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I. Research Notes

Morphological characters and meiotic associations in a *T. aestivum* L. var. *erythroleucon* Körn. × *Ae. biuncialis* Vis. hybrid

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In order to transfer the genes for resistance to stripe rust (*Puccinia striiformis* West.) of wheat from *Ae. biuncialis* (2n=28) to *T. aestivum* (2n=42) an attemp was made to cross these two species during the spring of 1980. Emasculating and crossing techniques were detailed in the previous study of ÖZGEN (1983 a). 18 ears with 457 florets were polinated with pollen of *Ae. biuncialis* and 114 seeds were obtained. Control of chromosome numbers was made by examining root tips under the microscope and the hybrids were found to be pentapoloid (2n=

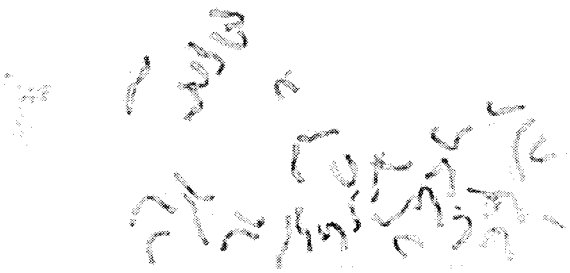

Fig. 1. Mitotic metaphase in a pentaploid hybrid between *T. aestivum* var. *erythroleucon* × *Ae. biuncialis* (×1335).

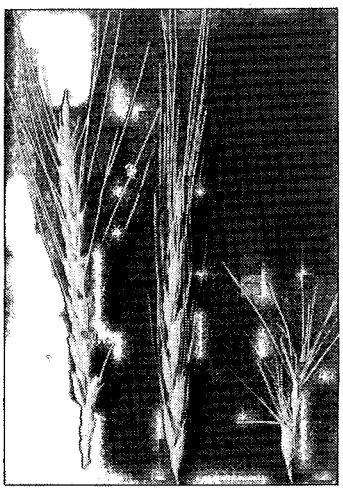

Fig. 2. Spikes of *T. aestivum* var. *erythroleucon*, F_1 pentaploid hybrid and *Ae. biuncialis* (from left to right).

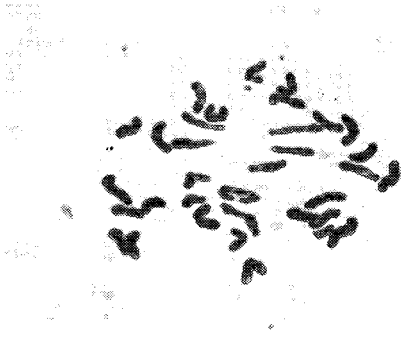

Fig. 3. Metaphase I chromosome associations in F_1 hybrids between *T. aestivum* var. *erythroleucon* × *Ae. biuncialis* (×1250).

35) (Fig. 1). All seeds of the hybrids germinated and 114 F_1 plants were obtained. However, only 51 of those plants were able to head.

The F_1 plants were intermediate with respect to most of the morphological characters, but dominance was observed for some of the characters. Although the hybrid heads looked more like wheat than *Ae. biuncialis*, they carried some characteristics of the male parent (Fig. 2). Some characteristics of the parents and hybrids are given in Table 1.

Hybrid plants as predicted by MAAN (1975), were pollen sterile with nondehiscent

Table 1. Some characters of *T. aestivum* var. *ervthroleucon* x *Ae. biuncialis* F_1 hybrids and their parents

	Rachis	Spike density[1)]	Lower internodes with/without (angle, knee)	Auricle color hairness	Growth habit	Resistance to stripe rust
T. aestivum	Tough	15.04±0.31	Without	White Glabrous	Erect	S[2)]
Ae. biuncialis	Weak	8.39±0.25	With	Red Hairy	Prostrate	R
F_1	Weak	9.62±0.15	With	Red Hairy	Prostrate	R

[1)] No. of spikelets/10cm
[2)] S : Susceptible, R : Resistant

Table 2. The mean and range of meiotic configurations in the F_1 hybrids *T. aestivum* var. *erythroleucon* x *Ae. biuncialis*

I	II Rod	II Ring	II Total	III	IV	Number of cells
27.35	2.40	0.26	2.66	0.74	0.74	167
8-35	0-11	0-2	0-12	0-4	0-4	

Table 3. Meiotic configurations of F_1 PMC's at the fiirst metaphase(%)

PMC's	0_{II}	1_{II}	2_{II}	3_{II}	4_{II}	5_{II}	6_{II}	7_{II}	8_{II}	Others
	18.5	15.0	15.0	24.0	9.0	10.0	3.5	1.0	2.5	1.5

anthers. Only 2 seeds were obtained from 2265 heads from 51 F_1 plants, with free pollination.

Meiotic behaviour of the F_1 hybrids was analyzed at the first metaphase stage and chromosome pairing was observed (Table 2 and 3). This showed that the number of bivalents varied between zero to twelve and most of them were of the rod type, but there were some ring types too (Fig. 3).

As it is known, chromosome pairing in hybrid shows the level of relationship between parents (DEWEY 1982). Chromosome pairing in the F_1 hybrids of *T. aestivum* × *Ae. biuncialis* were found to be higher than for *T. durum* × *Ae. umbellulata*'s F_1 hybrids (ÖZGEN 1983 b). As indicated by this study, it appears easier to transfer genes from *Ae. biuncialis* to *T. aestivum* than to transfer genes from *Ae. umbellulata* to *T. durum*.

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Chromosome location of a fertility-restoring gene of a common wheat Chinese Spring for the *Aegilops mutica* cytoplasm

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At present, two sources of *Aegilops mutica* cytoplasm are available in our laboratory, the cytoplasms introduced into the common wheat *Triticum aestivum* cv. Selkirk by MAAN (1977) and that introduced into *T. aestivum* cv. Penjamo 62 by PANAYOTOV (1980). These two cytoplasms have been introduced into 12 common wheats by repeated backcrosses (TSUNEWAKI & TSUJIMOTO 1984). The cytoplasm obtained from MAAN's line induces complete male sterility in three of the 12 common wheats, while the cytoplasm obtained from PANAYOTOV's line causes complete sterility in all 12 common wheats. The chromosomal location of the fertility-restoring gene of Chinese Spring wheat for the first *mutica* cytoplasm was determined in the present work.

Materials and Methods

The two alloplasmic lines with *Aegilops mutica* cytoplasm were kindly provided by Drs. S.S. MAAN (North Dakota State University, USA) and I. PANAYOTOV (Institute for Wheat and Sunflower, Bulgaria), and were used as the cytoplasm donors to the following 12 common wheats; *T. aestivum* var. *erythrospermum* (abbrev. Tve), strain P168 (P168), cv. Chinese Spring (CS), cv. Norin 26 (N26), strain Salmon (Slm or Salmon), cv. Jones Fife (JF), cv. Selkirk (Sk or Selkirk), and cv. S-615 (S615), *T. sphaerococcum* var. *rotundatum* (Sphr), *T. compactum* cv. No. 44 (Cmp), *T. spelta* var. *duhamelianum* (Splt or Spelta) and *T. macha* var. *subletschchumicum* (Mch or Macha).

Ditelocentric 1BL and 1BS lines of Chinese Spring which were produced by SEARS & SEARS (1978), were used to locate a fertility-restoring gene in Chinese Spring for MAAN's *mutica* cytoplasm.

Pollen fertility indicates here the percentage of normal pollen grains with a vegetative and two wedge-shape male nuclei. Acetocarmine staining was used for this observation. Selfed seed fertility indicates the percentage of the seed setting in the first and second florets of an ear bagged before anthesis.

Results and Discussion

Fig. 1 illustrates the selfed seed fertilities of the 12 alloplasmic lines of common wheat with two *mutica* cytoplams used in this study. Three common wheats, *i.e.*, Salmon, Spelta and Macha, showed almost complete sterility to MAAN's *mutica* (abbrev. *mutica* M) cytoplasm, whereas the other nine wheats had almost normal fertility. This fertility spectrum

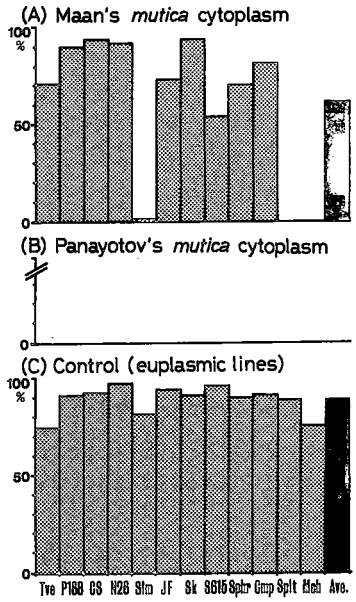

Fig. 1. Fertility spectra of two *Ae. mutica* cytoplasms; expressed by selfed seed fertility (%) of 12 common wheats having these cytoplasms.

is the same as those produced by *Ae. kotschyi*, *Ae. variabilis* and *Ae. uniaristata* cytoplasms, which are classified as type II fertility spectrum by TSUNEWAKI & TSUJIMOTO (1984). PANAYOTOV's *mutica* (abbrev. *mutica* P) cytoplasm caused complete male sterility in all 12 common wheats, of which fertility spectrum is similar to those produced by *T. boeoticum*, *Ae. comosa and Ae. heldreichii* cytoplasms, and is classified as type VIII fertility spectrum. Two *mutica* cytoplasms are known to have identical chloroplast DNAs so far as the restriction fragment patterns produced by eight restriction enzymes are concerned (TERACHI *et al.* 1984)

In order to determine the chromosomal location of a fertility-restoring gene(s) of Chinese Spring for the MAAN's *mutica* cytoplasm, male sterile (*mutica* M)-Salmon was crossed as female to ditelo-1BL and 1BS of Chinese Spring. In the F_1 generation, the following three types of plants were produced; monotelo-disomics, haplo-diplo twins and haploids.

