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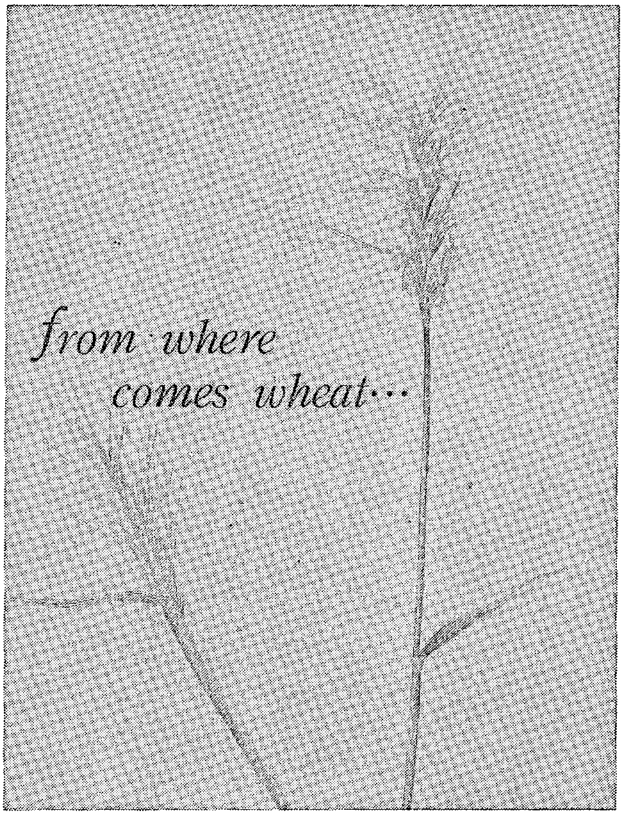

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Contents

I. Research Notes:

II. Editorial Remarks:

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I. Research Notes

Morphological characters and meiotic associations in a *T. durum* Desf. var. *hordeiforme* Körn. X *Ae. umbellulata* Zhuk. hybrid

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In order to transfer the genes of resistance to stripe rust (*Puccinia striiformis* West.) of *Ae. umbellulata* (2n=14) to *T. durum* var. *hordeiforme* (2n=28) an attempt was made to cross these two species. As far as we know the first attempt to cross wheat species to *Ae. umbellulata* was made by Sears (1956). However in that study *T. aestivum* was used as the female parent in the cross. In this study a variety of *T. durum* var. *hordeiforme* entries, susceptible to stripe rust, was crossed to resistant *Ae. umbellulata* entries in the spring of 1980, under field condition. 30 ears with 886 florets were pollinated with pollen of *Ae. umbellulata* and 99 seeds were obtained. Emasculating and crossing techniques were detailed in the previous study (Özgen 1983). Control of chromosome numbers under microscope at root tips has proven that these hybrids are tripolids (2n=21) (Fig. 1).

Fig. 1. Mitotic metaphase in a F_1 triploid hybrid between *T. durum* var. *hordeiforme* × *Ae. umbellulata* (× 880).

The 50 F_1 plants obtained from the hybrid seeds were intermediate regarding most of the morphological characters, although some characters of the parents were dominant. The ears of the hybrid plants looked more like wheat than *Ae. umbellulata* (Fig. 2). Some characteristics of the parents and hybrids are shown in Table 1.

Hybrid plants, as predicted by MAAN (1975), were pollen sterile with non dehiscent anthers. Only 121 seeds were obtained from 1546 ears with free pollination.

Meiotic behaviour of the F_1 hybrids was analysed at the first metaphase stage and chromosome pairing behaviour was observed (Table 2 and 3). This showed that the

Fig. 2. Spikes of *T. durum* var. *hordeiforme*, F_1 triploid hybrid and *Ae. umbellulata* (from left to right).

Table 1. Some characters of *T. durum* var. *hordeiforme* × *Ae. umbellulata* F_1 hybrids and their parents

	Rachis	Spike density[1]	Lower internodes with/without (angle, knee)	Auricle		Growth habit	Resistance to stripe rust
				color	hairness		
T. durum	Tough	26.13±0.47	Without	White	Glabrous	Erect	S[2]
Ae. umbellulata	Weak	19.10±0.73	With	Red	Hairy	Prostrate	R
F_1	Tough	18.96±0.28	With	Red	Hairy	Semierect	R

1) No. of spikelets/10 cm

2) S: Susceptible, R: Resistant

Table 2. The mean and range of meiotic configurations in the F_1 hybrids *T. durum* var. *hordeiforme* × *Ae. umbellulata*

I	II Rod	II Ring	II Total	III	IV	Number of cells
18.20 5-21	0.88 0-8	0.08 0-2	0.96 0-8	0.12 0-3	0.01 0-1	248

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

PMC's	0_{II}	1_{II}	2_{II}	3_{II}	4_{II}	5_{II}	6_{II}	7_{II}	8_{II}
%	63	15.5	7	5	2	3	2.5	1	1

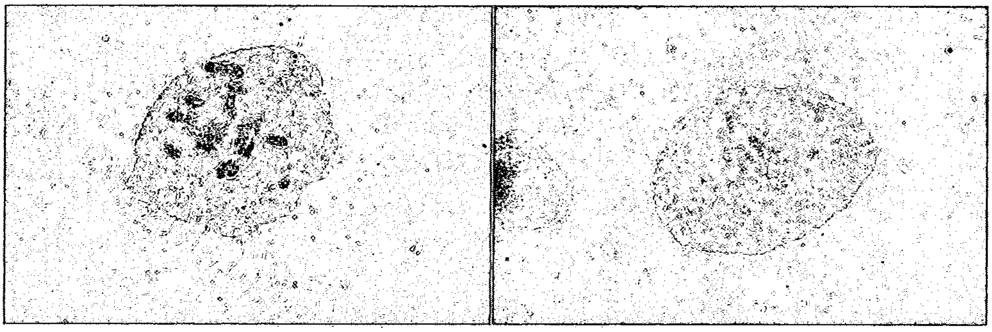

Fig. 3. Metaphase I chromosome associations in F_1 hybrids between *T. durum* var. *hordeiforme* × *Ae. umbellulata* Left: 9_I+6_{II}. Right: $6_I+3_{II}+3_{III}$ (×580).

number of bivalents varied between zero and eight and most of them were of the rod type, some of them looked like the ring type (Fig. 3).

As pointed out by DEWEY (1982), chromosome pairing shows the level of relationship between parents. In this study, chromosome pairing in F_1 hybrids of *T. durum* var. *hordeiforme*×*Ae. umbellulata* showed that it is difficult to transfer genes from *Ae. umbellulata* to *T. durum* var. *hordeiforme*.

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Evidence on the origin of the G genome in wheat: Physiological and quantitative character variation in a *Triticum timopheevi*-like mutant

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There has been uncertainty on the question of the origin of the G genome of wheat (LELLY 1976). Certain workers have proposed a separate origin of the G genome of *Triticum timopheevi* from that of the B genome of wheat (LILLIENFELD & KIHARA 1934; KOSTOFF 1936, 1937). Because of close cytological affinity between *T. timopheevi* and *T. araraticum* chromosomes (SVETOZAROVA 1939) it has been proposed that *T. timopheevi* arose from *T. araraticum* (SEARS 1948; JAKUBZINER 1958). SHANDS & KIMBER (1973) proposed that *Aegilops speltodies* contributed the G genome of *T. timopheevi* and not the B genome of *T. turgidum*. However, SACHS (1953), WAGENAAR (1961) and TANAKA & ICHIKAWA (1972), using evidence of pairing between *T. timopheevi* and *T. turgidum* chromosomes, and ANIOL (1973) using evidence from serological tests and GERLACH *et al.* (1978) using satellite DNA hybridization, proposed a common monophyletic origin of the B and G genome.

This view is in accord with the recent finding of a spontaneous *T. timopheevi*-like somatic mutat in *T. turgidum dicoccoides*, the chromosome pairing, karyomorphology and plant morphology of which has recently been described (KUSHNIR & HALLORAN 1983a, 1983b). The aim of the present study was to investigate changes to developmental physiology and certain quantitative characters of the mutant compared with its *T. turgidum dicoccoides* parent.

Materials and Methods

The *T. turgidum dicoccoides* line used in this study was part of a collection of this species made by one of us (U.K.) from wild habitats in Israel. Amongst 350 lines of this collection one plant of the variety *spontananeum nigrum* milhi (from Upper Galilee) developed four late tillers with *T. timopheevi*-like morphology, distinctly different from the other tillers on the *dicoccoides* mother plant. Seed from heads of the apparently mutated sector all gave *timopheevi*-like progeny, verifying the heritable nature of the somatic mutant.

Sowings were made of the *T. turgidum dicoccoides* mother plant, the *timopheevi*-like mutant and three different lines of *T. timopheevi*. The *timopheevi* representatives were obtained from the Australian Wheat Collection, Tamworth, N.S.W. Two of them, lines 1 and 2 were *T. timopheevi* var. *typicum* Zhuk. and line 3 was *T. timopheevi* var. *viticulosum*. To quantify the influence of vernalization on rate of development and spikelet number two sets of the above plant material were vernalized, one for 30 days and the other for 60 days.

Imbibed seed was vernalized in a cold room at 4°C under 8 hour photoperiod provided by low intensity (photo-inductive) incandescent light. Following this treatment eight vernalized and eight non-vernalized seedlings of each line were planted in two 18 cm diameter pots (four seedlings per pot) containing a potting mix (1 part washed sand: 1 part Perlite: 1 part Derrimut red brown loam by volume). The non-vernalized lines were grown under two photoperiod regimes – short day of 12 hours and long day of 24 hours; the vernalized material was grown under long photoperiod only.

All plants grew under temperatures of 20°C (day) and 15°C (dark). The number of days from sowing to floral initiation was determined by the non-destructive method of AITKEN (1976). Observations were made of final leaf number, days to anthesis and spikelet number on the main shoot of each plant. Plant height, tiller number, grain number per spikelet, grain number per head, seed fertility (per cent) and kernel weight were measured for the main shoot of the unvernalized plants grown under the short day regime.

Results and Discussion

The *timopheevi*-like mutant exhibited similar developmental responses (days to floral initiation, final leaf number and days to anthesis) under both long and short photoperiod as the three lines of *T. timopheevi*. While its photoperiod response was much stronger than the *T. turgidum dicoccoides* 'parent' its vernalization response was much lower than it and very similar to the *T. timopheevi* lines.

Since the *timopheevi*-like somatic mutant has been found to be a product of chromosome rearrangement (KUSHNIR & HALLORAN, a1983a, b), the changed photoperiod sensitivity and vernalization response of the mutant appear to be a consequence of this rearrangement and is a possible explanation for similarity of its developmental pattern with that of the *T. timopheevi* lines. WAGENAAR (1966) noted similarly that all the introductions of *T. timopheevi* he obtained from USSR were of spring habit. It is feasible that spring habit of *T. timopheevi* could have generally arisen from *T. turgidum dicoccoides* by way of macromutation. Such an occurrence could have provided *T. timopheevi* with better adaptation to different habitats north of the area of natural distribution of *T. turgidum dicoccoides* in the southern states of the Soviet Union. This change in ecological range could have caused it to become separated from the parental species. Alternatively, or in conjunction with changes in encological adaptation, the non-shattering character of such a *timopheevi*-like mutant could have attracted man's attention as being better adapted for domestication and cultivation than shattering tetraploid forms, leading to its propagation and wider geographical distribution.

