)				
	1931～32	1932～33	1933～34	average data for 3 years	percentage
Norin 10	2,335	3,808	3,137	3,093	128
Norin 1	1,860	3,359	2,013	2,411	100

The flour yield of *Norin 1* (±standard variety) in the crop year 1932～33 was 68%, while that of *Norin 10* was 72.5%, whereas the amount of wet gluten of the former was 26.8% and that of the latter 28.2%.

6) Character test at the Iwate Agricultural Experiment Station:

a) Adaptibility for conditions of cultivation—

In order to obtain uniformity of soil conditions, the surface soil was first removed, the base soil was leveled, and then the well-mixed surface soil was overlaid evenly. On

thus prepared field a conbination of the amount of fertilizer and spacing was designed according to the precision culture micro test method (the purpose of which was mainly to observe reaction towards nutrition and sunlight). The characteristics connected closely to yield were then tested. The following tables show the comparisons of the respective characters between *Norin 10* (semi-dwarf type) and *Norin 14* (normal type), both being derived from *Turkey red*×*Fultz-Daruma.*

Table 3. (a) Stem length (cm) (1934~35)

Variety		*Norin 10* (semi-dwarf type)					*Norin 14* (normal type)				
Fertilizer \ Spacing (cm)		50	100	150	200	250	50	100	150	200	250
Base fertilizer		—	—	44	44	44	—	—	68	63	64
Little 〃	0.5	—	—	39	48	49	—	—	74	75	75
Standard 〃	1.0	—	49	48	53	—	—	76	79	78	—
Much 〃	1.5	50	53	56	—	—	78	81	84	—	—
Double 〃	2.0	51	54	55	—	—	82	85	89	—	—

F.N. Base fertilizer consists of compact and slaked lime only. Standard fertilizer (1.0) consists of N 1.649 g. P_2O_5 1.492 g, K_2O 1.730 g per are. Spacing : the number of plants withid the 50 cm length.

Table 4. (b) Spike length (cm) 1934~35

Variety		*Norin 10* (semi-dwarf type)					*Norin 14* (normal type)				
Fertilizer \ Spacing (cm)		50	100	150	200	250	50	100	150	200	250
Base fertilizer		—	—	9.3	9.1	8.7	—	—	8.2	8.3	7.9
Little 〃	0.5	—	—	9.5	9.2	9.0	—	—	8.2	8.4	8.1
Standard 〃	1.0	—	10.4	9.9	9.9	—	—	9.2	9.4	9.1	—
Much 〃	1.5	10.0	10.4	10.4	—	—	9.9	9.5	9.4	—	—
Double 〃	2.0	10.9	10.7	11.1	—	—	10.4	9.8	10.4	—	—

Average number of kernels on one spike was 19~28 for *Norin 14* (normal type) and 21~31 for *Norin 10* (semi-dwarf type), while the 1,000 kernel weight for the former was 31~35.8 g and for the later 24.8~34.6 g, especially *Norin 10* in case of much fertilizer and dense planting, the kernel weight became lower due to an outbreak of powdery mildew.

b) Cold and snow resistance tests—

Tests were made as the to percentage of survival plants and survival stems in the swelled seed beds with 100 plants of strains following F_3. The cold and snow resistance of *Norin 10* was stronger than either the local varieties or *Norin 1*, but it could not be said that *Norin 10* is perfectly safe in the Tohoku district.

c) Reaction to diseases—

Yellow rust and leaf rust appeared to some extent every year, but any difference was noticed according to conditions of culture. There was, however, a serious outbreak

of yellow rust in the spring of 1933 and of leaf rust in the spring of 1936. *Norin 10* showed as high resistance as almost immune against yellow rust, but was damaged slightly by leaf rust.

Powdery mildew and red mould appeared in the years with moist climate just at the time when kernels were filling in. In *Norin 10* it was observed that a serious outbreak occurred in the case of application of much fertilizer and dense planting, although the damage from red mould was fairly low.

d) Seed germination on spikes by rain fall—

In a variety with a short dormant period seeds tends to germinate on the spikes, while they are still standing, when there is much rain fall during the harvest time. Since *Norin 10* exhibited an intermediate dormancy character, it could not be said that this variety is safe if there is much rain during the harvest time.

e) Grade of winter habit—

The grade of winter habit is usually divided into classes from I to VII in Japan. Classes I and II are spring wheat and are suited for southwestern moderate climates. The rests possess winter habits, among which classes III and IV are suited for autumn sowing in Kanto district, classes V and VI for Tohoku district and classes VI and VII for Hokkaido. *Norin 10* was found to belong to class IV, while *Fultz* belonged to V.

7) Ecological adaptability tests:

Adaptability of *Norin 10* were made in the 1932~33 and the 1933~34 crop years at five Agricultural Experiment Stations or Branch Stations in the Perfectures of Aomori, Akita, Yamagata and Fukushima. Due to wrong handling of seeds in the 1933~34 year test, poor germination was caused and uneven test results were obtained. Therefore, some of the odd results are not given in the table.