The mechanism of the haploid induction in (*kotschyi*)-Salmon was clarified by KOBAYASHI & TSUNEWAKI (1980): Salmon possesses a chromosome consisting of an arm of rye's 1R chromosome and the short arm of chromosome 1B of common wheat (ZELLER 1973). This translocation chromosome is written as "1B/1R". All female gametes of (*kotschyi*)-Salmon carrying the 1B/1R chromosome form the haploid embryo, giving rise to the haploid or haplo-diplo twin pair. Thus, this translocation chromosome is not transmitted from the female parent to the offspring as a rule. Accordingly, (*kotschyi*)-Salmon always remains heterozygous for normal 1B and translocation 1B/1R chromosome through many generations of successive backcrosses with the pollen of Salmon.

If the same mechanism is operating for the haploid induction in (*mutica* M)-Salmon, the F_1 progeny between (*mutica* M)-Salmon and the ditelo-1BL or 1BS of Chinese Spring are expected to segregate the various plant types shown in Fig. 2. Selfed seed and pollen

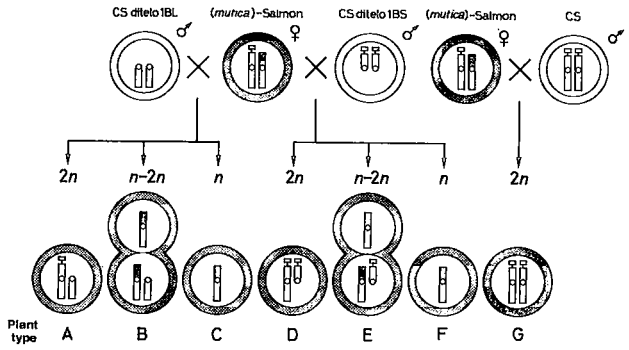

Fig. 2. Segregation of various plant types among the F_1 progeny between (*mutica* M)-Salmon and Chinese Spring (CS) ditelo-1BL or 1BS.

Table 1. Selfed seed and pollen fertilities of various plant types segregated among the F_1 progeny between (*mutica* M)-Salmon and Chinese Spring ditelo-1BL or 1BS.

Plant type[1)]	A	B	C	D	E	F	G
Dose of 1BL	2	2	1	1	1	1	2
Dose of 1BS	1	0	0	2	1	0	2
Expected genotype	*Rfm1*/—	—/—	—	*Rfm1*/*Rfm1*	*Rfm1*/—	—	*Rfm1*/*Rfm1*
Seed fertility (%)	7.4	0.0	0.0	63.5	0.0	0.0	91.3
Pollen fertility (%)	10.5	—	—	75.2	—	—	90.0

[1)] Refer to Fig. 2.
Note) B and E; 2*n* partners of the *n*-2*n* twin pairs.

fertilities observed in each plant type are given in Table 1 : Diploid partner of the *n*-2*n* twins is presumed to have the 1B/1R translocation chromosome, because it derives from a synergid having a karyotype identical with that of the egg cell. Consequently, the diploid partner of the *n*-2*n* twins from the cross, (*mutica* M)-Salmon×Chinese Spring ditelo-1BL (Plant B in Fig. 2) has no 1BS arms carrying a satellite. Complete male sterility of the 2*n* partner of the twin, in contrast with partial male fertility of the type A plants indicates that a fertility-restoring gene for MAAN's *mutica* cytoplasm is located on the short arm of the 1B chromosome of Chinese Spring. The same conclusion is drawn from normal fertility of the type G plants, contrasting with low fertility level of the type A plants. To this fertility-restoring gene, a symbol, *Rfm1*, will be tentatively given. This gene restores little fertility under its hemizygous condition because diploid F_1's between (*mutica* M)-Salmon and Chinese Spring ditelo-1BL (Plant A) had very low fertility.

The fertility of the diploid plants (Plant D) from the cross, (*mutica* M)-Salmon×Chinese Spring ditelo-1BS is lower than that of the diploid F_1's between (*mutica* M)-Salmon and normal Chinese Spring (Plant G). This indicates that the long arm of the chromosome 1B of Chinese Spring also concerns with fertility restoration, *i.e.*, it carries a promoter. However, this gene itself can not restore any fertility because the plant carrying two chromosomes, 1B/1R and 1BL (Plant B) is completely sterile. The diploid partner of the *n*-2*n* twins (Plant E) from the cross, (*mutica* M)-Salmon×Chinese Spring ditelo-1BS was completely male sterile,

probably due to an additive effect between the hemizygous conditions for both *Rfm1* gene and a promoter on 1BL arm. Both *n*-2*n* twins and single haploid showed somewhat weak vigor and complate sterility.

Spelta and Macha become male sterile by the introduction of MAAN's *mutica* cytoplasm (Fig. 1) although they have normal 1B chromosomes. Apparently, their 1B chromosomes do not possess the fertility-restoring gene, *Rfm1*, and the genotype can be designated *rfm1 rfm1* for them.

MAAN (1977) concluded that the D genome of Selkirk has a fertility-restoring gene (s) for male sterility induced by *Ae. mutica* cytoplasm, because *T. durum* with the *mutica* cytoplasm becomes completely male sterile, whereas Selkirk with the same cytoplasm shows normal fertility. The present results, however, indicate that the gene for fertility restoration for the MAAN's *mutica* cytoplasm is located on the short arm of chromosome 1B of common wheat but not on a D-genome chromosome. Most likely, *T. durum* studied by MAAN (1977) possesses the *rfm1* allele like our Spelta and Macha. On the other hand, Selkirk is considered to have the *Rfm1* allele for fertility restoration.

The fertility-restoring gene, *Rfm1*, for MAAN's *mutica* cytoplasm might be the same as *Rfv1*, a fertility-restoring gene for *Ae. kotschyi* and *Ae. variabilis* cytoplasms, and *Rfun1*, a fertility-restoring gene for *Ae. uniaristata* cytoplasm, because all the three genes locate on the short arm of chromosome 1B of Chinese Spring (MUKAI & TSUNEWAKI 1979; MUKAI 1984), and because all theree cytoplasms show the type II fertility spectrum (TSUNEWAKI & TSUJIMOTO 1984), and induce haploids in Salmon (TSUNEWAKI *et al.* 1976; MUKAI 1981). The allelic relationship between the three genes must be thoroughly investigated before a conclusive decision on their symbols is made.

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Studies on fertility restoration in male sterile wheats derived from *Aegilops comosa* cytoplasm

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Keeping in view the practical importance of fertility restoration in hybrid wheat programme, studies were initiated to find out specific combination with *comosa* cytoplasmic background where partial to complete fertility restoration can be obtained. It may be mentioned that the problems of restoration still exists, the restorer so far reported are effective for certain varieties and with specific alien cytoplasm (WILSON & ROSS 1962; TSUNEWAKI 1974, 1980). There is significant fluctuations in their expressions as such more studies in this area would be useful.

Materials and Methods

Prof. K. TSUNEWAKI (Japan) developed some Chinese Spring alloplasmic lines having *Ae. comosa* Sibth et. Sm (2n=14; MM) cytoplasm in background. These lines were used as cytoplasm donor for the production of male sterile lines in wheat. Twenty four cultivars of common wheat (*Triticum aestivum* L., 2n=42, AABBDD) were selected as nucleus donors. Series of crosses between cytoplasmic donor as female and nucleus donors as pollen parent were attempted in 1978-79 and subsequently these pollen donors were used as the recurrent male parent in the substitution backcrosses. On each side of male sterile rows one row of corresponding nucleus donor was grown at a distance of 45 cm between the rows and 5 meters long each row. Observations on pollen and seed fertility were taken from different alloplasmic lines for F_1 in 1980, BC_1 in 1981 and BC_2 in 1982 grown at IARI New Delhi farm. For calculating seed fertility in open and selfed (bagged) spikes, average of five main spikes of different plants was taken and then percentage was worked out (KARIM 1982). Prefix 'allo' refers to different male sterile lines having *comosa* cytoplasmic background.

Results and Discussion

Normal fertile anthers were noticed in BC_2 alloplasmics, comprising of nucleus donors Lal Bahadur, Ridley and HD 1944, where average pollen fertility was recorded as 91%, 32% and 19% respectively. Allo-Lal Bahadur restored pollen fertility (91%) very close to the nucleus donor Lal Bahadur (95%) (Table 1). Pollen fertility observations were further confirmed with better selfed seed set, where allo-Lal Bahadur produced 41%, allo-Ridley had 27% and allo-HD 1944 showed 22% selfed set. Pollen fertility and selfed seed data indicated

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that Lal Bahadur Ridley and HD 1944 carry weak fertility restoring gene(s). Fertility factors present in variety Lal Bahadur appear to be more active. Cytological studies have revealed that all the three alloplasmic lines possess one additional chromosome in each line, which were transmitted from *Ae. comosa* alongwith its cytoplasm to wheat background. Allo-Lal Bahadur contained near medium chromosome, allo-Ridley showed sub-median chromosome, where as allo-HD 1944 had terminal chromosome. All these three chromosomes of *comosa* transmitted separately in three different lines, apparently appeared to have different effects on pollen and seed fertility in these lines.