While plant height of the *timopheevi*-like mutant was found to be greater than that of *T. turgidum dicoccoides* and similar to that of *T. timopheevi* lines, tillering was slightly higher than *T. turgidum dicoccoides* and higher than that of *T. timopheevi* (Table 2). A significant deviation of the somatic mutant was in spikelet number per head (Table 1) which

Table 1. Developmental responses of *Tritium turgidum dicoccoides*, *T. timopheevi*-like mutant and

Species or Mutant	Days to Floral Initiation				Final Leaf Number		
	Short photoperiod 12 h	Long photoperiod 24 h			Short photoperiod 12 h	Long photoperiod	
	No vernalization	No vernalization	30 days vernalization	60 days vernalization	No vernalization	No vernalization	30 days vernalization
T. turgidum dicoccoides	43	31	28	10	11.0±0.0*	9.6±0.3	8.6±0.4
T. timopheevi-like mutant	37	13	12	10	10.9±0.0	6.0±0.0	6.0±0.0
T. timopheevi 1	41	13	12	10	10.0±0.2	6.0±0.0	6.0±0.0
T. timopheevi 2	42	13	12	10	10.0±0.0	6.0±0.0	6.0±0.0
T. timopheevi 3	37	12	12	10	10.0±0.0	5.9±0.1	6.0±0.0

* All figures are means±standard error

Table 2. Morphology and fertility of *Triticum turgidum dicoccoides*,

Species or mutant	Plant Height (cm)	Tiller No./ Plant	Spikelet No. on Main Head	Head Density (Spikelet No. per 10 cm length of rachis)
T. turgidum dicoccoides	82.3±13.4*	9.0±1.0	13.5±0.5	15.5±0.5
T. timopheevi-like	115.8± 2.3	9.9±0.9	22.1±0.9	26.4±1.2
T. timopheevi 1	114.5± 3.0	6.6±0.7	22.6±0.8	25.1±0.5
T. timopheevi 2	119.3± 1.6	6.9±1.0	21.1±0.4	25.8±0.5
T. timopheevi 3	111.4± 3.7	7.0±0.5	23.4±0.5	28.6±1.0

* All figures are means±standard error

increased from a mean value of 13.50 in the *dicoccoides* mother plant to a mean of 22.12 in the mutant with a significant increase in head density from 15.50 to 26.38 spikelets (per 10 cm length of rachis) respectively. In both characters the *timopheevi*-like mutant exhibited close similarity to the lines of *T. timopheevi*. Despite decreased grain number per spikelet and percentage fertility in the *timopheevi*-like mutant head compared with the *dicoccoides* mother plant it exhibited increased grain number per head which could probably enhance its survival and spread in natural environments. The reasonably high fertility, high grain number per head and genetic stability, i.e. homozygous nature (KUSHNIR & HALLORAN 1983a, 1983b) of the mutant appears to have provided it with a high potential for immediate fitness in natural environments. The close similarity in growth habit between the *timopheevi*-like mutant and the lines of *T. timopheevi* indicates that the potential for ecological adaptation is provided by the macromutation in addition to the chromosome and plant morphology modifications that occurred in the *timopheevi*-like somatic mutant. A three lines of *Triticum timopheevi* grown under short (12 hours) and long (24 hours) photoperiod.

	Days to Anthesis				Spikelet Number			
24 h	Short photoperiod 12 h	Long photoperiod 24 h			Short photoperiod 12 h	Long photoperiod 24 h		
60 days vernalization	No vernalization	No vernalization	30 days vernalization	60 days vernalization	No vernalization	No vernalization	30 days vernalization	60 days vernalization
6.4±0.2	94.2±2.0	72.0±0.7	62.6±1.0	49.1±0.3	13.5±0.5	11.1±0.4	9.4±0.3	7.0±0.0
6.3±0.2	97.0±1.4	50.4±0.3	49.0±0.5	47.8±0.7	22.1±0.9	8.6±1.0	10.0±0.3	9.0±0.4
6.0±0.0	100.7±1.4	50.5±0.7	49.6±0.3	48.2±0.7	22.6±0.8	8.3±0.4	10.3±0.2	10.3±0.2
6.0±0.0	98.0±1.0	49.6±0.4	51.3±0.6	49.0±0.4	21.1±0.4	7.8±0.2	9.6±0.2	9.9±0.3
6.1±0.1	97.4±1.0	46.9±0.4	48.4±0.3	47.5±0.3	23.4±0.5	8.5±0.3	9.9±0.3	10.9±0.2

T. timopheevi-like mutant and three lines of*Triticum timopheevi.*

Grain No./ Spikelet	Grain No./ Head	Fertility %	Grain Wt./ Head (g)	Kernel Weight (mg)
1.5±0.1	21.0±2.0	74.8±5.1	1.0±0.1	47.8±1.4
1.3±0.1	23.9±2.4	61.2±5.5	1.2±0.1	40.9±1.9
1.5±0.1	34.4±1.5	76.5±2.9	1.5±0.1	45.3±3.6
1.6±0.0	33.3±1.4	79.1±2.4	1.0±0.1	29.6±2.1
1.5±0.1	34.9±1.4	74.4±2.6	0.8±0.1	23.4±2.0

similar type of macromutation (the *erectoides* mutation) with a wide range of drastic modifications was described in Golden barley and, similar to the *timopheevi*-like mutant, caused changes in plant morphology, karyo-morphology and cross-sterility and ecological adaptation were reported (GUSTAFFSON 1954; VON WETTSTEIN 1954).

The origin of *T. timopheevi* from *T. turgidum dicoccoides* from chromosome interchange was suggested by WAGENAAR (1966) and his view is supported by the physiological evidence in this study. The similarities in morphology and growth habit between the *timopheevi*-like mutant and the lines of *T. timopheevi* investigated in the present study, and the uniformity of these characters found in all the introductions of *T. timopheevi* from USSR studied by WAGENAAR (1966) indicate the possibility for some "pre-tendency" for the occurrence of a particular pattern of rearrangement of the *dicoccoides* chromosome complement giving rise to a phenotype similar to *T. timopheevi*. Such a "pre-disposition" might account for the lack of intermediate forms between *T. timopheevi* and *T. turgidum dicoccoides* and the possibility of repetitive evolution of the *timopheevi* form of wheat from a *turgdium* prototype. It is also possible that alternative chromosome rearrangements, if they were to occur, might not be viable and thus eliminated.

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Hybrid necrosis in wheat

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Hybrid necrosis is the pre-mature gradual death of leaves and leaf sheaths in certain wheat hybrids. Some of the Indian wheat varieties like C 306, C 286, C 273 and NP 890 have been reported to give complete or partial necrosis with the genes present in Maxican germplasm (NARULA *et al.* 1966; ANAND *et al.* 1969; GILL *et al.* 1969, 1972; CHOWDHURY, 1982). HERMSEN (1963) opined that two complimentary genes Ne_1 and Ne_2 when brought togather either in homo- or hetero-zygous condition could lead to hybrid necrosis, the degree of necrosis in F_1 plants varying considerably due to multiple alleles (s, m and w) of Ne_1 and Ne_2. Therefore, he distinguished 9 grades of necrosis viz.:

0–3: Weak necrosis (normal seeds)
3–6: Moderate necrosis (pre-mature seeds)
6–9: Severe (No seed)

Indian varieties as mentioned above, have been referred to be as the probable source of Ne_1 gene while Maxican varieties are supposed to have Ne_2 gene. This has been the major barrier encountered by the plant breeders in bringing togather desirable genes of some of the desirable cutlivars. For instance variety C 306, having good quality grains and drought resistance may not be included in many combinations when the other variety in combination carries Ne_2 gene.

During the year 1980–81, with a view to transfer drought/rust resistance into high yielding genotypes, a crossing programme was initiated at this centre in which four high yielding genotypes namely; P48–B, WH 157, P 1206 and Raj 1482, were crossed with a number of varieties having drought/rust resistance in a 'line × tester' design. P 1206 strain has very long ears with more number of spikelets per ear while WH 157 and Raj 1482 are approved high yielding varieties for timely sown, high fertility irrigated conditions. Strain P48–B is a double dwarf with high yield potential. All the F_1 hybrids were grown in the field during the year 1981–92. Among these hybrids, seedlings of nine hybrids started yellowing at 2–3 leaves stage and finally died at 4–6 leaves stage without producing any ear showing the characteristic symptoms of severe necrosis of grade 7 as described by HERMSEN (1963). The whole material was sown under six different irrigation levels to see the impact of management, if any, to improve the growth of seedlings. The average mean for different traits under different irrigation levels have been given in Table 1. It is obvious

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Table 1. Mean values of various F_1 hybrids for different

Cross	Plant height (cm)						Tillers/seedling					
	1	2	3	4	5	6	1	2	3	4	5	6
1. C306×P48B	24.3	11.3	11.7	13.7	11.3	13.8	3.5	5.6	2.6	3.0	2.3	3.4
2. C306×P1206	19.4	17.6	15.2	13.0	15.3	13.8	2.4	3.9	3.2	3.0	3.0	2.5
3. C306×Raj 1482	18.5	12.5	10.1	11.0	11.2	11.0	3.5	3.2	3.7	3.8	3.4	4.6
4. C281×P48B	29.0	19.0	9.7	5.0	15.0	16.0	4.5	3.5	4.5	1.0	2.6	5.0
5. C281×P1206	30.0	26.4	9.7	13.0	12.5	15.2	2.5	3.0	1.5	3.4	1.5	2.0
6. NP401×P48B	23.3	—	—	—	—	18.4	4.9	—	—	—	—	6.8
7. NP401×P1206	19.3	—	—	—	—	13.3	2.8	—	—	—	—	4.0
8. NP401×Raj 1482	17.3	—	—	—	—	13.0	4.5	—	—	—	—	3.9
9. Narbada 4×P48B	-	—	—	—	—	20.4	—	—	—	—	—	3.0
10. Narbada 4×Raj 1482	28.7	—	—	—	—	17.5	1.6	—	—	—	—	3.5

Table 2. List of carrier/non-carrier of necrotic genes

Ne_1 carrier	Ne_2 carrier	Non-carrier of Ne_1		Non-carrier of Ne_2
C 306	P48-B	Kalyansona	HG 137	WH 157
NP 401	P1206	KT/Bg-FN/4×BZa	K 7229	
C 281	Raj 1482	Kiran	HG 144	
Narbada-4	WH 147	P118-1	HI 738	
	HD 2009	DL 39-1	CPO 633×(FAO 11-475)	
	K 227	Girja	HD 2009	
		Raj 1762	Hindi 62	
		WC 457	Raj 939	
		HS 90	Kharchia 65	
		UPK-1	E 8682	
		HD 2204	HG 117	
		Bb(4A) R	WH 147	
		Catz 5270	D 65	
		HG 129	IWP 503	
		Kenya Plume	IWP 500	
		CPAN 1378		

from this table that all the hybrid plants died between 4–6 leaves stage. There was no obvious effect of irrigation levels on number of leaves. Similar was the case for tiller number per seedling. This shows that the death of the hybrid plants was genetically determined at this stage of plant growth. On the other hand, the plant height and joints per tiller were maximum under rainfed condition and minimum in fully irrigated conditions. Though there was no marked difference under various irrigation levels on these traits, however, there was reduction towards higher number of irrigations.

It is well established that varieties C 306 and NP 401 carry strong allele(s) of Ne_1 gene (Gill *et al.* 1969; Anand *et al.* 1969; Chowdhury 1982), therefore, rest of the varieties involved in hybrid combinations namely P48–B, P1206 and Raj 1482 are supposed to be the carrier of strong allele(s) of Ne_2 gene, thereby giving severe hybrid necrosis.

There were some more crosses in our hybridization programme, where also we morphological traits under different irrigation levels.