8) *Norin 10* and local varieties in Iawte and Yamagata Prefectures:

In Iwate Prefecture local varieties had been those obtained by pure line selection

Table 5. Characteristics of respective varieties under adaptability test

Exp. Station	Yamagata			Aomori	
Characteristics \ Varieties	*Norin 10*	*Nisimura*	*Fultz*	*Norin 10*	*Martin 1*
The percentage of survival plans against winter killing	100	93	98	98	100
Ripening date	Jul. 1	June 24	Jul. 2	Jul. 11	Jul. 14
Stem length (cm)	52	121	133	63	96
Spike length (cm)	9.3	8.1	9.6	9.2	10.1
Effective tillers (within 50 cm row length)	93	100	108	112	135
Grain weight (kg/ha)	2,800	3,426	2,473	2,488	2,865
1,000 kernel weight (g)	35	34	38	35	35

F.N. : Average of 2 year experiments.

of endemic varieties like *Shisen 1* and *Soshu 1* and of an introduced variety like *Fultz 1*, but in 1929 these varieties were replaced by the recommended varieties *Norin 1* and *Norin 2* (*Shiro-Daruma* × *Velvet*), while, *Norin 10* became the recommended variety in 1935. In 1942 31% of the wheat cultivation area in Iwate Perfecture was occupied by *Norin 10*. After that, however, there was a gradual decrease of this variety, and in 1953 it was replaced by *Kokeshi-komugi*. As compared with *Norin 10*, *Kokeshi-komugi* had higher cold and snow resistance, and therefore it gave more tillers and higher yield, especially in case of much fertilizer.

In Yamagata Perfecture *Nishimura* and *Fultz* were the recommended varieties, but in 1935 the large spike and short stem of *Norin 10* called attention, and this became the recommended variety. From 1942 till 1951 *Norin 10* occupied from 22% to 28% of the total wheat cultivation area, but in 1953 it was replaced by *Kokeshi-Komugi*.

9) The use of *Norin 10* in further breeding is summarized in the following table (Table 6).

Table 6. Strains and varieties derived from *Norin 10* crosses

Cross combination	Bred strains	Bred varieties	Named & registered (year)	Recommended Prefectures
Norin 10 × *Norin 16*	Tohoku 71			
	〃 72			
〃	〃 77	*Susono-Komugi* (*Norin 77*)	1950	Yamanashi
〃 × Hokuriku 17	Tohoku 75			
〃 × Tohoku 106	〃 117	*Miyagino-Komugi* (*Norin 102*)	1964	Miyagi
〃 × Tohoku 107	Tohoku 127			
	〃 130			
〃 × Honiku 127	Hokkai 224			
〃 × Akasabishirazu 1	〃 226			
〃 × Rubin	〃 230			
〃 × Hokuriku 11	Hokuriku 28			
	〃 33			
〃 × Hokuriku 13	〃 29			
〃	〃 30	*Kokeshi-Komugi* (*Norin 89*)	1953	Iwate Yamagata

Literature cited

Quesenberry's Biography 1967. Wheat Breeding what it means to Japan, Seminar Proceedings, the U.S. Wheat Exhibit and Seminar.

Reitz, L. P. and S. C. Salmon 1968. Origin, History and Use of *Norin 10* Wheat. Crop Science Vol. 8.

Boraug, N. E. 1968. Wheat Breeding and its Impact on World Food Supply, Proceedings of the Third International Wheat Genetics Symposium.

Matsumoto, T. 1968. *Norin 10*—A Dwarf Winter Wheat Variety, JARQ, Vol. 3, (4).

Swaminathan, M. S. : Introduction of the Norin Dwarf Genes in Wheat Breeding I.C.A.R. General Crop Series, India.

CIMMYT Report 1968~69. On Progress Toward Increasing Yield of Maize and Wheat Introduction. International Maize and Wheat Improvement Center.

III. News

Publication of Barley Genetics II

(Proceedings of the Second International Barley Genetics Symposium)

Barley Genetics II (Proceedings of the Second International Barley Genetics Symposium) was published in February 1971. It contains 69 papers under the following main headings: Germ Plasm Sources and World Collections of Genes; Origin and Evolution; Chromosome Aberrations and Their Utilization; Mutations—Induction and Utilization; Linkage Data and Chromosome Mapping; Genetic Fine Structure Analyses; New Phenomena Important to Barley Genetics and Breeding; Breeding Techniques; Hybrid Barley; Genetics of Yield; Genetics of Hardiness, Growth Habit and Aluminum Reaction of Winter Barley; Population Genetics; Genetics of Disease and Insect Resistance; and Genetics of Feed and Malt Quality. It also includes reports from committees concerned with: genetic marker stocks, nomenclature and gene symbols; origin, phylogeny and exploration; chromosome aberration stocks; and barley literature.

The volume of xvi plus 622 pages will cost 20 US dollars. Orders for this book should be addressed to the Washington State University Press, Washington State University, Pullman, Washington, 99163, U.S.A. (R. A. Nilan)

IV. Editorial Remarks

Announcement for future issues

WIS No. 33 will appear in August, 1971, and No. 34 will be published as soon as the manuscripts cover the planned pages, by March 1972.

WIS is open to all contributions regarding methods, materials and stocks, ideas and research results related to genetics and cytology of *Triticum*, *Aegilops*, *Secale*, *Agropyron*, *Haynaldia* and related genera. Manuscripts should be typewritten in English, and submitted with duplicates. One article should not exceed five printed page, including one text-figure (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, but extra copies will be printed by order at cost price. Communications regarding editorial matters should be addressed to:

Dr. Kosuke YAMASHITA
Wheat Information Service
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Kyoto, Japan

Subscription

The yearly subscription fee (U.S. $1.00) should be paid in U.S. Dollar by a Demand Draft. The Demand Draft should be specified for payment at the Dai-Ichi Bank Ltd., Tokyo; otherwise considerable loss is caused due to the money exchange rules since October 1970. The Foreign Postal Money Order is accepted with no trouble.

Acknowledgement

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The Managing Editor

Explanation of the Figure on the Cover

Fig. 1. Spikes of *Aegilops candata* G 593 (a), *Ae. caudata*-G 593 × *Ae. umbellulata* G 494 amphiploid (b), and *Ae. umbellulata* G 494 (c). (cf. J. G. WAINES and B. L. JOHNSON, pp. 22~24).