MAAN & LUCKEN (1968) indicated that certain common wheat cultivars have genes for partial male fertility restoration, whose action is expressed under certain favourable environments. MIRI *et al.* (1970) reported that NP 839 and NP 883 restored fertility in male sterile lines of Kalyansona, NP 880 and Lerma Rojo having *timopheevi* cytoplasm. But NP 880 and NP 839 did not restore fertility in the present *comosa* cytoplasmic interaction. TSUNEWAKI *et al.* (1976) showed Junrei Komugi and Norin 69 had weak fertility restoring gene (s) with *timopheevi* cytoplasm. The differential behaviour of fertility restoration in genetically diverse male sterile lines may be attributed to the specificity of modifiers and of partial or full fertility restoration factors in normal cultivars. This led to the assumption that stability of

Table 1. Seed fertility percentage of *Ae. comosa* male sterility lines at different generations

Cultivar	Nucleus donor	F_1-Alloplasmics			Nucleus donor	BC_1-Alloplasmics			Nucleus donor	BC_2-Alloplasmics		
	Open pollinated	Crossed	Open pollinated	Selfed	Open pollinated	Crossed	Open pollinated	Selfed	Open pollinated	Crossed	Open pollinated	Selfed
1. Kundan	63.26	63.40	14.84	0.0	65.18	79.03	22.42	0.0	53.06	64.52	28.40	0.0
2. NP 880	74.68	70.10	14.10	0.0	79.61	70.07	36.38	0.0	68.07	58.31	32.79	0.0
3. Ridley	61.75	44.64	32.55	0.0	57.17	92.68	32.72	0.0	50.72	65.11	36.80	27.50
4. Kharchia-65	71.27	63.53	34.91	0.0	69.27	40.57	39.11	0.0	59.16	14.28	68.63	0.0
5. NP 839	75.12	73.04	10.41	0.0	68.08	41.46	29.31	0.0	65.26	54.41	28.10	0.0
6. Mukta	69.32	70.74	31.77	0.0	67.50	61.07	65.55	0.0	63.23	42.25	37.40	0.0
7. NP 876	73.35	48.05	25.00	0.0	77.89	44.59	23.30	0.0	63.68	33.00	24.59	0.0
8. Lal Bahadur	78.64	66.37	14.14	0.0	74.78	50.40	40.73	0.0	61.30	62.27	32.42	41.24
9. Cninese Spring	80.59	58.92	10.54	0.0	76.00	79.87	3.12	0.0	88.44	54.97	19.04	0.0
10. NP-4	69.18	60.00	31.38	0.0	68.18	71.65	30.79	0.0	61.84	48.59	35.56	0.0
11. K-852	66.01	64.26	11.81	0.0	57.29	70.63	5.65	0.0	57.65	69.16	15.31	0.0
12. HD-2030	69.50	77.94	8.77	0.0	71.66	62.24	10.31	0.0	38.83	44.22	13.97	0.0
13. Girija	65.31	72.02	8.83	0.0	62.16	63.37	36.69	0.0	62.87	44.62	25.79	0.0
14. Tanori	89.84	68.23	32.32	0.0	97.00	49.01	32.74	0.0	74.52	23.64	28.62	0.0
15. WG 377	85.12	50.83	0.0	0.0	91.88	56.16	22.05	0.0	48.09	55.73	26.54	0.0
16. Timgalin	72.67	55.90	27.14	0.0	65.95	62.02	36.84	0.0	42.30	38.88	29.56	0.0
17. Ridley mutant	94.55	84.71	10.64	0.0	99.00	79.65	32.00	0.0	88.69	—	—	—
18. HD. 2009	79.01	70.94	23.50	0.0	87.14	69.41	35.64	0.0	64.04	52.35	28.33	0.0
19. UP 368	91.78	55.63	9.83	0.0	98.5	58.27	36.33	0.0	65.34	33.45	35.85	0.0
20. HD. 1949	79.45	55.24	9.43	0.0	77.47	77.49	18.37	0.0	60.52	62.80	26.06	0.0
21. HD. 1941	81.33	61.59	12.33	0.0	89.04	68.24	27.13	0.0	68.58	72.61	33.36	0.0
22. HD. 1944	67.20	65.95	9.50	0.0	71.20	59.93	35.94	0.0	60.93	65.85	41.42	22.22
23. Mex. C. B. 116	87.15	62.29	17.12	0.0	89.13	57.71	17.73	0.0	53.30	48.08	27.90	0.0
24. Olesan dwarf	93.77	79.17	8.33	0.0	90.78	63.94	11.80	0.0	81.66	78.72	24.14	0.0

male sterility and the restoration of male fertility depended on genetic and environmental conditions (TSUNEWAKI *et al.* 1976)

Crossed seed fertility was observed in male sterile lines with a view to find seed fertility and female lethality. Results summarised in Table 1 would indicate that there was no significant departure on the crossed seed set percent in all the generations thereby indicating normal female fertility. PANAYOTOV (1980) reported that the foreign cytoplasm did not show any harmful influence on crossability.

Seed set under natural cross pollination in the present study revealed that the highest seed set was 68% in BC_2 allo-Kharchia followed by 65% in BC_1 allo-Mukta and in F_1 allo-Kharchia showed 34%. The substantial variations in seed set between the generations and different male sterile lines can be attributed to many factors which include nonsynchronous flowering, stigma respectively, pollen availability and environmental changes (IMRIE 1966; KIHARA 1967). As cross pollination in a highly self pollinated crop like wheat is of great hinderance in economic exploitation of hybrid wheat due to its closed floral nature, future breeding strategy should be towards modification of floral structure and selection of good pollinators having flower synchrony.

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Induction of apomixis in *Aegilops squarrosa* L.

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The term apomixis embraces all types of asexual reproduction that tend to replace or act as substitutes for the sexual method (STEBBINS 1950). The phenomenon was discovered in the *Gramineae*, in *Poa*, by MUNTZINB (1933). Thirty two genera of grasses have been subsequently reported to contain apomictic species (CONNOR 1979) but no occurrence has been reported in the genera *Aegilops* or *Triticum*. GUSTAFFSON (1947) maintained that in diploid and tetraploid species growing under unfavourable environmental conditions such as long or short day, low light intensity or temperature, flower formation or seed setting may be restricted or prevented. In the present study evidence is presented for environmental induction of apomictic vegetative reproduction in *Aegliops squarrosa*.

Materials and Methods

This study was based on a strain of *Aegilops squarrosa* var. "meyeri" which was collected in Iran by Kyoto University Scientific Expedition (KUSE 2144) and kindly supplied by N. NAKAI, Laboratory of Genetics, Faculty of Agriculture, Kyoto University, Kyoto. This strain, which has a strong vernalization response, was grown under two treatments with four plants per treatment. In one treatment the seed did not receive vernalization and was sown at the end of summer in pots in a glasshouse maintained at approximately 20℃ under 16 h photoperiod (natural photoperiod extended to 16 h using incandescent lights) for two months and then transferred to natural photoperiod (9.4-11.5 h) at the same temperature. In the second treatment imbibed seed was given ten weeks vernalization after which the seedlings were sown in the glasshouse under natural photoperiod (9.4-11.5 h) with the unvernalized plants. For vernalization, imbibed seeds were placed in a cold room at 4℃ under an 8 hour photoperiod provided by low intensity (photoinductive) incandescent light.

Results and Discussion

The vernalized plants grew normally and produced culms that headed 140-150 days after planting out after vernalization (Fig. 1). The unvernalized plants were much more profusely tillered than the vernalized plants. Their culms exhibited internode elongation but most of them did not head, remaining as "blind shoots". Very few culms (2-3 per plant) headed, producing only small heads, which occurred 210-215 days after sowing. Of the tillers that headed, internode elongation occurred long before the appearance of the head. In both the headed and non-headed culms of the unvernalized plants, axillary buds developed at the culm nodes to give plantlets with initial roots (Fig. 2). This phenomenon occurred in all the plants

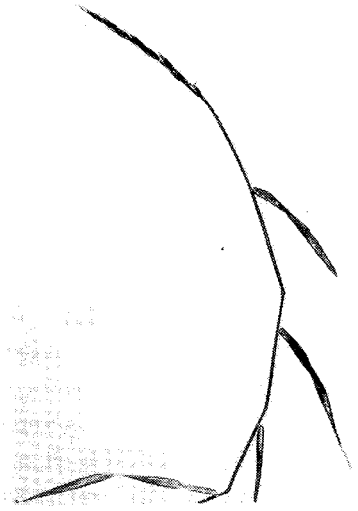

Fig. 1. Normal culm of vernalized plant of *Ae. squarrosa* var. *meyeri*.

Fig. 2. Culm showing plantlet development at culm nodes of unvernalized plant of *Ae. squarrosa* var. *meyeri*.

of unvernalized treatment.

This form of vegetative reproduction exhibited by this strain of *Aegilops squarrosa* could be considered to be apomictic because it appeared to substitute for sexual reproduction which was almost completely absent. The phenomenon bears implications for the potential survival of an annual species such as *Ae. squarrosa* in certain unfavourable growing conditions, as for instance the occurrence of unusual climatic conditions during growth e.g. the rise of winter temperatures when the species germinates and grows outside its normal growing season so that genotypes with strong vernalization response do not have the response satisfied. Under these conditions normal sexual reproduction can either be reduced or totally inhibited. The capacity to develop axillary buds under such circumstances could confer regenerative potential on the species by way of vegetative reproduction.