No. of leaves/main tiller						No. of joints/main tiller					
1	2	3	4	5	6	1	2	3	4	5	6
5.1	5.6	3.6	4.6	4.7	4.9	2.3	1.7	1.5	2.0	1.0	1.0
4.7	4.9	4.9	5.0	4.9	5.0	2.9	1.9	1.8	1.8	1.3	1.0
4.7	4.4	4.4	5.0	4.9	4.7	2.6	1.5	1.5	1.5	1.0	0.7
5.5	4.5	5.0	5.0	5.0	5.0	2.8	1.7	4.3	1.0	1.6	1.0
6.0	5.4	4.0	4.8	5.0	5.2	3.0	2.0	4.0	1.4	5.0	1.3
4.8	—	—	—	—	5.3	3.2	—	—	—	—	1.5
4.6	—	—	—	—	5.0	2.4	—	—	—	—	1.2
5.2	—	—	—	—	5.0	2.5	—	—	—	—	1.2
—	—	—	—	—	5.4	—	—	—	—	—	1.6
4.6	—	—	—	—	5.2	4.3	—	—	—	—	1.7

observed necrotic hybrid plants. Variety C 281 reported to be the carrier of Ne_1 gene (ANAND *et al.* 1969) produced some necrotic hybrid plants and some normal plants when crossed with P48–B, P1206, HD 2009 and K 227 while with Raj 1482, a Ne_2 carrier, all the hybrid plants were normal. Similarly, Narbada-4 variety when crossed with P48–B and Raj 1482, the Ne_2 carriers, produced some necrotic and some normal plants while with P1206, also a Ne_2 carrier, no necrotic hybrid plant was produced. So the varieties C 281 and Narbada–4 posses both Ne_1 and ne_1 genes in their genotypes and thus are not homogeneous for Ne_1. Some of the plants of these varieties carry Ne_1 and others are non-carrier. Similar results were reproted by ANAND *et al.* (1969).

The varieties, which are supposed to be the carrier of Ne_2 gene had Mexican germ plasm and other varieties, the carrier of Ne_1 gene were of Indian origin. Thus, these findings support the view of ZEVEN (1966) on geographical distribution of Ne_1 and Ne_2 genes. Based on these observations, varieties possessing/not possessing Ne_1 and Ne_2 genes have been listed in Table 2. These informations will be of importance to the wheat breeders/geneticists in their hybridization programmes.

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Hybrid necrosis in hexaploid triticale

by

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Hybrid necrosis is a physiological disorder which leads to morphological abnormalities or seedling lethality, depending upon the strength and expressivity of necrotic genes in the parents. The effects of necrotic genes and their alleles present in *Triticum aestivum.*, L., have been well documented (HERMSEN 1963; GILL *et al.* 1972; ZEVEN 1975) but little is known about distribution of these genes in durum wheat and triticale. Survey of durum selections at CIMMYT (Mexico) indicated the presence of Ne_1 allele in twenty strains. This allele was found in some triticale lines also. Present study deals with six inter-varietal combinations where one or the other abnormality was recorded.

Materials and Methods

Six F_1's along with their parents were evaluated for germination and seedling growth *in vitro*. Visual observations for plant growth were also recorded in field conditions. One year old seeds stored at room temperature were soaked in 10 ppm solution of Gibberellic acid (GA_3) for four hours and placed in petri plates lined with filter paper soaked in 10 ppm GA_3 solution. These plates were then kept in incubator at 25°C.

In the second set cold treatment was given. Seeds were soaked in distilled water for four hours and then placed in petri plates lined with wet filter paper for 48 hours at 4°C. These petri plates were then transferred to the incubator in which the temperature was 25°C.

The third set was kept as control *ie* soaking of seeds in distilled water for four hours then transferring petri plates to incubator (25°C). Germination was recorded at 3rd and 7th days after sowing.

Results and Discussion

Experimental results revealed that in control set (table 1) most of the parents showed fairly high germination on 3rd day and slight increase in germination was recorded on 7th day, whereas hybrids invariably recorded no germination or very poor germination with reduced seedling vigour.

To test whether non-germination of F_1 seeds was due to dormancy or hybrid necrosis, gibberellic acid and cold treatments were tried as they are known to break dormancy

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Table 1. Seed germination and plant vigour of parents and F_1 hybrids.

S.N.	Genotypes	Germination (%)						Seedling/Plant Vigour
		Control		Cold Treatment		GA_3 Treatment		
		3rd Day	7th Day	3rd Day	7th Day	3rd Day	7th Day	
	Parents							
1.	T1	60	85	50	80	—	—	Normal Seedling Growth (16–22 cm)
2.	6TA204	50	85	65	100	—	—	No Seedling Lethality
3.	Koala 'S'	65	80	50	90	—	—	Vigrous Plant Growth With Various Floret
4.	TH2 'S'	50	60	65	95	—	—	Fertility Levels
5.	D.S.	45	70	55	80	—	—	
	Crosses							
6.	Koala 'S'×6TA204	0	0	0	5	5	15	Very Poor SeedlingGrowth (0–10 cm)
7.	D.S.×T1	0	0	0	0	10	25	No Plant Growth
8.	T1×6TA204	0	15	15	25	25	35	Seedling Lethality
9.	DS.×6TA204	0	10	15	35	20	40	Satisfactory Seedling Growth (10–15 cm)
10.	Koala 'S'×T1	0	15	10	25	20	45	Relatively Stunted Plant Growth with Leaf
11.	TH2 'S'×6TA204	5	20	0	20	30	30	Tip Burning

(Naylor & Simpson 1961). Since the germination of parental genotypes was satisfactory, gibberellic acid treatment was only applied to F_1 seeds.

In control set, two F_1's: Koala 'S' × 6TA204 and DS × T1 showed either no or very poor germination on 3rd and 7th day respectively. However, F_1 seeds of these crosses initiated germination in GA_3 but the growth of radicle and plumule was checked at very initial stages. This eliminates the possibility of seeds being dormant. The failure of proper seed germination may be attributed to some kind of hybrid necrosis leading to loss of seed vitality or seedling vigour.

In the rest of the four combinations, though the germination of seeds was poor, yet few seeds could give rise to seedlings of satisfactory length (10–15 cm). However, in field conditions the germination was relatively poor and in one case, T1 × 6TA204 seedling lethality was observed in few plants. In the other three combinations; DS × 6TA204, Koala 'S' × T1 and TH2 'S' × 6TA204 plants manifested poor growth with more leaf tip burning as compared to their parents. Such effects may be attributed either to the presence of weak necrotic genes or the presence of modifiers in parents or better buffering in storage conditions.

Hybrid necrosis in triticale is likely to occur if triticale strains carrying Ne_1 are crossed with triticale lines derived from crosses involving wheat genotypes carrying Ne_2. Since the exact pedigree of lines we have been using is not known, sources of Ne_1 and Ne_2 could not be traced. Effect of storage duration and conditions might also have affected parents and F_1's differentially. However, present study points to an interesting situation that these abnormalities were recorded in only six out of one hundred cross combinations and as such presence of hybrid necrosis may be speculated. It is therefore suggested that triticale lines should be screened for the presence of necrotic genes and their alleles so as to avoid or minimize chances of failure to obtain progenies of simple or complex crosses for genetic analysis or further improvement work.

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Efficacy of single crosses versus three-way hybrids in tetraploid *Triticum* species

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Improvement of yield in wheat through conventional breeding methods has reached a level at which phenomenal increase seems to be rather difficult (Singh & Singh 1971). One of the important breeding approach for bringing about further genetic upgrading in any crop plants is through the utilization of useful genetic resources from allied species (Hawkes 1977). Tetraploid *Triticum* (emmer) group includes species and subspecies known for some important agronomic features, that help in building up various yield components and ultimately the yield. This sort of component breeding approach has also been suggsted by Williams (1959, 1960), Grafius (1959) and Moll *et al.* (1962). In case of interspecific hybridization, once the desirable genes from allied species are incorporated, it is necessary to recover the proper agronomic base. This is achieved through three-way cross involving third parent as well adapted one. Such an approach has potential advantages over single crosses by way of creating a genetically heterogeneous population. This heterogeneity may give an opportunity for transgressive segregation,better recombinants and some degree of populational buffering (Walsh & Atkins 1973). The present study deals with the magnitude of heterosis in single and three-way cross hybrids and also assesses the extent of improvement of three-way hybrids over single cross. Heterosis studies involving emmer species is very limited.

Materials and methods

A line x tester design involving five tetraploid *Triticum* species and four *durum* cultivars were used as parents to get 20 F_1 hybrids. Part of the seeds from all 20 single crosses were grown at Wheat Breeding Regional Research Station, Wellington (Nilgiris) during summer for attempting three-way crosses with an adapted variety JNK–4w–184 as a pollinator. The five tetraploid *Triticum* species viz., *T. dicoccum* var. NP. 202 (A), *T. polonicum* var. Polish (B), *T. carthlicum*–39584 (C), *T. turgidum*–45(D) and *T. pyramidale* var. Sendioni (E) were selected on the basis of their diversity of origin and widely different yield components. Similarly five *durum* types namely, A_{206}(F), Raj_{911}(G), NP_{404}(H), Sel.

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Table 1. Expression of per cent heterosis in the

Single cross	Flag leaf area		Ear Weight	
	MP	BP	MP	BP
(AF)	− 2. 21	− 2. 41	30. 53*	18. 52
(AG)	28. 72**	8. 20*	24. 54**	1. 68
(AH)	7. 29	−10. 49**	15. 57	8. 42
(AI)	19. 88**	16. 49**	26. 90*	15. 74
(BF)	14. 17**	− 9. 98**	19. 75	− 5. 07
(BG)	12. 33	3. 93	−18. 80	−23. 59**
(BH)	17. 45**	9. 61**	−20. 18*	−27. 41**
(BI)	17. 19**	− 5. 42	24. 95*	− 0. 58
(CF)	29. 23**	12. 91*	12. 57	− 5. 39
(CG)	42. 04**	7. 04	23. 79*	−16. 34*
(CH)	11. 32*	−16. 64**	− 0. 82	−26. 27*
(CI)	34. 01	14. 06*	71. 98**	43. 96**
(DF)	8. 05	− 2. 40	16. 86	5. 61
(DG)	21. 59**	11. 94**	4. 47	−14. 36
(DH)	11. 88**	2. 13	−23. 08*	−27. 48**
(DI)	36. 44**	26. 78**	−30. 98	−37. 34*
(EF)	18. 62**	7. 42	− 2. 65	−15. 32
(EG)	2. 98	− 5. 44	−22. 17*	−33. 92**
(EH)	9. 90**	0. 05	−53. 99**	−54. 77**
(EI)	19. 09**	10. 95*	−52. 07**	−58. 13**

* and **; significant at 5% and 1% level respectively.

Table 2. Expression of percent heterosis in the

3-way hybrid	Flag leaf area		Ear weight	
	MP	BP	MP	BP
(AF) J	39. 93**	27. 12**	38. 16**	23. 17**
(AG) J	7. 44	−19. 30**	23. 83**	−2. 37**
(AH) J	15. 00**	− 8. 24*	40. 38**	23. 03
(AI) J	20. 84**	− 0. 57	45. 67**	31. 23**
(BF) J	8. 78*	−17. 69**	42. 90**	21. 52**
(BG) J	18. 31**	−14. 56**	35. 06**	19. 54**
(BH) J	−10. 94**	−36. 71**	48. 03**	41. 92**
(BI) J	0. 05	−24. 35**	37. 24**	14. 54*
(CF) J	27. 79**	9. 20*	57. 96**	44. 40**
(CG) J	15. 40**	−13. 01**	33. 64**	13. 65*
(CH) J	34. 81**	10. 53**	55. 69**	48. 13**
(CI) J	60. 19**	32. 92**	49. 51**	33. 33**
(DF) J	20. 95**	0. 49	40. 77**	31. 59**
(DG) J	− 2. 40	−27. 52**	37. 38**	15. 90**
(DH) J	14. 69**	−12. 71**	47. 43**	39. 18**
(DI) J	4. 44	−21. 18**	65. 33**	39. 80**
(EF) J	31. 21**	3. 94	49. 25**	48. 70**
(EG) J	15. 21**	− 9. 30**	41. 55**	33. 55**
(EH) J	2. 81	−21. 21**	100. 48**	55. 50**
(EI) J	8. 79	−13. 76**	18. 54**	67. 16**

* and **; significant at 5% and 1% level respectively.

single cross for five characters in *durum* wheat.

Grains/ear		1000-grain weight		Grain yield/plant	
MP	BP	MP	BP	MP	BP
−4.41	−11.59	8.23*	−8.39	60.67	48.08
12.20*	−6.46	11.47**	15.63**	115.58**	79.40**
−3.45	−8.87	8.57**	16.17**	93.27**	62.98**
−0.32	−11.52	19.53**	22.63**	98.49**	85.62**
17.30**	15.76**	5.57	−10.92*	48.52	44.40
4.05	−6.05	−14.56**	−18.87**	6.48	−17.18
−25.06**	−33.70**	4.01	−11.68**	19.76	−3.40
−5.89	22.74**	7.50*	2.98	104.30**	101.72**
−36.86**	−44.72**	68.37**	44.33**	14.84**	−19.21
−8.17	14.03**	26.71**	2.03	51.21**	17.41
−28.28**	−30.05**	18.13**	−16.56**	−1.55	−39.17
−18.94*	−23.90**	47.12**	13.08**	127.35*	58.51
−36.11**	−38.57**	38.36**	32.59**	33.59	15.48
−10.93*	−17.61**	44.52**	32.55**	44.74	3.33
−29.33**	−38.89**	22.99**	0.26	−11.97	−37.34
−91.07**	−92.82**	21.41**	10.42*	−38.93	−47.90
−22.12**	−22.39**	6.32	−5.98	−13.04	−16.07
−9.17	−20.09**	−7.75*	−7.98	−24.03	−39.13
−65.66**	−68.81**	1.13	−11.42**	−23.42	−37.87
−89.37**	−91.07**	20.00**	18.60**	63.81	−69.44

three-way cross for five characters in *durum* wheat.

Grains/ear		1000-grain weight		Grain yield/plant	
MP	BP	MP	BP	MP	BP
8.24*	−5.89	8.66**	8.25**	23.16*	5.01*
1.56	1.35	26.83**	21.37**	13.81*	36.31*
4.67	−13.03*	24.03**	18.93**	−11.49	−30.83**
16.60*	−5.06	19.87**	10.18**	24.67*	14.01*
4.00	3.65	10.63**	9.11**	17.56*	4.63*
−1.07	−1.09	13.59**	7.11**	−14.68	−16.59
13.11	−11.26*	4.94	−1.83	−4.23	−9.67
19.30*	−0.81	7.44**	1.49	−12.62	−23.97
−14.44**	−17.69**	4.32	0.30	14.12	−13.88
7.71	3.15	−24.72**	10.03**	−21.43	−31.02**
15.56	−15.55**	12.63**	8.24**	12.82	−6.22
35.40**	0.03	−2.56	−8.19**	9.07*	7.35*
2.80	−20.01**	17.73**	13.06**	10.04	−4.88
1.06	−5.15	−1.04	−12.30**	−8.34	14.80
11.93	−13.05*	8.38	−4.24*	20.81	1.66
32.46*	−29.46**	12.03**	8.66**	14.34*	23.44*
7.03	−12.22*	7.23*	2.85	1.95	−20.00
1.43	−6.15	19.83**	14.04**	12.98	−4.78
52.02**	−4.82	7.49**	0.43	18.49*	15.18*
87.92**	0.73	4.55	−3.65	40.35	−0.01

389 (I) and JNK–4w–184 (J) are under cultivation in different zones of India. The alphabets in parenthesis will be used while referring the cross combinations.

The experiment consisted of 10 parents, 20 each of single cross (SC) and three-way cross (TWC) populations. The layout was randomised block design with three replications. Out of 120 rows in each replicate, 4 rows were sown to each parent, 2 rows to each SC and TWC. The sowing was done by dibbling the seed at a distance of 30 cm rows in 3 meter long, spaced 15 cm apart. Ten random plants were selected and following observations were recorded viz.; ear weight, 1000-grain weight, grains per ear, flag leaf size and grain yield per plant.

Analysis of variance was done on the data for each of the five characters. Heterosis was determined as percentage increase or decrease in SC and TWC hybrids over their corresponding mid parent and better parent. The heterosis in three-way hybrids was computed like F_1, but the mean of mid parent (MP) in this case of $\bar{F}+\bar{P}_3/2$ (where, $\bar{P}_3$= mean of third parent involved in the cross). The 't' tests were done to determine whether the F_1 and three-way cross hybrid value differed significantly from the value of mid or better parent.

Results and Discussion

The precentage heterotic values over mid parent (MP) as well as better parent (BP) in single cross and three-way cross hybrids are presented in Table 1 and 2 respectively.

In general, it appears that good number of three-way hybrids exhibited significantly positive heterosis for yield and it's few important components over mid and better parents. This is quite expected because the parents involved in all the single crosses were unadapted types. However, the use of a well adapted parent in 3-way cross, helped in recovery of desiriable agronomic characters like ear weight, 1000–grain weight and grains per ear. Similarly in case of yield per plant, of the 20 crosses, 4 crosses in F_1 and 7 crosses in three-way hybrids exhibited significant heterosis over better parent. On the contrary, for flag leaf area, the number of crosses indicated significant heterosis over better parent were more in single crosses than three-way cross hybrids (8 in SC and 4 in TWC).

An ideal three-way hybrid combination would be one which show an increased heterosis over single cross. Many such combinations were identified and listed in Table 3. It is interesting to note that significantly positive heterosis was observed in a number of three-way hybrids although in many of the corresponding single crosses the heterosis was non-significant or negative. For grains per ear, 7 hybrids which were showing low heterosis in F_1 indicated high heterosis in TWC. Of these crosses, *T. pyramidale* × Sel. 389 was showing significantly negative heterosis over both mid and better parents, exhibited the highest heterosis (87.92%) in TWC. In case of 1000-grain weight ten F_1 crosses involving *T. dicoccum*, *T. polonicum* and *T. pyramidale* showed non-significant heterosis. The threeway crosses between these F_1 with JNK–4w–184 indicated significant heterosis. Similarly non-significant heterosis was observed over mid parent for the ear weight in a number of F_1 hybrids (14 out of 20 crosses) between five species (A, B, C, D and E) and four *durum* cultivars

Table 3. Comparative heterosis of single cross versus (SC) three-way cross (TWC) hybrids in tetraploid wheat.

Single cross	Characters	3-way cross
AF	(1), 2, 3, (4), (5)	(AF) J
AG	1, 2, (3), 5	(AG) J
AH	(2), (3), (4)	(AH) J
AI	(1), 2, (3), 4, 5	(AI) J
BF	1, (2), (3), 4, (5)	(BF) J
BG	(2), (3), (4)	(BG) J
BH	(2)	(BH) J
BI	(1), (3)	(BI) J
CF	(2), 4	(CF) J
CG	2, 4	(CG) J
CH	(2), 3, (4)	(CH) J
CI	(1), 2, 4, (5)	(CI) J
DF	(2), 3, (4)	(DF) J
DG	(2)	(DG) J
DH	(2), 3, 4	(DH) J
DI	(1), (2), 3, (5)	(DI) J
EF	(2), (3), 4	(EF) J
EG	(2), (3), (4)	(EG) J
EH	(1), (2), (3), (5)	(EH) J
EI	(2), (3)	(EI) J

Note: Numbers within brackets are in combination with L → H.

Numbers without brackets are in combination with H → H.

Where, H=Significant and positive heterosis over mid or better parent.

L=Non-signifieant or negative heterosis over mid or better parent.

1=grains/ear; 2=ear weight; 3=1000-grain weight; 4=flag leaf area; 5=grain yield per plant.

(E, F, G and H). But in combination with third parent (I) heterosis was significant over mid parent (all the 20 three-way crosses) and better parent (18 out of 20 crosses). As regards to flag leaf area, the SC cross *T. dicoccum* × A_{206} showed negative heterosis over both the parents, while the same cross in three-way combination recorded the significant and positive heterosis. Considering grain yield per plant, three crosses namely, *T. turgidum*-45 × Sel. 389, *T. pyramidale* × NP_{404} and *T. dicoccum* × A_{206} did not show significant heterosis but these crosses with JNK-4w-184 recorded the significant and positive heterosis over both the parents.

Besides, this study has also shown that there were some crosses showed significantly positive heterosis over both parents in single crosses as well as three-way hybrids simultaneously for all the characters studied (Table. 3).

Emphasising all the characters at a time, it appeared that six three-way hybrids viz., (*T. dicoccum* × A_{206}) JNK-4w-184; (*T. dicoccum* × NP_{404}) JNK-4w-184; (*T. dicoccum* × Sel.

389) JNK-4w 184; (*T. polonicum* × A_{206}) JNK-4w-184; (*T. tugidum*-45 × Sel. 389) JNK-4w-184; (*T. pyramidale* × Sel. 389) JNK-4w-184, would be studied further for exploiting better recombinants by virtue of their favourable response for important yield components as well as yield.

It will be of considerable interest to know the causes of heterosis in grain yield. There can not be any gene system for yield *per se* and the yield is an end product of the multiplicative interaction between the yield components (WHITEHOUSE *et al.* 1958; GRAFIUS 1959). Hence it would indicate that the heterosis for yield should be through heterosis for yield components (SINGH & KANDOLA 1969). Accordingly, a clear picture has emerged from this study that heterosis is present in all the four/three components viz., grains/ear, ear weight, 1000-grain weight and flag leaf area. Thus, it is obvious that increase in grain yield in three-way crosses (as indicated earlier) are the result of increase in yield components.

Thus, use of JNK-4w-184 with number of single crosses involving unadapted species and adapted *durum* cultivars appeared to have increased the potentiality of expression of some of the important yield components and ultimately the yield. Such a three-way combination of genotypes followed by judicious selection would help in introgressing the useful and diverse sources along with the proper agronomic base.

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A note on effect of gamma irradiation in wheat

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The induced mutations have been used in various crop plants to improve various characteristics. MIKE (1975) has given a list of crop cultivars evolved through induced mutagenesis. GAUL (1964) described plant breeding as the controlled evolution. By mutations, plants can be genetically improved. However, future importance of mutation breeding depends on whether it succeeds in securing better control of the whole complicated process of "Obtaining mutants" starting with mutation induction to selection.

Generally, all type of mutagens reduce seed germination and increase seeding lethality (CAMPOS *et al.* 1960 and other). It has been attributed to be the killing effect of the mutagen. In some crop plants increase in germination has also been reported at lower doses (FUJII & MATSUMURA 1966 and others).

In the present study, dry seeds of six well adapted varieties having 12 percent moisture were exposed to different doses of gamma irradiation as elsewhere reported by CHOWDHURY (1982) to see the effect of gamma irradiation on germination and survival and also to isolate desirable mutants in the succeeding generations. Percent germination and survival were calculated for each variety/dose taking control as 100 percent.

The relative increase/decrease in seed garmination and survival percentages in each dose/variety have been given in Table 1 and plotted in Figure 1. It is clear from this table that the germination was reduced in all the doses compared to their control. The germination was, however, increased in 10 KR dose of WH 147 and Sonalika to 6.3 and 2.7 per cent respectively. There was a symmetric reduction in germination in all the varieties towards higher doses of gamma rays (Fig. 1). Meximum reduction was observed in HD

Table 1. Germination and survival percentage for different varieties/doses.

Genotype	Germination in control (%)	Percent Germination increased/ decreased over control				Survival percentage				
		10 KR	20 KR	30 KR	40 KR	Control	10 KR	20 KR	30 KR	40 KR
1. C 306	94.0	−3.2	−14.5	−40.4	−81.2	95.7	96.4	87.9	81.2	76.3
2. Sonalika	96.0	2.1	−18.1	−51.4	−70.5	92.4	90.7	80.0	52.7	51.0
3. WH 147	88.7	6.3	− 3.4	−38.8	−67.0	100.0	81.8	72.7	53.8	49.6
4. WH 157	97.3	−3.4	−26.7	−57.5	−74.0	99,4	97.7	95.5	89.5	85.0
5. Kalyansona	96.0	−2.7	−12.8	−34.4	−65.3	97.6	96.8	95.6	91.8	81.6
6. HD 2009	92.7	−1.8	−10.1	−58.6	−84.9	95.0	94.8	95.7	72.8	51.9

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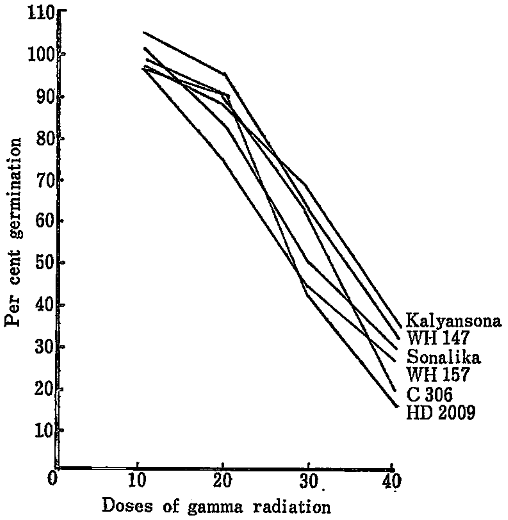

Fig. 1. Per cent germination of different wheat varieties in various doses taking control as 100 per cent.