As other reports have been made of environmental influences on the development of vegetative apomxis in plants GUSTAFFSON (1946) reported *Malaxis paludosa* (*Orchidaceae*), which occurs in Scandinavia, far north as 63° latitude had poor fruit-setting and its dispersal was mainly as bulbils formed from the leaves, while in Britain fruit-setting was normal. He also reported that *Wolfia arrhiza* (*Lemnaceae*) which occurs in Europe, Africa Asia and Australia reproduces vegetatively in the northern temperate zone and is without flowering but in warmer climates it reproduces sexually. SÖYRINKI (1938) showed that the change to vegetative reproduction in phanerogram species in alpine vegetation of Petsamo-Lapland occurs mostly in the species whose primary habitat is not alpine. Environmental induction of apomictic agamospermy has also been reported in the *Graminae*. Short photoperiod was found to induce apomictic embryo sac development in *Dichanthium aristatum* (KNOX 1957), *Themeda australis* (EVANS & KNOX 1969) and *Heteropogon contortus* (TOTHIL & KNOX 1968). In the Tribe *Hordeae* apomixis as diplospory has been reported so far only in *Agropyron scabrum* in New Zealand (HAIR 1956; CONNOR 1979). It occurs either as a facultative or obligate expression in conjunction with forms with normal sexual reproduction (HAIR 1956).

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The control of ear emergence by vernalization and photoperiod in three wheat crosses

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Floral development and ear emergence in wheat is largely controlled by the plant's response to vernalization and photoperiod. A third factor, basic development rate, also appears to exert an important influence on wheat development (FLOOD 1983). Optimum flowering time and its consequent effect on yield potential is, therefore, strongly influenced by vernalization, photoperiod and basic development rate.

There is conflidence concerning the physiological interaction of vernalization and photoperiod in controlling floral development, although recent evidence suggests that prolonged vernalization does not remove the requirement for long days and short days do not replace the need for vernalization (FLOOD 1983). These responses do, however act alone and together to exert strong influence on leaf number (PUGSLEY 1968) and spikelet number per ear (PUGSLEY 1968; HALSE & WEIR 1970).

This experiment was designed to study the inheritance of photoperiod response associated with a weak vernalization response in three wheat crosses. The influence of vernalization and photoperiod responses on spikelet number per ear, an important component of grain yield, was also examined.

Materials and Methods

Three cultivars of different photoperiod responses, Sunset, Kogat and Thatcher were hybridized with the cultivar Condor which has a low level of vernalization response. The developmental characteristics of the parents are listed in Table 1. The three crosses were

Table 1. Developmental responses of the four parental cultivars used in this experiment

Line	Vernalization response	Relative photoperiod sensitivity	Country of origin
Sunset	Nil	Nil	Australia
Condor	Weak	Weak	Australia (from CIMMYT material)
Kogat	Weak	Strong	Alaska
Thatcher	Weak	Very strong	Canada

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made by one of us (G.M.H.) and F_2 seed of each cross was used in the present experiment.

Seeds of the parents and crosses were vernalized for six weeks by allowing seed to imbibe for 48 hours at room temperature and then sown into a sterile mixture of sand and peat (1 : 1 by volume) with adequate nutrients and placed in a cold room at 3℃ for vernalization. On emergence, the seedlings were given a 12 hour photoperiod for the duration of the vernalization treatment, provided by two 60 W incandescent lamps 40 cm above them. After vernalization the seedlings were kept at room temperature for three days to prevent possible de-vernalization (CHOUARD 1960).

Vernalized seedlings plus an unvernalized set (germinated five days befor the end of the vernalization treatment) were transplanted (4 per 18 cm diameter pot) into of a mixture sand a loam (1 : 1 by volume) with adequate nutrients.

Between 20 to 30 plants of the four parents and the three F_2's were grown under two photoperiod regimes following two vernalization treatrents, as shown below.

6 weeks vernalization : Short photoperiod-natural photoperiod

No vernalization : Long photoperiod-18 h photoperiod

The short photoperiod was natural daylength which ranged from 9.6 to 12.3 h during the course of the experiment (11 June to 30 September, 1979). The long photoperiod was obtained by extending natural daylength by the use of incandescent lamps operated through a time clock.

Days from transplanting to ear emergence and total spikelet number per ear were recorded for the main stem of each plant.

Results

Differences in days to ear emergence of unvernalized plants of the different genotypes grown under long photoperiods is largely a measure of their relative vernalization responses. On the other hand differences in days to ear emergence in vernalized and unvernalized genotypes grown under long day would be a measure largely of their actual vernalization responses.

Table 2. Frequency distributions of days from transplanting to ear emergence for F_2 plants from crosses between Condor and (a) Sunset, (b) Kogat and (c) Thatcher and the four parents after 6 weeks vernalization and grown under an 18 h daylength

Cultivar or Crossbred	Days from transplanting to ear emergence (+)												
	29	32	35	38	41	44	47	50	53	56	59	62	65
Condor			4	14	3								
Sunset	5	5	8	0	1								
Kogat					1	3	3	0	1	4	4	2	1
Thatcher				4	14	1	1						
Condor x Sunset							2	12	5	2			
Condor x Kogat									11	9	7	3	
Condor x Thatcher								9	11	8	1	1	

(+) Days to ear emergence are listed as the mid-point of three day intervals

Table 3. Frequency distributions of days from transplanting to ear emergence for F_2 plants from crosses between Condor and (a) Sunset, (b) Kogat and (c) Thatcher and the four parents unvernalized and grown under an 18 h daylength

Cultivar or Crossbred	Days from transplanting to ear emergence (+)											
	35	38	41	44	47	50	53	56	59	62	65	68
Condor				12	7	1						
Sunset	3	8	3	0	3	1						
Kogat						3	2	2	5	5	1	2
Thatcher					7	5	1	2	2	3	1	
Condor x Sunset						6	9	10	3	1		
Condor x Kogat								10	16	4		
Condor x Thatcher							7	10	9	4		

(+) see footnote Table 2.

The F_2 population of the Condor×Sunset cross (both spring wheats) shows transgressive segregation for days to ear emerience beyond the later parent Condor in both the vernalized and unvernalized conditions under long day (Tables 2 and 3). The vernalized and unvernalized F_2 populations had similar distributions and the mean value for the two populations differed by only 3.2 days indicating the presence of very little vernalization response.

Days to ear emergence in unvernalized F_2 plants of the cross Condor×Thatcher grown under long day had a range intermediate between the two parents but vernalized plants grown under the same daylength thowed transgressive segregation for delayed ear emergence. Again the difference in mean days to ear emergence between the two vernalization treatments (ca. five days) of the F_2 population indicates the presence of a small vernalization response.

The response of vernalized plants to a short photoperiod is an indication of the effect of photoperiod on delaying ear emergence in the absence of vernalization influences. Under these conditions the whole F_2 population of Condor×Sunset again showed transgressive segregation for delayed ear emergence (Table 4) possibly due to increased photoperiod sensitivity as indicated by a comparison between this treatment and vernalized plants grown under long day (Table 2).

The F_2 population of Condor×Kogat showed some transgressive segregation for increased photoperiod sensitivity (Table 4) but that of Condor×Thatcher was intermediate between the two parents for days to ear emergence (Table 4).

Unvernalized plants grown under the short photoperiod (normal daylength) give an indication of the interaction of vernalization and photoperiod in controlling ear emergence (Table 5). In this environment 18 of 30 plants of the F_2 population of Condor×Sunset showed transgressive segregation for delayed days to ear emergence and in the Condor× Kogat cross only 1 out of 23 plants was later to ear emergence than both parents (Table 5). The F_2 population of Condor×Thatcher was intermediate between the two parents for days to ear emergence.

None of the three F_2 segregating populations in any of the four treatment cmobinations

Table 4. Frequency distributions of days from transplanting to ear emergence for F_2 plants from crosses between Condor and (a) Sunset, (b) Kogat and (c) Thatcher and the four parents after 6 weeks' vernalization and grown under a short daylength (natural photoperiod)

Cultivar or Crossbred	Days from transplanting to ear emergence (+)																					
	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101	104	107
Condor		1	3	5	10																			
Sunset	1	8	7	4	1																			
Kogat																		2	1	0	8	10	1	
Thatcher																					8	7	4	2
Condor x Sunset										2	6	2	1	1	0	2	0	3						
Condor x Kogat															3	2	2	6	7	3	0	2	0	1
Condor x Thatcher													1	4	11	9	4	0	2					

(+) see footnote Table 2.

Table 5. Frequency distributions of days from transplanting to ear emergence for F_2 plants from crosses between Condor and (a) Sunset, (b) Kogat and (c) Thatcher and the four parents unvernalized and grown under a short daylength (natural photoperiod)

Cultivar or Crossbred	Days from transplanting to ear emergence (+)																				
	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101	104	107
Condor								3	7	9	1	1										
Sunset	10	7	3	1																		
Kogat																				18	2	
Thatcher																				7	12	2
Condor x Sunset									1	5	4	5	2	4	2	4	1					
Condor x Kogat														3	4	2	0	3	5	4	1	1
Condor x Thatcher														3	13	6	2	1	4			

(+) see footnote Table 2.

(Tables 2 to 5) showed segregation into early and late types that would be consistent with simple inheritance.

There was a close relationship between mean days to ear emergence and mean spikelet number in the four parental varieties (Table 6) with spikelet number being lowest in the vernalized, long day treatment and highest in the unvernalized, short day treatment. In the F_2 populations of the three crosses differences in days to ear emergence between vernalized and unvernalized treatments were small (i.e., no vernalization response) under both long and short photoperiods and this was reflected in small differences in spikelet number. Short compared with long photoperiod gave substantial increasese in spikelet number (Table 6).

Discussion

There were significant amounts of transgressive segregation for days to ear emergence in the F_2 populations particularly for the Condor×Sunset cross in all four combinations of vernalization and photoperiod. When photoperiod would have limited development several plants of the F_2 potulation of the Condor×Kogat cross showed transgressive segregation for

Table 6. Spikelet number per ear for the parental cultivars and three crossbreds, vernalized and unvernalized and grown under long and short daylengths

Cultivar or Crossbred	Vernalization Treatment[A] (weeks)	Photoperiod Treatment[B] (daylength)	Mean spikelet number per ear (±S.E.)
Condor	6	S	19.6±1.4
	0	S	27.4±1.6
	6	L	10.6±1.9
	0	L	15.5±1.4
Sunset	6	S	13.1±1.0
	0	S	14.1±0.9
	6	L	8.1±1.4
	0	L	12.5±1.7
Kogat	6	S	26.9±1.7
	0	S	27.8±1.6
	6	L	14.4±1.6
	0	L	16.5±2.8
Thatcher	6	S	24.3±1.6
	0	S	22.9±1.5
	6	L	9.6±1.5
	0	L	13.5±1.6
Condor	6	S	17.0±2.3
x	0	S	17.2±3.4
Sunset	6	L	10.8±1.6
	0	L	11.2±2.1
Condor	6	S	21.1±2.6
x	0	S	21.5±2.7
Kogat	6	L	12.9±1.6
	0	L	13.5±1.1
Condor	6	S	17.3±1.6
x	0	S	19.4±2.3
Thatcher	6	L	11.9±1.4
	0	L	13.4±1.4

A_6 weeks cold treatment at 3°C or no cold treatment
B_5=short day; L=long day (see text)

days to ear emergence (Tables 4 and 5). None of the F_2 populations gave segregation ratios which would support simple inheritance. Photoperiod sensitivity in wheat was found to be controlled by two genes (PUGSLEY 1966; KEIM *et al.* 1973) and KLAIMI & QUALSET (1973) proposed a two gene system whth three alleles at each locus. Transgressive segregation in the Condor×Kogat F_2, which occurred in both the vernalized and unvernalized populations grown under long day, however, does not necessarily imply complex inheritance for photoperiod response.

Transgressive segregation of the entire F_2 potulations occurred with the Condor×Sunset cross in three of the four treatments also in the Condor×Thatcher cross when vernalized plants were grown under long day. This was most marked in the vernalized long day treatment (Table 2) in which both vernalization and photoperiod did not limit rate of development. Under such conditions differences in days to ear emergence are likely to be due to differences in basic development rate (FLOOD 1983), i.e., development rate differences in the absence of vernalization and photoperiod influences. If this character was quantitatively inherited it is possible that it could cause transgressiveness for days to ear emergence in the types of environmental regimes of this study. Another possible explanation for the complete transgressiveness in certain of the F_2 populations of the study could be the influence of the Condor cytoplasm (as female parent) on the expression of the "development" genes of the respective male parent. While there is little evidence in bread wheat for maternal inheritance, significant effects of alien cytoplasm on developmental responses in wheat have been reported (KINOSHTA *et al.* 1979; WARD *et al.* 1983).

This study reveals the dependence of spikelet number on rate of development in wheat. In the absence of vernalization response, long photoperiod caused substantial reductions in spikelet number compared with short photoperiod, e.g., Kogat showed a reduction from 28 to 16 spikelets under short compared with long photoperiod. Similar effects have been observed by other workers (HALSE & WEIR 1970; RAWSON 1970, 1971; WALL & CARTWRIGHT 1974).

The strong dependence of spikelet number on developmental responses in wheat raises the possibility of manipulating vernalization and/or photoperiod response to raise the yield potential as increased spikelet number. In the present study the cultivars Condor and Kogat both exhibited maximum spikelet numbers of ca. 28 (unvernalized/short photoperiod) but their developmental responses were markedly different. Kogat has no vernalization response but is strongly sensitive to photoperiod while Condor has a weak response to vernalization and a slight response to photoperiod. Without considering the genetic components of spikelet number control in these two cultivars, the production of the same number of spikelets per ear was associated with very different combinations of developmental responses. Thus, it may be possible to increase yield potential by breeding to incorporate developmental responses that confer optimum flowering time for maximum spikelet number. This approach to raising wheat productivity is also advocated by VINCE-PRUE & COCKSHULL (1981) as an alternative to the production of photoperiod insensitive wheats.

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Evaluation of wheat mutants for days to maturity

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Physical and chemical mutagens are know to induce earliness or lateness in crop plants. According to a recent estimate about one third of the mutant varietites evolved so far carry gene(s) for earliness or lateness. Altering flowering or maturity time by genetic means such as mutation induction, must always involve interference with one of the control mechanisms such as vernalization requirement, day length reaction or temperature sensitivity. Also, day length neutrality has been created by mutation induction and it can be suspected that many of the earlier or later mutants reported in fact have an altered day length response (MICKE 1979). It is therefore necessary to evaluate newly eovolved strains or mutants under different environmental conditions. We selected nine mutants out of forty two phenotypically stable mutants reported earlier (SIDDIQU 1972) for detailed study of longevity measured in terms of days to maturity.

Earthen pots measuring 22×20 cm were filled with 2.5 kg of air dried loamy soil, irrigated with 500 ml of tap water one day before sowing. The amount of mineral nutrients per pot was calculated equivalent to the field rate on soil weight basis (54 kg N, 27 kg P_2O_5 and 13.5 kg, K_2O per acre). The full dose was applied by thorughly mixing it in the soil of each pot before irrigating the soil for sowing. Twelve seeds per pot of 13 cultivars were planted at 2 cm depth with marked glass rod. The experiment was planned with complete randomized design having five repetitions. Detailed chemical and mechanical analysis of soil is reported earlier (LARIK *et al*, 1983).

Analysis of the mutants revealed that mean heading and maturity days of EMS-derived mutants significantly shifted towards earliness whereas, mutants originating from gamma rays treatments displayed highly significant lateness (Table 1). Mutant-7 of C-591 took significantly ($P \geq .01$) lesser time from heading to maturity as compared to its mother cultivar. Such early mutants have also been reported by other workers (GUSTAFSSON *et al*. 1960 ; EL-HATTAB & IBRAHIM 1970 ; IBRAHIM & SHARAAN 1974).

Hexaploid wheat, which apparently has a good amount of its genes in triplicate as evidenced by 7 homoeologous grous, presumably has a vast reservior of loci that can be mutated in various ways without being detrimental to the plant. Thus, early types and specificity in action at certain loci in EMS-derived mutants can all be due to the ability of

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Table 1. Estimates of mean values for number of days from sowing to maturity and grain yield under pot condition.

Genotype/Pedigree	Number of days		Total number of days from sowing to maturity	Grain yield gm/pot
	Sowing to heading	Heading to maturity		
C-951 (control)	80.20	34.00	114.20	5.35
M-7 (EMS 7hr)	77.80*	34.00	111.80**	6.35
M-28 (EMS 7hr)	78.20	35.00	113.20	5.58
M-38 (EMS 7hr)	80.00	32.80*	112.80	6.34
Nayab (control)	67.60	39.20	106.80	5.35
M-6 (25 KR)	74.00**	35.00*	109.00**	6.45
M-22 (20 kR)	78.60**	33.20**	111.80**	6.85*
M-27 (35 kR)	74.20**	35.40**	109.60*	6.45
Indus-66 (control)	72.80	35.20	108.00	5.59
M-13 (20 kR)	76.00**	34.00	110.00*	5.65
M-37 (20 kR)	77.00**	32.80**	109.80	5.45
M-39 (20 kR)	73.20	35.40	108.60	6.35
Mexi-Pak (check)	77.20	32.20	109.40	4.80
L. S. D (.05)*	2.40	1.40	1.90	1.32
L. S. D (.01)**	3.40	1.90	2.60	NS
S. E.	0.90	0.50	0.70	0.46
C. V. %	1.30	1.30	0.70	8.45

EMS to induce functional alteration in the genes.

Gamma originated mutants displayed lateness in heading and maturity time (Table 1). This shows that gamma irradiation causes deeper physiological damage before reaching lethality (MOES 1963). SWAMINATHAN *et al.* (1962) after an extensive study with wheat and barley concluded that in evolution of gene placement along the chromosome arms it is likely that linkage groups in which geness without need for recombination are located near the centromere would have had a selective disadvantage. The location of genes relating to earliness in the proximal segments and the high susceptibility of such regions to EMS action may perhaps be factor involved in the induction of a large number of early mutants in EMS-treated material. Data from linkage analysis in barley (ROBERTSON 1963 ; NILAN 1964) and studies on chromosomal aberration aberration (NATARAJAN & UPADHYA 1964) have provided eivdence in support of this view.

Association of heading and maturity with grain yield was also estimated. Heading was strongly associated ($r=.98^{**}$) with maturity. The relationship of these traits with grain yield was positive but not significant. However, earliness was accompanied by high yielding capacity of EMS induced wheat mutants compared to their mother cultivar (GAUL 1961 ; GUSTAFSSON 1963 ; IBRAHIM *et al.* 1966). All the early and late mutants produced higher grain yield than the respective mother cultivars. However, only mutant-22 derived from Nayab produced significantly ($P \geq .05$) higher yield than the mother cultivar.

The present study suggests that EMS is efficient in inducing earliness in wheat, likewise gamma rays appear to be a suitable mutagen for inducing lateness. The chioce of strategy would depend on the objectives of a particular plant breeding programme.