2009 followed by C 306 and WH 157. Variety WH 147 was least effected. It was interesting to note that the maximum increase in seed germination at 10 KR level was noticed in variety WH 147 where the seed germination in control was lowest (88.7 per cent) compared to other varieties. This shows that the lower doses of gamma rays may increase seed germination particularly in those genotypes where seed germination is low. However, in other genotypes, gamma irradiation may have deterimental effect on germination even at lower doses. The different genotypes showed different response towards gamma irradiation. The dose effects were highly significant. Also, the dose x genotype interaction was significant.

The differences in survival percentage between varieties and doses were highly significant. There was no significant difference between varieties C 306, WH 157 and Kalyansona and also between Sonalika and WH 147 as far the survival is concerned. The survival percentage has been associated with mutation frequency by several workers. According to one group of workers, the mutation frequency does not follow the linear increase with radiation dose. With medium or higher doses either a saturation effect or a decrease of mutation rates was observed. In contrast, GAUL (1963) demonstrated that the increase is linear with dose. In some cases, he even found exponential increase of mutation rates upto the highest killing rate namely 99 per cent of the treated seeds. This is in contrast of other scientist who proposed the use of a dose which results in 50 per cent survival.

This material has also produced desirable type of mutants which are being screened for various traits regarding their purity and desirability.

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Indentification of the chromosomal translocations in wheat

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Common wheat varieties are often differentiated by one or more chromosomal translocations. A number of chromosomal interchanges has been observed between many hexaploid wheat varieties by various workers (Baker & McIntosh 1966; Riley *et. al.* 1967; Mettin & Klein, 1973; Baier *et. al.* 1974; Bannier 1978; Vega & Lacadena 1982). Some of these interchanges have been located on specific chromosomes by means of crosses to complete series of 21 monosomic lines of the hexaploid wheat variety Chinese Spring.

This paper presents analysis of meiosis in F_1 hybrids derived from crosses between the spring wheat variety Norröna and mutant T-13, on one hand, and the monosomic lines of variety Chinese Spring, on the other hand.

Materials and Methods

Mutant T-13 of the spring wheat variety Norröna was induced by treatment of N-methyl-N-nitrosourea. It has more dense spike, higher productivity and moderate field resistance to leaf rust.

Chromosome pairing in pollen mother cells (PMC) was analyzed at the first meiotic metaphase (MI) in F_1 hybrids between monosomic plants of each of 21 Chinese Spring (CS) monosomic lines as female parent with mutant T-13 (M8 generation) and variety Norröna (male parents). The somatic chromosome counts of the CS monosomics and the monosomics of F_1 crosses were determined using Feulgen method. Spikes of the parents and hybrid F_1 plants were fixed in Newcomer's fluid. PMC were observed on acetocarmine smear preparations. Every PMC was scored for the presence of multivalents, and where multivalents occurred, the number of chromosomes involved and their configurations were recorded.

Results and Discussions

Analysis of the meiotic chromosome configurations of F_1 plants shows that mean value of rod bivalents per cell was 0.8 in Norröna and 0.6 in T-13, while in monosomic hybrids CS x T-13 it was higher and equals to about 3 bivalents per cell (Tables 1 and 2). The chromosome pairing in hybrids F_1 was less regular than in their parent plants and associations between chromosomes during meiosis were rather weak, which resulted in premature disjoining of bivalents and increase in number of additional univalents. Taking into account percent of PMC with the normal chromosome configurations at MI in F_1 monosomic hybrids $(20^{II}+1^{I})$ it was found that some chromosomes of variety Norröna and mutant T-13 affected pairing in meiosis. Thus, in monosomic F_1 plants from crosses CS x Norröna chromosomes 4A and 4B decreased pairing, whereas chromosomes 1B and 3D increased it (Table 1). In monosomic F_1 plants from crosses CS x T-13 chromosome 3B significantly decreased pairing, and in monosomic hybrids for chromosomes 5A, 1B and 7B meiosis was more regular as compared with F_1 disomics (Table 2).

The existence of further structural differences between the chromosomes of CS, on one hand, and variety Norröna and mutant T-13, on the other hand, is supported by the data on chromosome configurations and multivalent formations at MI in F_1 plants from crosses of CS monosomics with Norröna and mutant T-13.

The presence of reciprocal translocations between the chromosomes of wheat varieties leads to irregular pairing and hybrids produce quadrivalents and other chromosome associations at MI. With the monosomic hybrids, in which one of the chromosome implicated in the translocation is absent, trivalent configurations appears at meiosis (LAW & Worland 1972). The critical F_1 plants have a trivalents in a number of PMC, while the non-critical plants have a quadrivalent configurations (Morris Sears 1967; LINDE-LAURSEN & LARSEN

Table 1. MI of meiosis in monosomic F_1 hybrids from crosses between Chinese Spring and Norröna

Lines	No. of plants	Cells scored	Percent cells 21^{II}	Percent cells $20^{II}+1^{I}$	Percent cells with addition. univ.	Percent cells with multivalents	Mean value of rod bivalents
1A	1	18		66.6	33.3	0	2.4
2A	3	77		81.8	14.2	3.9	3.7
3A	3	74		79.7	12.1	8.1	2.8
4A	3	42		28.5**	35.7	42.8	2.9
5A	6	145		75.1	24.1	3.4	3.0
6A	4	96		84.3	15.6	0	2.6
7A	3	76		89.4	10.5	3.9	2.4
1B	4	93		94.6**	2.1	3.2	2.2
2B	4	67		82.0	16.4	1.4	2.8
3B	3	90		77.7	20.0	2.2	3.6
4B	3	92		63.0*	34.7	2.1	3.3
5B	1	30		73.3	23.3	0	2.5
6B	4	85		81.1	15.2	2.3	3.5
7B	4	75		90.6	9.3	0	1.9
1D	5	102		77.4	19.6	3.9	3.5
2D	3	64		70.3	29.6	0	2.5
3D	3	62		93.5*	6.4	0	2.3
4D	3	89		78.6	16.8	5.6	3.2
5D	4	96		79.1	17.7	6.2	1.9
6D	4	87		83.9	12.6	4.6	3.0
7D	4	83		87.9	10.8	1.2	2.4
Disom·F_1	3	88	79.5		15.9	3.4	4.1
Norröna	2	64	98.4		1.5	0	0.8
Chinese Spring	4	66	90.9		7.5	1.5	1.8

* $P<00.5$

** $P<0.01$

Table 2. MI of meiosis in monosomic F_1 hybrids from crosses between Chinese Spring and mutant T-13.

Lines	No. of plants	Cells scored	Percent cells 21^{II}	Percent cells $20^{II}+1^{I}$	Percent cells with addition univ.	Percent cells with multivalents	Mean value of rod bivalents
1A	4	73		87.6	10.9	0	2.2
2A	1	13		84.6	15.3	0	2.9
3A	2	42		90.4	7.1	4.7	1.9
4A	1	35		80.0	20.0	2.8	4.0
5A	2	54		96.3**	3.7	0	1.8
6A	2	41		73.1	24.3	2.4	4.3
7A	5	141		86.5	7.0	0.7	2.7
1B	4	104		90.3*	6.7	2.9	2.6
2B	3	68		89.7	7.3	2.9	2.9
3B	3	71		53.5**	45.0	2.8	4.9
4B	4	103		69.9	25.2	6.8	3.6
5B	3	65		89.2	7.6	1.5	2.2
6B	4	96		81.2	10.4	11.4	2.8
7B	3	95		92.6*	5.2	2.1	2.5
1D	2	35		91.4	8.5	2.8	2.7
3D	3	76		81.5	15.7	2.6	3.2
4D	3	65		78.4	20.0	3.0	3.0
5D	2	65		86.1	10.7	4.6	2.1
7D	2	67		85.0	5.9	10.4	2.6
Disom.·F_1	2	71	77.4		19.7	2.8	3.2
T-13	2	67	100.0		0	0	0.6
Chinese Spring	4	66	90.9		7.5	1.5	1.8

* $P<0.05$

** $P<0.01$

Spikes were not fixed in 2D and 6D lines.

Table 3. The trivalent frequency at MI of meiosis in monosomic hybrids F_1

Line	CS x Norröna	Line	CS x mutant T-13
	$19^{II}+1^{III}$		$19^{II}+1^{III}$
4A	30.95	3A	2.38
1B	3.22	1B	1.92
2B	1.49	4B	2.91
1D	2.94	6B	5.20
4D	4.49	3D	1.31
6D	1.15	7D	2.91

1974). The occurrence of at least two trivalents without univalents at MI in the F_1 hybrids is indicative of heterozygosity for chromosomal interchange.

As it is evident from Table 3, chromosomes 4A, 4D, 1B, 1D, 2B and 6D in hybrids F_1 CS x Norröna, and 3A, 4B, 1B, 3D, 6B and 7D in hybrids F_1 CS x T-13 are involved in translocations. On the basis of the frequency of trivalent formations we believe that the chromosomal interchanges between varieties Norröna and CS involve 4A/4D, 1B/1D and 2B/6D, whereas the mutant T-13 has reciprocal translocations 3A/4B, 1B/3D and 6B/7D in relation to the variety CS. The occurrence of low frequency of trivalent and quadrivalent formations in almost all monosomic and disomic F_1 hybrids is probably indication of rather small chromosome segments being involved in translocations. The exception is only the interchange 4A/4D in cross CS x Norröna, including a comparatively large segment of chromosome 4A, the evidence of this came from high rate, 30.95 per cent, of trivalent configuration in this line.

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Cytogenetical effects of radiation on the stability of triticale

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Ionizing radiations have been found effective in inducing a series of chromosomal alterations of diverse forms, creating greater variability than would result from chemical mutagens. Chromosome anomalies such as deletions, duplications, translocations, laggards, fragments and bridges have been frequently observed in irradiated populations of several crop plants (Larik 1978; Larik & Thomas 1979).

Extensive investigations on the effect of physical and chemical mutagens on the cytological behaviour of wheat and other crop plants have already been reported. An attempt has been made in the present work to extend these studies. This paper presents an analysis of meiotic anomalies in MI populations of three crop species and discusses their significance with reference to genetics and plant breeding.

Materials and Methods

Seed samples of three species, Viz. wheat (Local), triticale (Beagle), and rye (var, II). were exposed to doses of 1.5KR and 6KR of X-ray, and sown in pot house for cytological investigations. Young spikes were fixed in a fresh mixture of alcohol and glacial acetic acid "Cornoy" (3:1) and replaced by 70% alcohol after 24 hours. The material was stored at -4°C

Table 1. Cytological data in the M_1 generation after X-irradiation of the 3 species.
+fragment (B+F), micronuclei, anaphase cells with normal separation and

Treatment	Diakensis		Metphase I		
	II	Xta	I	II	Xta
W-0	21.0	38.88±0.54	0	21.0	39.7 ±0.34
W-1.5 KR	21.0	40.62±0.22*	0	21.0	38.54±0.43*
W-6 KR	21.0	38.06±0.15	0.24	20.88±0.08	38.44±0.46
T-0	21.0	35.6 ±0.97	0.48±0.24	20.76±0.24	34.72±0.90
T-1.5 KR	21.0	35.78±0.57	1.28±0.44	20.36±0.16	34.1 ±0.77
T-6 KR	20.68±0.16	33.26±0.66	2.2 ±0.49*	19.9 ±0.25	32.74±0.71
R-0	7.0	12.82±0.43	0.04±0.04	6.98 ±0.02	12.58±0.26
R-1.5 KR	6.9±0.2	12.65±0.2	0.75±0.13**	6.125±0.05**	12.2 ±0.54

The stars indicate significant

and stained in orceinacetic acid (Darlington & Lacour 1976). The meiotic observations were made on sqash preparations of pollen mother cells and recorded in terms of chiasmata, univalents and multivalents, bridges, bridge+fragment and micronuclei. All cells, which could be analysed, were registered. As far as possible diakinesis, metaphase I, anaphase-I and II, telophase and tetrad stages were investigated. Five plants from each treatment and 30 cells per plant were examined.