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Grain quality attributes of some hexaploid triticale lines

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In recent past, several agronomically acceptable hexaploid triticale lines have been developed. However, its end-use quality is still questionable and warrants for genetic improvement before it reaches farmer's field. In that context, information on genetic variability for physico-chemical characteristics of grain would serve as indices of direction and magnitude of selection pressure to be exerted for desired improvement. Present study deals with variability for proximate composition in some elite strains of hexaploid triticale developed recently in India.

Materials and Methods

Thirty eight lines of hexaploid triticale and three wheat checks were sown in randomised block design with three replications. Grain yield (g) per m^2 and 1000 grain weight (g) were recorded. Produce of five plants selected at random in each replication was mixed and used for the analysis of grain quality attributes. Grain crushing hardness was determined using the hardness tester (Model Kiya Seisakusha, Tokyo). Starch content (%) and Sedimentaion value (ml) were estimated according to CLEGG (1956) and AUSTIN & RAM (1971), respectively. Ash and fat contents (%) were estimated following AOAC methods. Grain protein content (%) was estimated by Microkjeldahl method (N × 5.7). Protein productivity per m^2 was calculated as: Protein productivity g/m^2 = Grain yield g/m^2 × Grain protein (%). Parameters of variability viz., mean, range, phenotypic (pcv) and genotypic coefficients (gcv), heritability (%, broad sense) and genetic advance (%) were computed.

Results and Discussion

Analysis of variance revealed significant differences among genotypes for the characters studied. This fact was further substantiated by appreciable range of variation (Table 1). In general, mean values of triticale lines were low as compared to mean of wheat checks. However, it was intersting to note that few triticale lines excelled or resembelled wheat checks for various quality attributes. Triticale lines UPT 72615 (54.00 g) and THS-4 (49.30 g) excelled wheat variety WH-147 for 1000 grain weight (46.80 g). Grain crushing hardness determines milling properties and grain flour recovery (BAKER 1977) and can therefore be considered as an index for selecting suitable genotypes (DUNDUCK & ERMAKOVA 1978). Accordingly, triticale lines, DTS-580 (9.40) TL-167 (9.10) THS-(8.86) resembelled grain

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Table 1. Variability parameters for some quality characters in triticale.

Character	General mean	Range	pcv	gcv	Heritability (%)	Genetic advance (%)
1. 1000 grain weight (g)	40.71	28.40– 54.00	12.10	11.20	86	8.72
2. Grain crushing hardness (kg/seed)	6.73	5.42– 12.30	24.32	20.28	73	2.46
3. Sedimentation coefficient (ml)	19.84	10.50– 34.00	23.46	19.39	68	6.52
4. Ash content (%)	1.83	1.24– 2.76	17.28	14.46	70	0.46
5. Fat content (%)	1.94	1.40– 2.70	17.10	12.62	55	0.37
6. Starch content (%)	45.89	34.20– 57.60	12.02	10.81	81	9.20
7. Grain protein ccontent (%)	12.56	10.40– 16.20	11.59	8.00	48	1.44
8. Grain yield (g/m^2)	322.25	184.78–452.10	17.00	14.00	69	15.00
9. Estimated protein productivity (g/m^2)	40.31	24.02– 67.70	20.10	16.28	66	11.07

crushing hardess of best wheat variety Kalyan Sona (9.10). Dough having sedimentation value between 20 to 39 ml is rated suitable for good 'Chapati' quality. Thus, triticale lines DTS1-8 (34.00), TL-520 (29.50), JNK6T-135 (27.00), THS-6 and DTS-601 (26.00) and TL403 and TL419 (23.00) appeared good for 'Chapati' purposes as wheat variety WH-157 (29.50). Rest of the lines appeared good for biscuits and cookies. For grain ash content, lines DTS1-8 (2.76), TL419 (2.70), THS-6 (2.60) and THS-4 (2.36) were found better than Kalyan Sona (2.14).

All the triticale lines exhibited significantly lower starch content, whereas, for fat content lines; TL202 (2.70), TL520 (2.40), DTS580 (2.45), THS-7 (2.50) and THS-8 (2.40) were superior to wheat variety WH-157 (2.00). In confirmity with the findings of RUCKMAN *et al.* (1973), average protein content in triticale (12.56) was almost equal to wheat (12.80). However, TL403 (16.20) and THS-8 (14.00) showed significantly higher grain protein content than wheat checks. Mean grain yield of triticale lines (322.25 g) was significantly lower than wheat checks (377.66 g). But lines TL403 (418.48 g) and THS-8 (452.10 g) were significantly superior to wheat checks, while, UPT77017, DTS10-1, TL419 and THS-5 were at with wheat checks. For bridging protein-calorie gap, grain protein production per unit area is to be increased (BHATIA 1975). For that matter, TL403 (67.79) execelled wheat variety WH-157 (57.49).

Progerss in triticale is hampered because of low genetic variation for grain quality attributes, particularly among selected elite lines. This fact is also corroborated by invariably low to moderate of pcv and gcv (Table 1). High heritability coupled with high genetic advance indicates that the character is governed by additive type of gene action (PANSE 1957) and in such cases simple selection should prove effective. In present study, though heritability (broad sense) was high to moderate, being highest for 1000 grain weight, followed by starch content and grain crushing hardness, yet low genetic advance, in general, indicates that simple selection would not be much effective. Moreover, low gcv warrants for increasing

spectrum of variation through multiple crossing. In that light, genotypes; TL403, TL419, THS-4, THS-8, THS-2 and DTS 580 merits consideration for their inclusion in hybridization programme followed by intense selection so as to exploit genetic potential of these elite lines in order to synthesize better triticale genotypes.

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Agronomic characteristics of induced mutants of Triticale

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Mutation appeared to be of a significant role in the evolution and breeding of the tribe Triticeae, and particulary of the genus *Triticum*.

Recently chemical mutagens are being extensively used in cereal plants to create genetic variability for desirable traits. A limited variability in existing Triticales offers an excellent opportunity to generate new genotypes in a relatively short time by use of the mutation breeding. To date, only very few studies have been reported, on the use of chemical mutagens in Triticale.

The study performed was to obtain winter Triticale mutants, which be used in improvment programs for yield, improved yielding capacity, protein content, and frost resistance.

Materials and Methods

Triticale improvment programs were initiated in our laboratory in 1977.

Seeds of a hexaploid Triticale initial line 2061 were presoaked in water for 12 hours at 25±1℃. Mutagen solution were freshly prepared at pH 7, 0. Seeds were treated in three concentration: 1, 5 mM, 2, 0 mM, and 2, 5 mM MNUA(N-nitroso-N-methylourea) for 3 hours at 25±1℃. After the treatment they were rinsed in distillated water for 1 hour. Seeds were space planted in a four meter long, and one meter in width plot with three replications in a randomized complete block.

The main pressure selection in M_2 and M_3 concerned on the yield and yield components.

The initial line 2061, and morphologically established strain of mutants were planted during the 1981-82 growing season in single row plots 5 meter long in a randomized complete block design replicated 3 times. Date on grain yield per spike, number of grains per spike, 1000 grains weight and grain yiled per plot of initial line and mutants were estimated using standard procedures, and frost resistance mutant forms were selected in climatic conditions in winter 1981/82 by such quality scores from 1 to 9(1; dead, 9; undamage). Protein contents in grains of initial line 2061 and mutant strains was established using micro-Kjeldahl method.

Results have been statistically calculated using a multivariate analysis of variance (MANOVA) and the ather multivariate methods related.

Results and Discussions

It has been now well established that in cereal plants mutagens when applied to plants are inducing mutations in polygenic characters(GAUL 1977; LARIK 1978).

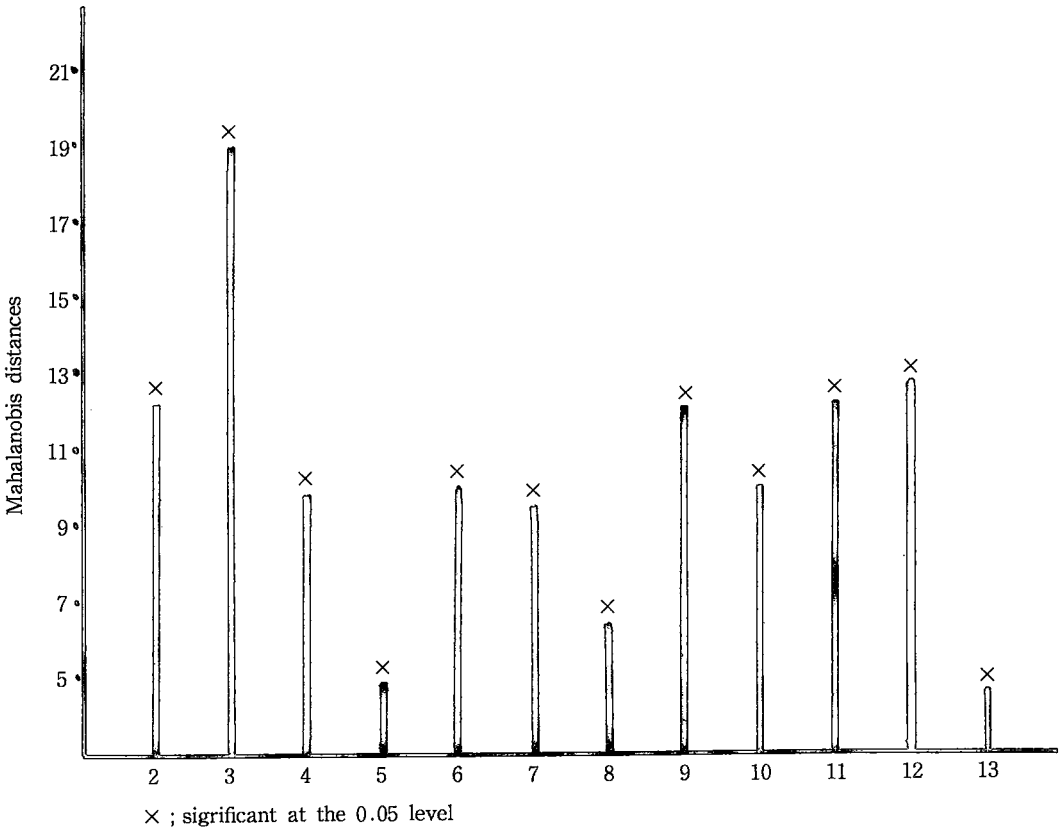

Fig. 1. Mahalanobis distance for complex of yield components between initial line 2061, and mutant strains.
2 ; 27/81, 3 ; 36/81, 4 ; 104/81, 5 ; 106/81, 6 ; 216/81, 7 ; 253/81, 8 ; 284/81, 9 ; 316/81, 10 ; 916a/79, 11 ; 916b/79, 12 ; 919/79, 13 ; 1445/79.

In the present study morphogically stable mutant strains were characterized an the basic of grain yield per spike, number of grains per spike, 1000 grains weight, grain yield per plot, frost resistance, and protein contents in grains, and compared to initial line 2061 (Table 1).

Grain yield per spike in all the mutant strains generally displayed mon-significant reduction over line 2061. All the mutants with exception strain 27/81 showed less grain per spike, when compared with line 2061. Means for 1000 grains weight, and grain yield per plot showed significant decrease, as compared to the initial line 2061.

In seems neccessary to point out on the mutant 106/81, which produced more grain yield per unit area. The presented results may be releted to those obtained by LARIK (1978), SIDDIQUI *et al.* (1980), in wheat. RAMANATHA & JOSHI (1976), RAJPUR & MALIK (1982) observed induced comparable variation of yield components in Triticale. After treatment of Triticale cultivar GRZESIK (1980) have selected improved mutants.

Phenotipically stable mutants have different characters in the complex of yield compo-

Table 1. Estimation of contrasts between initial line 2061 and mutant strains for yield components, frost resistance and protein contents in grain

Contrast	Value of contrast					
	Grain yield per spike gram	Number of grans per spike	1000 grains weight gram	Grain yield per plot gram	frest resistance	% of protein in grain
1/2061−27/81	−0.16	−15.77*	11.07	205.33*	3.00*	−0.17
2/2061−36/81	0.80*	1.67	13.47*	395.0*	4.00*	−0.80
3/2061−104/81	−0.54	− 5.77	−3.23	214.3*	2.00	0.97
4/2061−106/81	0.28	2.93	2.17	−110.0*	−1.67	1.67*
5/2061−216/81	0.15	− 8.47	10.53*	162.0*	0.67	−1.77*
6/2061−253/81	0.84*	11.03	4.50	189.67*	2.33*	0.47
7/2061−284/81	0.61	− 0.13	11.50*	− 30.00*	1.33	0.10
8/2061−316/81	1.10*	3.80	17.50*	130.00*	0.00	−1.63*
9/2061−916a/79	0.45	− 4.67	12.50*	146.00*	0.00	1.63*
10/2061−916b/79	0.64	− 1.47	13.23*	172.00*	−0.67	1.50
11/2061−909/79	0.73	− 8.27	19.57*	100.67*	−0.67	0.10
12/2061−1445/79	0.33	3.17	2.80	78.67*	−0.33	0.17

* ; significant contrast at the 0.05 level

nents, when compared to line 2061 (Fig. 1), particularly mutant 104/81.

Grain quality are usually the primary objectives of Triticale improvment. Two of 12 mutants there were found a higher protein content, than line 2061, namely 216/81, and 316/81. Similar results were obtained by SIDDIQUI *at al.* (1975), and CORPUS *et al.* (1983) in wheat.

The strains of mutant showed decrease frost resistance when compared with line 2061. One of the most important element of the winter Triticale varieties is frost resistance, but we have not selected any form with markedly increased frost resistance yet. It seems that such induced mutation could be successfully exploited for improvment of contemporary Triticale.

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Significance of genotype×environment interaction in breeding of spring wheats (*Triticum aestivum* L). I. Plant height and peduncle length parameters.

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Plant growth environment, a complex combination of soil, water and crop management factors, play a significant role in the physiological and other metabolic process taking place in plants for dry matter production (EBERHART & RUSSELL 1966 ; FREEMAN & PERKINS 1971 ; BOROJEVIC & WILLIAMS 1982). It is therefore desirable to determine the optimum level of growth environmental factors. As such, the present studies were undertaken to ascertain the behaviour of plant height and peduncle length traits under changing soil fertility conditions.

Materials and Methods

Eight promising wheat varieties (*Triticum aestivum* L.) were grown under four fertilizer levels with different combinations of nitrogen (N) and phosphate (P) i.e.

F_1=Control (6) lb. N+0 lbs P)). F_2=100 lbs. N+50 lbs P.

F_3=125 lbs N+75 lbs P. F_4=150 lbs. N+75 lbs P.

The experiment was laid out in split plot design with three replications. The data thus recorded in centimeters, was subjected to analysis of variance test and least significant differences (LSD) were observed, as described by STEEL & TORRIE (1960).

Results and Discussion

As it could be seen from the table the fertilizer application significantly increased the plant height in comparison with the control. Although, the difference in plant height was non significant among the various fertilizer treatments. This however, indicated that fertilizer application significantly increase plant height, but fertilizer doses have no significant difference among each other.

The examination of data further revealed that the maximum and minimum plant height of 121.31 cms, and 85.48 cms, were recorded for wheat varieties V1286 and Yacora respectively. The remaining six varieties fall between this range. The order of plant height, on variatal basis, was found to be V1286 > V1362 > Sandal > LU26 > V1266 > Pawon > Pari73 > Yakora.

So far, as, the peduncle length is concerned, the treatments did not affect this trait at any fertility level. However, the comparison of varieties indicated significant differences for peduncle length. The order of increase in peduncle length was found to be V1286 > Pavon,

Table 1. a. Plant height

Fertilizer	VARIETIES								AVERAGE
	LU 26	PARI 73	V 1266	V 1286	V 1262	PAVON	SANDAL	YACORA	
F_1	101.11	174.8	88.2	108.7	103.8	93.7	101.4	73.8	93.19b
F_2	114.6	94.7	118.7	126.9	122.3	99.9	121.9	89.5	111.06a
F_3	114.2	85.7	118.7	124.5	119.8	105.1	119.1	89.6	109.59a
F_4	118.4	88.1	115.5	125.7	125.0	102.1	122.2	89.0	110.75a
AVERAGE	112.08	85.61	110.27	121.31	117.74	100.20	116.15	85.48	
	bc	a	c	a	ab	d	abc	e	
	LSD (V) 5%=6.05		LSD (F) 5%=4.20			LSD (T) 5%=12.11			

b. Peduncle length

F_1	48.4	32.8	40.4	53.9	48.0	61.2	45.9	47.3	47.24a
F_2	51.5	42.6	52.8	56.7	53.8	50.3	54.2	37.4	49.91a
F_3	54.5	36.5	51.0	56.3	53.6	53.8	52.9	39.7	49.79a
F_4	53.1	40.3	51.5	57.7	54.5	51.2	54.6	41.7	50.59a
AVERAGE	51.88	38.08	48.92	56.12	52.46	54.11	51.88	41.53	
	ab	c	b	a	ab	b	b	c	
	LSD (V) 5%=6.21		LSD (F) 5%=4.39			LSD (T) 5%=12.43			

V1362, LU26, Sandal > V1266 > Yakora and Pari73. The variation observed in peduncle length, reflect the genotypic differences among the Varieties.

Although, the characters plant height and peduncle length are not yield components, yet, these carry great influence over the manifestation of plant yield. As such, these are considered as very important segments of growing plant and are worth to be included in the studies for evolving high yielding wheat varieties. Also the results suggest that the genotypes interact with environments for character manifestation which should express its fullest only in a spicific ecological niche and peak.

The results presented here are in agreement with those reported by TAN *et al.* (1979). TROUGHTAN (1970), FREEMAN *et al.* (1971) and KALTSIKES & LARTER (1970).

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Detection of larvae feeding on *Puccinia recondita* (Rob. ex. Desm. f. sp. *tritici*) uredospores.*

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During screening of wheat varieties towards their response to rust, on our Experimental Farm, some minute brick colour bodies were observed on the leaves of rust infested plants. They resembled rust pustule at a cursory glance and on macroscopic examination it was found that the minute objects were larvae of some insect (tentatively identified as belonging to the order Diptera).

Detailed microscopic studies revealed that the original colour of the larvae was creamy white but due to feeding on rust spores they assumed brick red colour. It was further observed that their midgut was full with rust uredospores. This observation provided further support that the larvae were exclusively feeding on rust spores and thus resembled rust pustules.

Reports regarding insects feeding on rust are already available in the literature. COBB (1890-94), COBB & OLLIFF (1891), and WEBSTER (1890) suspected some species of genus *Diplosis* and *Sminthurus* feeding on leaf rust spores in Kenya, Egypt and India respectively. They further pointed out that in addition to feeding exclusively on rust spores, the larvae were active disseminators of the rust fungus. According to CHESTER (1946), some workers in 40'ies, reported species of thrips feeding on rust spores.