Results

The results are presented in Table 1. Meiosis in wheat was very regular with 21 bivalents in the control as well as in most of the treated material. Chiasma frequency displayed decrease after the treatments, except in diakinesis, where it showed significant increase. The separation in the anaphase was normal in the control and after 1.5KR, whereas some irregularities, as lagging univalents and bridges, were observed after 6KR. In general wheat was less radiosensitive.

The hexaploid triticale showed 42 chromosomes with 2 rye and 4 wheat genomes. The tetraploid wheat usually forms 14 bivalents, the same behaviour was expected in the hexaploid triticale, however with additional 7 rye bivalents. In accordance with this expectation, 21 bivalents were established in the control of the present material, though a small frequency of univalents and multivalents appeared in metaphase I. Although the frequency of multivalents was very small in the treated material, yet 6KR dose seems to have increased the frequency of univalents. However, a nonsignificant decrease in the chiasma frequency was observed after 6KR dose.

In spite of normal chromosome pairing at diakinesis, a high number of meiotic irregularities was typical for the triticale. Disturbances were observed at all stages of miosis: in M_1 chromosomes outside the equatorial plate; in AI and AII, lagging chromosemes and

Frequency of univalents (I), bivalents (II), chiasmata (Xta), bridges (B) and bridge with laggards. Means and standard errors per cell.

Anaphase I				Anaphase II or telophase B or B+F		Tetrad micronuclei
21–21	$20\frac{1}{1}20$	$19\frac{2}{2}19$	$18\frac{3}{3}18$			
1.0	0	0	0	0		0
1.0	0	0	0	0		0
0.86	0.14	0	0	0.08		9
0.74±0.024	0.14±0.024*	0.12	0	0		0.66±0.17
0.54±0.06*	0.28±0.037*	0.12	0.02	0		1.98±0.56**
0.48±0.09*	0.26±0.04	0.12	0.08	0.06		2.4 ±0.25**
7–7	6–8	$6\frac{1}{1}6$	$5\frac{2}{2}5$	B	B+F	
1.0	0	0	0	0.04 ±0.04	0.02±0.02	0
0.8±0.07	0.075	0.05	0.075	0.275±0.25**	0.1 ±0.04	0

deviations from the control.

sometimes bridges in telophases and in tetrads many micronuclei, in addition to that polyads were also observed. Furthermore,.as it could be seen from Table I the meiotic irregularities increased with the increase in dose. In number of micronuclei and lagging chromosome there was a significant difference between the control and the treated population after 1.5KR and 6KR. The main conclusion is that triticale is more radiosensitive than wheat.

In rye, the meiotic studies comprised the 1.5KR treatment besides the control. Pairing at diakinesis was normal, 7 bivalents in the control and 6.9 in the treated population, a difference which is not significant. In the metaphase however, configurations other than bivalents were observed. There was a highly significant difference between the control and the treated material regarding the frequency of univalents and bivalents. A slight and nonsignificant decrease in the number of chiasmata occurred in the treated material at diakinesis and metaphase. Anaphase separation was normal in control, but some irregularies like dicentric bridges with or without acentric fragments, were observed at anaphase or telophase. Lagging univalents were also observed in the treated population. The frequency of bridges and fragments in same cells as well as the frequency of bridges was higher in the treated material than the control, only the latter being significant. In general the rye material was more affected than the wheat after the same dose.

Discussion

The frequency of chromosomal abberations induced in dormant seeds after X-ray doses indicates that wheat was less affected than rye. Since, the plants having small sized chromosomes are usually more radioresistant than plants with large chromosomes, the low chromosomal radiosensitivity of 6x wheat is not surprising (BHASKARAN & SWAMINATHAN 1960). However, in our material of triticale, meiosis was irregular in the treated material as well as in the control. The main meiotic irregularities were univalents, laggards and micronuclei in the tetrads. In addition to that spindle formation was much disturbed which consequently gave rise to polyads.

Perhaps the main cause of meiotic disturbance is the incompatability between rye and wheat genomes located in one cell, and the inactivation of some loci of the rye chromosomes in some cells, as suggested by RILEY (1960). From these studies of wheat lines with added rye chromosomes, it is concluded that rye chromosomes are unable to function adequately in the presence of full set of wheat chromosomes. Observations reported by SHKUTINA & KHVOSTOVA in 1971 are fully accorded with RILEY's opinion in showing that rye chromosomes are not controlled by wheat chromosomes in the process of cell division. Their studies indicated that chromosomes of the rye genome in triticale not only lag behind the wheat chromosomes, but also keep apart from them in the course of meiosis. This could sometimes be observed in prophase as well as in metaphase and anaphase.

Presumably, the separation of rye chromosomes is not controlled by spindle fibres and as such these are distributed randomly throughout the cell. This is in accordance with the abservations made by SANCHEZ-MONGE (1958), VETTEL (1960) and VEIMARCK (1975).

Inspite of the fact that meiosis was disturbed in the control of triticale, however the present results show an increase of irregularities with the increase in the mutagenic dose. Perhaps the genetic difference between rye and wheat chromosomes could be the possible reason for higher radiosensitivity in triticale than in wheat.

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Effect of plant density on the growth and yield potential of durum and bread wheat cultivars

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The development of the crop can be influenced by cultivation measures. A proper choice of cultivation measures contributes to high yields. One of these measures is the choice of proper spacing. Spacing influences root development, plant growth and yield. Too close spacing results in excess competition between plants and thus reduces yield. Too wide spacing do not make full use of the available soil surface and will not give an economic return (Kumbhar & Larik 1982).

Total dry matter production per unit area of a plant species, when grown under constant environmental and cultural consitions, does not show much variation, but the large dfferences occur in harvest index (the ratio of economic yield to biological yield). Though the genetic constitution of a variety with high harvest index is of prime importance, the cultural methods especially the distance between and within the rows should be manipulated to such a limit as to give the highest economic returns (Tosun & Eser 1975).

The present study was there fore, initiated to determine the influence of plant densities on different quantitative traits of durum and bread wheat varieties.

Material and Methods

The effect of varying plant density on the growth and yield potentials of two durum and three bread wheat cultivars was investigated at the fields of Faculty of Agriculture, University of Ankara, during the year 1978–79. Durum wheat cultivars 66T12, Red 5132 and bread wheat cultivars Tosun 22, 66T1435, Bezostaya 1, were hand sown at five between row spacings (10, 15, 20, 25, 30 cm) and five within row spacings (1, 2, 3, 4, 5 cm) in four replications. A split-split-plot experimental design was employed with cultivars as main plots, row spacings as sub plots and plant spacings as sub-sub plots. Each sub-sub plot consisted of three rod rows 1.5 m in length. Plants from 1 m length of the central row were counted and harvested manually.

Grain yield per m^2, number of spikes per m^2, number of seeds per m^2, days to heading and harvest index were determined. Total fertile heads were counted from 1 m length of the central row after harvest and were threshed to obtain grain yield and converted to m^2. Number of seeds per m^2 were then calculated. Days to heading were counted from 1st May till 50% of the culms in each plot had visible spikes. Harvest index was calculated by dividing grain yield per m^2 with its total dry weight and multiplying it with 100.

Results and Discussion

Estimates of mean values for grain yield per m^2, plants per m^2, spikes per m^2, seeds per m^2, days to heading and harvest index from different between and within row spacings are presented in Table 1. Data reveal that maximum yield was reached by all cultivars when spaced 1 cm apart in rows which were spaced 15 cm apart. This represents a seeding rate of 667 seeds per m^2. Yield was not significantly reduced, however, when plants were spaced 2 cm apart in 10 cm rows. This is equivalent to a seeding rate of approximately 500 seeds per m^2. In other words highest yields were obtained from the parcels with 500–667 plants per m^2. Very similar results have been obtained by Tsonev & Moskov (1975) with 500–600 seeds per m^2 and Simeonov & Kasimov (1978) with 600 seeds per m^2.

Row spacings and seeding rate had a significant effect on grain yield (Table 2). With decreasing row spacing grain yield increased upto optimum. Likewise highly significant ($P>.01$) differences among cultivars for the metrical traits were also observed. In addition a significant cultivar x row spacing interaction for yield was observed similar to Harrington (1941) and Stoskof (1967) with winter wheat. Further more C x S, R x S and C x R x

Table 1. Mean values of five winter wheat cultvars for different quantitative traits at varying population densities.

Row spacing (cm)	×	Plant spacing (cm)	Grain yield (gm)	Plants per m^2	Spikes per m^2	Seeds per m^2	Days to heading	Harvest index
10	×	1	495.92	990.50	990.50	21856	24.25	31.64
		2	517.34	495.50	756.00	20487	25.20	32.27
		3	477.89	326.00	666.50	18441	26.00	30.68
		4	441.87	248.50	638.00	16353	26.80	28.89
		5	426.65	197.50	598.16	15222	27.60	27.99
15	×	1	530.68	661.05	797.34	21523	24.80	33.01
		2	481.80	330.81	658.24	18320	25.75	30.69
		3	440.91	217.32	606.00	16268	26.55	28.72
		4	411.72	164.51	566.32	14689	27.20	27.64
		5	396.11	131.05	524.12	13672	28.10	26.72
20	×	1	503.22	498.25	712.84	19182	25.00	31.55
		2	449.62	247.50	598.52	16460	26.00	28.99
		3	414.19	163.25	536.52	14842	26.80	27.27
		4	380.31	122.75	501.26	13114	27.40	26.34
		5	364.69	98.25	453.77	12313	28.35	25.23
25	×	1	467.00	394.20	660.00	17613	25.45	30.33
		2	432.86	198.60	563.80	15531	26.50	27.71
		3	393.37	131.60	504.06	13728	27.25	26.69
		4	353.48	98.93	453.40	11979	27.85	25.08
		5	338.41	78.60	409.40	11244	28.55	23.99
30	×	1	436.78	331.45	617.68	16008	26.05	28.92
		2	402.92	163.68	533.49	14264	26.95	27.51
		3	376.59	109.41	468.49	12859	27.55	25.72
		4	340.11	82.29	415.16	11330	28.10	24.27
		5	327.45	66.69	382.00	10773	28.95	23.75

Table 2. Variance ratio from analysis of variance for quantitative traits of two durum and three bread wheat cultivars.

Source of variation	Yield	Plants per m^2	Spikes per m^2	Seeds per m^2	Days to heading	Harvest index
Cultivar (C)	118.35**	5.59**	3248.92**	325.53**	654.07**	18.93**
Row spacing (R)	292.89**	45401.66**	735.41**	790.54**	48.52**	42.46**
Plant spacing (S)	976.65**	178347.15**	1748.41**	1918.85**	1128.96**	141.83**
C×R	2.26*	1.44	7.80**	12.63**	1.39	0.79
C×S	4057**	1.54	18.98**	21.42**	14.00**	3.12**
R×S	14.77**	7443.89**	24.89**	10.04**	1.45	3.32**
C×R×S	3.91**	1.34	14.49**	4.38**	1.05	1.26

*, ** Denote significance at $P \geq .05$ and $P \geq .01$ respectively.

S interactions were significant. A cultivar x density interaction had also been reported by Sakai & Iyama (1966) and Rule & Fiddian (1974).

The number of plants per unit area is a direct, positive linear function of seeding rate. Row spacing and seeding rate had a definite effect on number of plants per unit area. Darwinkel *et al.* (1977) reported a parallel increase in plants per m^2 with increase in seeding rate. Consistent changes in the number of spikes per m^2 with changes in row spacing and seeding rates were observed. C x R, C x S, R x S and C x R x S interactions were significant for this trait.

Plant density had a marked effect on number of seeds per m^2. Row spacing, seeding rate and their interactions with cultivar had significant effects on number of seeds per m^2. Seed number per unit area increased with increasing density upto the optimum plant density, then it showed a tendency towards decreased seed number at the above optimum density (Table 1). Grain production is greatly influenced by the amount of carbohydrates available for ear development. A very distinct decline in crop growth for the higher populations during the later stages of ear development was reported by Puckridge & Donald (1969), resulting in reduced amount of carbohydrates available for ear development, a reduction in number of grains per unit area and a subsequent decrease in final grain yield.

Population level had a pronounced effect on days to heading. Treatments of the low seeding rates were slower to head than were their counterparts at the higher seeding rates. Cultivars headed earlier in narrow row spacings than in their wide-row equivalents. Moreover, cultivar x seeding rate interaction was significant for days to heading. Similar results were obtained by Finlay *et al.* (1971). The decreasing leaf area, particularly the flag-leaf area and the competition for light at increasing population levels causes the plants to enter earlier in their generative phase.

Harvest index was clearly influenced by row spacing and seeding rate. Cultivar x seeding rate and row spacing x seeding rate interactions were also significant. At high population levels plants compete for nutrients and for light, hence the tillering is reduced to the extent that much part of the crop comprises of main tillers. As the side tillers share a little in the final yield, but some of the tillers remain headless in wider spacing, resulting in reduced harvest index of low population levels. GENC (1978), also reported a reduction in harvest index with increasing tillers per plant.

One of the reasons of the increasing yield with increasing densities upto optimum is the control of weeds with narrow rows. In wide rows weeds develop quickly and vigorously consuming water and nutrients otherwise available to the crop under cultivation. BURNSIDE *et al.* (1964) reported reduced weed growth in narrow rows. They obtained a highly significant negative correlation between grain yield and weed growth ($r=0.30^{**}$). Today, therefore, the best control of weeds could be achieved by reducing the distance between rows. Chemical weed control affects the micro-organisms present in the soil, causes genetic variations in the crop and increases the cost of production. With increasing seed rates, the number of fertile tillers per unit area increased resulting in yield increases upto an optimum after which despite of increase in seeding rate and fertile tillers, yield decreased most probably because of acute reductions in leaf area and the reduced seed number per spike and the seed weight at above optimum densities. The number of grains per ear is the chief variable accounting for the decline in grain yield in above optimum population (WILLEY & HOLLIDAY 1971). Precise recommendations for any situation are not possible, but the implications are that the optimal plant density depends on the amount of nitrogen available to the crop and possibly on other growth factors. Nevertheless, more yield trials of a similar nature are needed before a positive recommendation can be made. The most important agronomic characters are the maximum yield, early heading and a high harvest index. This experiment has shown that differences in population density can have marked effects on the growth of the plants, nevertheless, narrow row spacing with optimum plant densities appear most suitable for optimizing these characters.

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Estimation of genetic effects for agronomic traits in wheat

by

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The most efficient breeding procedures and the expected gain from selection for quantitative traits depend upon the magnitude of gene effects and their mode of action. Many workers developed genetic model for the estimation of different genetic effects (Mather 1949, Hayman 1958, Gamble 1962 and others).

Sun *et al.* (1972) by using six-parameter model found that epistasis was affecting in the inheritance of kernel weight. Regarding yield and plant height, Chapman & Mc-Neal (1971) found highly significant epistatic effects. Amaya *et al.* (1972) found that dominance effects were relatively more important than additive in the inheritance of yield but the additive effects were predominant for plant height and heading date and they detected epistatic effects in some crosses. Matzinger *et al.* (1960) noted that failur to include epistatic effects in heritability estimate may bias estimates of additive genetic variation and prediction gain from selection.

In the present investigation a cross of two hexaploid wheat cultivars was made to obtain information about heterosis, the nature of gene effects, heritability and genetic advance under selection for the more importnat agronomic traits.

Materials and Methods

The experimental populations in this investigation were derived from crosses and backcrosses of Samma (Saudi) and Super-x (Mexican) wheat cultivars. Crosses between parents were made in the green-house in season 1979, and the F_1 was backcrossed in 1980 to each of the parents (P_1 and P_2) to produce the first backcross generations B_1 ($P_1 \times F_1$) and B_2 ($P_2 \times F_1$). The parental cultivars, F_1, F_2 and backcrosses were grown in a randomized complete block field experiment with three replications at Faculty of Agriculture (Olisha), King Sauid University in season 1981. With each replication the non-segregating generations composed of one row, two for each backcross and four for the F_2. Each rows were 4 m long, 50 cm apart and seeds were space-planted 20 cm allowing a total of 20 plants per row.

The data were obtained on each plant for the following traits:

Date headed: Number of days from sowing to the day when spike of tallest culm was fully exserted from the flag leaf sheat.

Plant height: Height in centimeters from the soil surface to the base of the spike of tallest culm.

Harvest index: The ratio of grain dry weight to the total aboveground weight at maturity.

Grain yield: Weight of grains in grams harvested from each plant.

Spike length: Length in centimeters of the spike on the tallest culm (awns excluded).

100-kernel weight: Weight in grams of 100 random kernels of each plant.

Weight of kernels, number of spikelets and kernels per spike were based on the spike of tallest culm.

Analysis Procedures

Analysis of variances including all generations as well as separate analysis for each population were conducted for each trait. Scaling tests have been calculated to test the adequacy of additive-dominance model using Mather's formulae (1949). A joint scaling test attributed to Cavelli by Mather and Jinkes (1971) was also conducted to evaluate the goodness of fit of the three-parameter model.

The means of all generations were analysed by the method outlined by Hayman (1958) to provide a six-parameter model. Those parameters using Gamble's notation (1962) were the F_2 population mean or mean effects (m), the pooled additive effects (a), the pooled dominance effects (d), the pooled additive x additive epistatic effects (aa), the pooled additive x dominance epistatic effects (ad) and the pooled dominance x dominance epistatic effects (dd).

Heritability in the narrow sense (h^2 ns) and their standard errors were calculated for each trait using the method of Warner (1952). The expected genetic advance from selection (G.S) was estimated following Allard (1960) at 5% level of selection.

Results and Discussion

Means and variances

Analysis of population means and variances are given in Table (1). The results proved that the six generations were differed significantly for all traits under study. Mean values for different agronomic traits as shown in Table (2) indicated that Super-X cultivar was earlier than Samma cultivar and larger in grain yield per plant, weight and number of kernels per spike, 100-kernel weight and harvest index. The F_1 showed to be lower than the parental mean value for all traits except plant height (Table 2). These significant deviations of F_1 indicating a sizable amount of nonadditive gene action for all traits except date headed and harvest index. It can be concluded that there were a preponderance of recessive genes plus modifiers at the loci which the parents differed. Similar results were obtained for kernel weight by SUN *et al.* (1972), for spikelets and kernels number per spike and 1000-kernel weight by HASSANIEN *et al.* (1974) and for spikelet number per head by HALLORAN (1975). Date headed, plant height and 100-kernel weight in this investigation were in agreement to the findings of KETATA *et al.* (1976). WIDNER and LEBSOCK (1973) found that the F_2 was higher in mean grain yield than the F_1.

Table 1. Mean squares for the analysis of variance of parental, F_1, F_2

Source of variation	df	Date headed	Plant ht, cm	Harvest index
Replications	2	0.676	8.172	0.00013
Genotypes	5	107.828**	67.510**	0.00489**
Error	10	0.965	7.595	0.0040

**: Significant

Table 2. Estimates of generation means, standard error and

Generation	Date headed	Plant ht, cm	Harvest index	Grain yield/ plant, g
$\bar{P}_1$(Samma)	82.21±0.56	57.00±1.06	0.421±0.014	9.55±0.44
$\bar{F}_2$(Super x)	66.11±0.63	50.47±0.83	0.508±0.012	12.20±0.58
$\bar{F}_1(P_1 \times P_2)$	70.62±0.55	63.36±1.05	0.440±0.015	7.11±0.42
$\bar{F}_2$	78.29±0.71	55.47±1.17	0.394±0.009	8.38±0.45
$\bar{B}_1(P_1 \times F_1)$	79.29±0.46	54.09±0.91	0.396±0.012	6.01±0.50
$\bar{B}_2(P_2 \times F_2)$	76.74±0.92	61.18±1.22	0.425±0.012	7.13±0.13
F_1–MP	−3.54	9.63**	−0.024	−3.76**

**: Significant

Table 3. Scaling tests (A, B and C), heritability in the narrow sense (h^2ns) and ex-

	Date headed	Plant ht, cm	Harvest index	Grain yield/ plant (g)
A	5.750±1.209	−12.180±2.353	−0.069±0.032	−4.64 ±1.17
B	16.750±2.021	8.530±2.783	−0.098±0.030	−4.95 ±1.58
C	23.600±3.160	−12.310±5.303	−0.233±0.050	−2.35 ±4.48
h^2ns	0.747±0.502	0.925±0.455	0.322±0.674	0.441±0.92
G.S. (%)	8.3	17.1	0.05	3.1

Table 4. Estimates of gene effect for different agronomic traits

Model and effects	Date headed	Plant ht, cm	Harvest index	Grain yield/ plant (g)
Three-parameter:				
m	75.83±0.39	52.68±0.62	0.45 ±0.01	10.08±0.32
a	7.54±0.38	1.36±0.61	−0.04 ±0.01	− 1.07±0.32
d	− 5.08±0.68	9.13±1.19	−0.06 ±0.02	− 3.93±0.55
X^2	151.01	113.89	28.17	44.32
P	<0.001	<0.001	<0.001	<0.001
Six-parameter:				
m	75.29±0.09	55.47±0.15	0.394±0.001	8.38±0.06
a	2.55±0.16	− 7.09±0.25	−0.029±0.003	− 1.12±0.12
d	− 4.64±0.50	18.29±0.80	0.042±0.008	−10.96±0.37
aa	− 1.10±0.49	8.66±0.78	0.066±0.007	− 7.24±0.34
ad	− 5.50±0.19	−10.36±0.30	0.015±0.004	2.54±0.15
dd	−17.50±0.79	− 5.01±1.26	0.101±0.014	16.83±0.60

and backcross data for the agronomic traits in Summa × Super-x cross.

Grain yield/ plant, g	Spike length, cm	Spikelets/ spike	Kernels/ spike	Kernel wt/ spike, g	100-Kernel wt, g
0.743	0.029	0.839	20.991	0.029	0.005
1.528**	18.714**	18.714**	133.888**	0.473**	0.461**
0.064	1.146	1.146	8.260	0.023	0.058

at 0.01 level.

F_1-midparent deviations (F_1-MP) in Samma × Supar-x cross.

Spike length, cm	Spikelets/ spike	Kernels/ spike	Kernel wt/ spike, g	100-Kernel wt, g
10.83±0.15	39.65±0.62	59.24±2.04	1.66±0.08	2.79±0.07
9.25±0.17	33.76±0.64	64.06±2.04	2.24±0.10	3.47±0.09
9.21±0.11	33.40±0.55	43.80±1.32	1.10±0.05	2.53±0.07
10.34±0.16	36.90±0.67	55.44±1.84	1.57±0.07	2.82±0.08
10.38±0.17	35.19±0.66	53.14±2.21	1.23±0.08	2.32±0.11
10.68±0.23	38.06±0.78	57.14±2.15	1.54±0.09	2.59±0.12
−0.83**	−3.30**	−17.85**	−0.85**	−0.60**

at 0.01 level.

pected genetic advance (G.S.) for different agronomic traits in Samma × Sup er-x cross.