Therefore, when they are abundent and scattered all over the leaf surface the plants may be rated as susceptible on the basis of present technique of screening. As a result of this "deception factor" being reported for the first time from Pakistan, the workers screening for rust resistant varieties are cautioned not to discard their material without carefully differentiating between the larvae and pustules.

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Differential behaviour of *aestivum* and *durum* wheats to races 77 and 106 of leaf rust (*Puccinia recondita* Rob. ex Desm.)

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Indian wheat is subject to attack by all the three rusts, although their importance and distribution varies from region to region. Three species of wheat, viz., *Triticum aestivum*, *T. durum* and *T. dicoccum* are cultivated in India at present. While monitoring the field virulences of these rusts, they are all considered together irrespective of the fact on which species of wheat they are found. Since most of the area is under *aestivum* wheats (a little over 85%), the race situation so obtained, gives information mainly of *aestivum* wheats only ignoring the tetraploids, namely, the *durum* and *dicoccum* wheats.

The information on field virulences of rust pathogen is used as a guide line for breeding rust resistant wheats including the *durum* wheats. In a *durum* multiline programme, 10 *durum* parents, namely, NI 146, 'Bijaga Yellow', HD 4519, HD 4530, CC 422, CPAN 1311, CPAN 1469 CPAN 1471, CPAN 1480 and CPAN 1548 were tested for their seedling reactions against leaf rust races of India to match these reactions with the known reactions of Lr lines of *T. aestivum*. The behaviour of *durum* lines and Lr lines of *aestivum* to aggressive (77) and weak (106) races of leaf rust is mentioned in Table 1.

Table 1. Reaction of *durum* and *aestivum* lines to aggressive (77) and weak (106) races of leaf rust India.

Details of lines tested	Number of lines tested	Number of lines		Number of lines	
		Resistant to 77	Susceptible to 77	Resistant to 106	Susceptible to 106
Durum lines	10	7	3	3	7
Lr lines and two *aestivum* varieties carrying Lr 10	24	4	20	20	4

Data in Table 1 show that race 106 considered to be a weak race is weak only on *aestivums* but aggressive on *durums*. Similarly race 77 considered to be an aggressive race is aggressive only on *aestivums* but weak on *durums*. Evidently no generalization can be made with regard to the status of a race as weak or aggressive as it is subject to the genotypes grown. Of the 10 *durum* varieties tested against races 77 and 106 of leaf rust, 7 varieties (HD 4530, CC 422, CPAN 1311, CPAN 1469, CPAN 1471, CPAN 1480 and CPAN 1548) were found to be resistant to race 77 while only 3 varieties (HD 4530, CPAN 1311 and CPAN 1469) were resistant to race 106. In case of Lr lines, the picture is just the reverse.

Of the 22 Lr lines and two *aestivum* wheats carrying Lr 10 tested, only 4 lines (Lr 9, Lr19) Exe. (Lr 10) and Lee (Lr 10)) were resistant to race 77 while 20 were resistant to race 106.

To find out the presence of probable Lr genes in *durum* parents, seedling reactions of the 10 *durum* varieties to leaf rust races were matched with the known reactions of Lr lines of *aestivum*. Matching of reactions revealed that of the 7 *durum* varieties resistant to race 77, only 2 varieties (CPAN 1311 and CPAN 1469) were found to carry Lr 10 while 5 varieties did not show the presence of Lr 10 in them. Subsequently the reactions of these test varieties were matched with the known reactions of lines/varieties carrying Lr 24, Lr 25, Lr 26, Lr 27, Lr 28 and Lr 29, which give resistance to race 77 in addition to other important races/ biotypes. These genes too did not show their presence in the *durum* varieties. Thus other than the alien genes, Lr 10 and Lr 27 are the only known genes which impart resistance to race 77. This suggests that the Lr genes worked out in the *T. aestivum* background either do not hold good for *T. durum* or there is some other unknown gene/s responsible for resistance to race 77 in the *durums*. Hence, it is important to take into consideration this variable behaviour of *durums* and *aestivums* in breeding for rust resistance, in general, and to leaf rust in particular. It will also be very interesting to extend these studies to other races of leaf rust and also to stem and stripe rust races, as well.

Conclusions

Lr genes in *aestivums* and *durums* appear to be different for race 77. Similarly a general classification of races into weak and aggressive categories for hexaploid and tetraploid wheats together requires rethinking.

Acknowledgement

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II. Record

Catalogue of gene symbols for wheat, 1983 supplement

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This Catalogue is being completely reviewed for presentation at the 6th International Wheat Genetics Symposium, 1983.

Hairy Leaf

Hl (155A)	v:	Milturm 321 (155A); Saratov 29 (155A); Saratov 321 (155A).	4A (155A)
hl	v:	Chinese Spring (155A).	

Uniculm Stunt

Stunting is favoured by a combination of long days and low ndght temperatures (100A). Caused by duplicate recessive genes *us1* and *us2*

Genotypes:	Normal *Us1 us2*	Alfa; Jaral
:	Normal *us1 Us2*	Mabruk
:	Stunted *us1 us1*	Line 492

Proteins

Shikimate dehydrogenase

Skdh-A1 (127AAAA)	v:	Chinese Spring	5AS (127AAAA)
Skdh-B1 〃	v:	〃 〃	5BS 〃
Skdh D1 〃	v:	〃 〃	5DS 〃

Similar genes in 5PS and 5U (127AAAA).

Glucose Phosphate isomerase

Gpi-A1 46A	v:	All wheats (46A).	1AS (46A)
Gpi-B1 46A	v:	All wheats (46A).	1BS (46A)
Gpi-D1a 46A	v:	Chinese Spring (46A); most wheats (46A).	1DS (46A)
D1b 46A	v:	CS[1] (46A); certain CS aneuploids (46A).	
Gpi-R1 46A	v:	*S. montanum* (46A); *S. cereale* cv. King II (46A).	1R (46A)
Gpi-U1 46A	v:	*Ae. umbellulata* (46A).	1U (46A)
Gpi-Ag1	v:	*Agr. elongatum* (46A).	1E (46A)
Gpi-H^{Ch}1	v:	*H. chilense* (46A).	1H^{Ch} (46A)

Endosperm Proteins

Glutenin

Glu-A1a	196C, 196CA	v: 28%, Hope*.	
A1b		v: 28%, Bezostaya-1.	1AL (196C)
A1c		v: 44%, Chinese Spring.	
Glu-B1a	196C, 196CA	v: 19%, Flinor.	1BL (196C)
B1b		v: 25%, Chinese Spring.	
B1c		v: 30%, Bezostaya-1.	
B1d		v: 18%, Hope.	
B1e		v: 3%, Federation.	
B1f		v: Rare, Lancota.	
B1g		v: Rare, NS335.	
B1h		v: Rare, Sappo.	
B1i		v: 4%, Gabo.	
B1j		v: Rare, Dunav.	
B1k		v: Rare, Serbian.	
Glu-D1a	196C, 196CA	v: 56%, Chinese Spring.	1DL (196C)
D1b		v: 3%, Hobbit.	
D1c		v: 5%, Champlein.	
D1d		v: 35%, Hope.	
D1e		v: Rare, Flinor.	
D1f		v: Rare, Danchi.	

*Proportion of 300 wheats carrying designated allele and nominated standard (196CA).

Gliadin

Gli-A1	196C	v:	1AS (196C)
Gli-B1		v:	1BS (196C)
Gli-D1		v:	1DS (196C)

Reaction to *Puccinia graminis tritici*

Sr34	171AA	v: See 1980 Supplement.	4BL (171AA)
Sr35	169AB	v: *T. monococcum* C69.69 selection (169AB); G2919 (169AB). Various hexaploid derivatives (169AB) Arthur; Arthur 71	3AL (169AB)
Sr36	163 *SrTt1*	v: CI 12632; CI 12633; Cook; Idaed 59; Songlen; Timgalen; Timson; Timvera.	2BS
Sr37	163 *SrTt2*	v: Steinwedel/*T. timopheevii* selection.	4Aβ

Genetic Linkages

Chromosome 1A		
Glu-A1-Centromere	7.7±1.8 cM	196C
Glu-A1-Gli-A1	66.0±5.7 cM	196C
Chromosome 1B		
Glu-B1-Centromere	10.2±2.4 cM	196C
Glu-B1-Gli B1	66.0±5.7 cM	196C
Chromosome 1D		
Glu-D1-Centromere	10.2±2.4 cM	196C
Glu-D1-Gli-D1	48.3±2.4 %	46B
Glu-D1-Gpi-D1	36.2±4.5 %	46B
Gli- D1-Gpi-D1	34.5±4.4 %	46B
Chromosome 3A		
Sr35-Centromere	35%	169AB
Sr35-R2	1%	169AB
Chromosome 4BL		
Lr28-Centromere	39.2±2.7 %	171AA

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III. Editorial Remarks

Announcement for Future Issues

WIS No. 59 will be planned for publication in October, 1984. Manuscripts for this issue are most welcome and accepted any time, not later than August 31, 1984.

WIS is open to all contributions regarding methods, materials and stocks, ideas and research results related to genetics, breeding and cytology of *Triticum, Aegilops, Seeale, Haynaldia* and related genera. Manuscripts should be typewritten (double-space) in English, and submitted withduplicates. One article should not exceed five printed pages, including two textfigures (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 price. Communications regarding editorial matters should be addressed to :

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Explanation of the Figure on the Cover

Culm showing plantlet development at culm nodes of unvernalized plant of *Ae. squarrosa* var. *meyeri*. See the text of article by KUSHNIR & HALLORAN for the details.

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