Spike length, cm	Spikelets/spike	Kernels/spike	Kernel wt/ spike, g	100-Keruel wt, g
0.720±0.388	−2.760±1.559	3.420±5.044	−0.300±0.186	−0.680±0.241
2.900±0.503	8.960±1.774	6.420±4.939	−0.260±0.212	−0.820±0.266
2.860±0.714	7.390±3.031	10.860±8.334	0.180±0.324	−0.040±0.367
0.096±0.632	0.586±0.541	0.274±0.595	0.251±0.611	−0.391±0.723
2.4	6.2	8.0	0.3	—

in a cross Samma × Super-x by three and six-parameter models.

Spike length, cm	Spikelets/ spike	Kernels/spike	Kernel wt/spike, g	100-Kernel wt, g
10.33±0.10	37.17±0.40	56.88±1.27	1.87±0.05	3.07±0.05
0.65±0.11	−0.24±0.41	− 0.24±0.41	0.91±0.06	−0.32±0.06
−0.86±0.16	−3.02±0.70	−21.23±1.95	−0.84±0.08	−0.63±0.09
34.76	52.47	52.47	472.22	16.73
<0.001	<0.001	<0.001	<0.001	<0.001
10.34±0.02	36.90±0.09	55.44±0.24	1.57±0.01	2.82±0.01
−0.30±0.05	−2.87±0.17	− 4.00±0.52	−0.31±0.02	−0.27±0.03
−0.07±0.13	−4.41±0.51	−19.13±1.45	−1.59±0.06	−2.06±0.02
0.76±0.13	−1.10±0.49	− 1.28±1.42	−0.74±0.05	−1.46±0.07
−1.09±0.55	−5.82±0.20	− 1.59±0.63	−0.02±0.03	0.07±0.03
−4.38±0.21	−5.19±0.81	− 8.46±2.35	1.30±0.09	2.96±0.11

Gene effects

The results of A, B and C scaling tests are given in Table (3). For all traits except number and weight of kernels per spike there were highly significant values for one or more of these tests. Hence, the additive-dominance model was inadequate indicating that epistasis was involved in the inheritance of most traits studied.

The joint scaling test is more powerful than any of the other test in detecting epistasis since it uses information from all six populations. A three-parameter model (m), (a) and (d) proved to be satisfactory in explaining the genetic differenes. The estimates of the three-parameters and the test of goodness of fit for the model are given in Table (4). Chi-square (x^2) values for the differences between observed and expected population means provided significant values. These results were agreed with A, B and C scaling tests in showing that the additive-dominance model was inadequate. ABO-ELENIN and GOMMA (1972) studied the nature of gene effects for plant height by using scaling tests and they detected inadequace of additive-dominance model on this trait. The estimates of dominance genetic effects (d) were larger than the additive genetic effects (a) for all traits except date headed and kernels weight per spike and always negative. The signs of (a) and (ad) depends upon which parent is considered as P_1 or P_2. The highest dominance effects (d) were involved for plant height and number of kernels per spike. The additive genetic effects (a) were smaller in magnitude but significant for all traits exept number of kernels per spike. It can be concluded that both additive and dominance effects were involved in the behavior of all traits except number of kernels per spike which controlled by dominance effects.

Because of epistasis, the three-parameter model was not sufficient to explain the genetic variation. Therefore the six-parameter model (Table 4) was invoked to determine the type and magnitude of gene action. The estimates of dominance effects (d) from the three-parameter model were smaller than the estimates from the six-parameter model. The six-parameter analysis showed that the magnitude of dominance effects (d) were greater than the estimates of additive effects (a). While the dominance x dominance effects (dd) were relatively larger in magnitude and more important than the other two types i.e. (aa) and (ad) for all traits except plant height. It can be concluded that dominance x dominance epistatic effects (dd) as well as dominance (d) played the major contributions to the inheritance of most traits studied. These results agreed with that obtained for kernel weight (SUN *et al.*, 1972), grain yield (AMAYA *et al.*, 1972) and for harvest index (ALI and EL-HADDAD, 1978). On the other hand, additive (a) and additive x dominance epistasis (ad) played an important part in the inheritance of some traits such as plant height and number of spikelets per spike. Similar results were obtained by BHATT (1972) and KETATA *et al.* (1976). The estimates of epistasis, dominance and additive gene action may have been influenced by genotype-environment interactions in both three and six-parameter model.

Heritability and Genetic Advance

Narrow-sense heritability estimates for different traits are given in Table (3). The values were véry high for plant height, moderate for date headed and number of spikelets per spike and low for the remaining traits. Small narrow sense heritabilities for most traits may be due to the dominance and epistatic effects on these traits. The negative estimate of heritability observed for 100-kernel weight may be attributed to several causes, such as sampling error, differential responses of the F_2 vs. the backcrosses to environment and non-additive genetic effects.

Estimates of the expected genetic advance (G.S.) are reported in Table (3). The results showed that heritability and genetic advance generally agreed in showing those traits for which selection in the F_2 would lead to substantial improvement. The highest estimates of heritability and genetic advance were presented for plant height, date headed and spikelets per spike indicating that selection for these traits would be effective in this material , Contradictory the low heritability estimates for the major traits should result in a low genetic advance. Similar results were obtained by Bhatt (1972) and Abo-Elenin and Gomma (1977) for plant height, and Ali and El-Haddad (1978) for harvest index. Regarding earliness, hight and kernels per spike Fonseca and Patterson (1968), and Ketata *et al*, (1976) gave similar findings. The low heritability obtained for grain yield are in agreement with that reported by Johnson *et al.* (1966).

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Interrelationship of polygenic traits affecting grain yield in *Triticum aestivum* L.

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Breeding high yielding varieties of crop requires information on the nature and magnitude of variation in the available material, association of characters with yield and among themselves and the extent of environmental influences on these characters. Correlation coefficient has been used to identify the grain yield components (Larik, 1978; Siddiqui *et al.* 1980) but the technique of path coefficient analysis measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effect (Dewey & Lu, 1959; Larik, 1979) which can successfully be employed in formulation of meaningful selection strategies.

Material and Methods

Homogeneous seeds of *Triticum aestivum* L. ($2n=6x=42=$AA BB DD) cv. Nayab were grown during Rabi 1980–81 at the Botanical Garden, Sind Agricultural University, Tandojam, Pakistan. Seeds were sown in five rows each 6 m long with 30 cm interrow distance. Observations were recorded on 60 index plants selected randomly. The following characters were measured: X_1=Spike length, X_2=Spikelets per spike, X_3=Seeds per spike, X_4=Yield per spike, Y=Yield per plant (dependent character).

Correlation and path coefficients were calculated by)he technique outlined by Dewey & Lu (1959) in which the end product

$$Y = \sum_{i}^{N} P_i X_i$$

Component of correlation

$$r_{xiy} = P_i + \sum_{i=j}^{N} P_j r_{ij}$$

which indicate direct as well as indirect effect of one variable through another one on the end product. Multiple correlation and partial regression was calculated by using the formula suggested by Steel & Torrie (1960).

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Results and Discussion

Correlation and Path coefficient analysis.

The path ways through which the four yield components operate to produce their phenotypic associations with grain yield revealed that seeds per spike exerted preponderant effect on yield per plant and formed 83.79% of the total phenotypic correlation followed by spikelets per spike (43.32%). The direct effect of spike length on grain yield was low and negative (–.0726) the indirect effect via seeds per spike was very high and positive (.5366). High positive correlation of spike length with grain yield was mainly due to indirect effect via seeds per spike and spikelets per spike. The direct effect of spikelets per spike on grain yield per plant was positive (.2989). The indirect effect via spike length was very low and negative (–.0559) and seeds per spike was high and positive (.4609). However, the total effect of spikelets per spike on yield per plant was 0.690 which was mainly due to its indirect effect via seeds per spike. Therefore this yield component can be regarded as reliable selection criterion of the second order.

The phonotypic correlation coefficient (.821) of seeds per spike with grain yield per plant was mainly due to its direct effect. However, indirect effect via spike length (–.0567) and yield per spike (–.1172) hav some what diluted the direct effect. Hence seeds per spike can be used as most reliable criterion in the selection of high yielding genotypes. The direct effect of yield per spike on grain yield per plant was very low and negative (–.0192). The indirect effect via spike length and spikelets per spike was –.0450 and .2266 respectively, via seeds per spike it was high (.4196). The total correlation coefficient .620 between grain yield per plant and yield per spike was mainly due to indirect effect via seeds per spike. Therefore, yield per spike can not be used as a reliable criterion in the selection of high yielding wheat genotypes. These results are in agreement with LARIK (1979) and SIDDIQUI *et al.* (1980).

Multiple correlation and partial regression

Detailed information on the effectiveness of different quantitative attributes and their contribution towards final yield was obtained by working out multiple correlation and partial regression (Table 1). This was accomplished by assessing the cumulative effect of yield components on grain yield per plant, taking grain yield per plant as the dependent variable and the other traits as independent variables. The multiple correlation coefficient between yield per plant and other characters was .8425 which means that 71% of the variation in yield per plant can be attributed to four independent variables. The calculated F-value 33.66 (Table 2) reveals that the multiple correlation coefficient is highly significant at the 1% level of probability. The 't' test for significance of the partial regression cofficients indicates that only seeds per spike contributed significantly towards yield per plant while the other three variables (Spike length, spikelets per spike and yield per spike) do not contributed significantly towards yield per plant. This is also confirmed by path coefficient analysis which indicates that the character having the maximum influence on

Table 1. Estimates of phenotypic correlation, path coefficient, partial regression and multiple correlation for yield components in bread wheat.

Characters correlated	Mean	Standard deviation	Correlation coefficients					Partial regression coefficient	t-test
			Phenotypic	Path coefficient					
				X_1	X_2	X_3	X_4		
X_1 Spike length	10.82	0.1075	0.678**	−.0726 (10.71%)	.2309 (33.95%)	.5366 (79.14%)	−.0119 (1.76%)	−.0401 ±.0738	−.5439
X_2 Spikelets/ spike	19.10	0.1955	0.690**	−.0559 (8.10%)	.2989 (43.32%)	.4609 (66.80%)	−.0171 (2.48%)	.0908 ±.0591	1.5349
X_3 Seeds/ spike	58.73	0.9492	0.821**	−.0567 (6.90%)	.2003 (24.39%)	.6880 (83.79%)	−.1172 (1.43%)	.0430 ±.0074	5.7600**
X_4 Yield/ spike	2.06	0.0536	0.620**	−.4504 (7.26%)	.2660 (42.91%)	.4197 (67.68%)	−.0192 (3.09%)	−.0213 ±.1804	−.1179
Y Yield/plant (dependent character)	5.003	—	—	—	—	—	—		

Multiple Correlation Coefficient = 0.8425
Estimated Error = 0.2567
$Y = 1.21439 - 0.04014X_1 + 0.09082X_2 + 0.04306X_3 - 0.02128X_4$

D.F = 55
**='t' at 1% level=2.693

Tabie 2. Test of significance of multiple regression coefficient

Source of variation	D.F	SS	MS	F-value
Regression on four variables	4	8.8742	2.2185	33.665**
Residual	55	3.6257	0.0659	
		(by subtraction)		
Total	59	$\sum Y^2 = 12.5$		

yield per plant is seeds per spike. These results are in accordance with the results obtained by LARIK (1979), SIDDIQUI *et al.* (1980) and SANDHA *et al.* (1980).

The relative contribution of the basic yield components would be expected to vary considerably depending upon the range in the genetic population and environment (WORLEY *et al*, 1976). It is therefore advisable to pinpoint the yield components most susceptible to alteration in a particular agricultural environment. From the path coefficient and partial regression analyses carried out in the present work, it may be inferred that seeds per spike is the effective yield component of the wheat cultivar Nayab.

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II. Editorial Remarks

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WIS No. 58 will be planned for publication in March, 1984, Manuscripts for this issue are most welcome and accepted any time, not later than December, 1983.

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