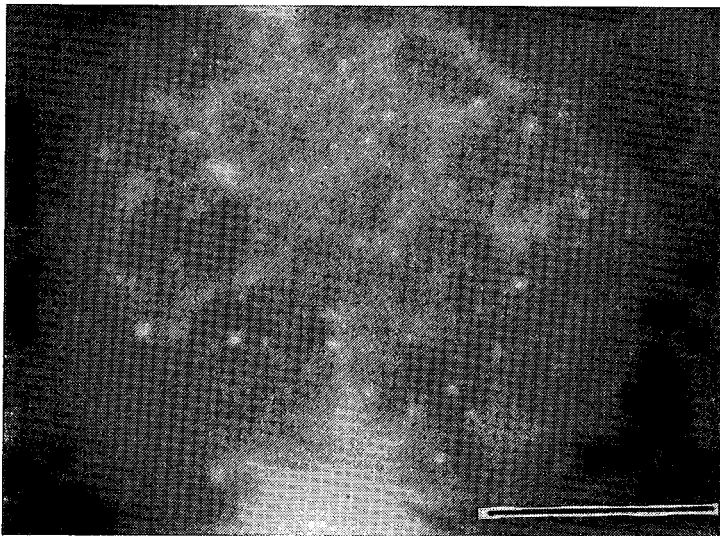


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## I. Research Notes

### Visualization of wheat chloroplast DNA *in situ* with the DNA fluorochrome

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Genetic information of plant cells is separately pooled among their nuclei, mitochondria, and plastids. It is well known that such organelle DNAs are predominant determinants of cytoplasmic inheritance<sup>1)</sup>. The contribution of cytoplasmic genome to speciation on the wheat genus *Triticum* and its related genus *Aegilops* has been revealed from analyses of genetic characters of the cytoplasm by the nucleus substitution<sup>2-5)</sup>. Molecular biological analyses of the problem are needed at present<sup>6)</sup>.

Since WILLIAMSON and UNNELL<sup>7)</sup> showed that a trypanocide, 4'6-diamino-2-phenylindole (DAPI) can be a probe for detection of mitochondrial DNA in yeast by fluorescence microscopy, DAPI has been employed to visualize mycoplasma<sup>8)</sup>, kinetoplast DNA<sup>9)</sup>, and chloroplast DNA in algae<sup>10)</sup> and in isolated chloroplasts of higher plants<sup>11)</sup>. This paper reports a simple and rapid method for cytological detection of chloroplast DNA *in situ* of wheat mesophyll protoplasts using the DNA fluorochrome, DAPI.

The first foliage leaves of 10-day-old wheat seedlings (*Triticum aestivum* L., cv. Chinese Spring) grown under a normal diurnal light regime, 16 h light (5000 lux)-8 h dark, at 25°C were used throughout this study. The mature regions of the leaves were finely chopped with a razor blade, and suspended in the enzyme solution containing 10% (w/v) mannitol and 10 mg/ml Cellulysin (Calbichem, B grade) in 0.2 M phosphate buffer (pH 5.7). The suspension was incubated at 37°C in the dark for 4-5 h. Released protoplasts were collected by centrifugation at 1000 rpm for 10 min after being filtered through two layers of Miracloth. The sedimented protoplasts were fixed in 0.5% glutaraldehyde on a microscope glass slide for 10 min. A drop of 15 µg/ml DAPI solution was added to the fixed protoplasts and it was kept standing for 10 min, followed by being placed a cover slip over. Preparations were

examined with a Nikon fluorescence microscope under epifluorescent illumination by UV light from a 200 W mercury lamp. The observation of the DAPI fluorescence was done with a UV-F100 objective, using a U excitation filter in combination with a 420 K suppression filter.

Within chloroplasts numerous blue-white fluorescent dots were discretely observed, while nuclei were overall brightly stained as shown in Fig. 1.

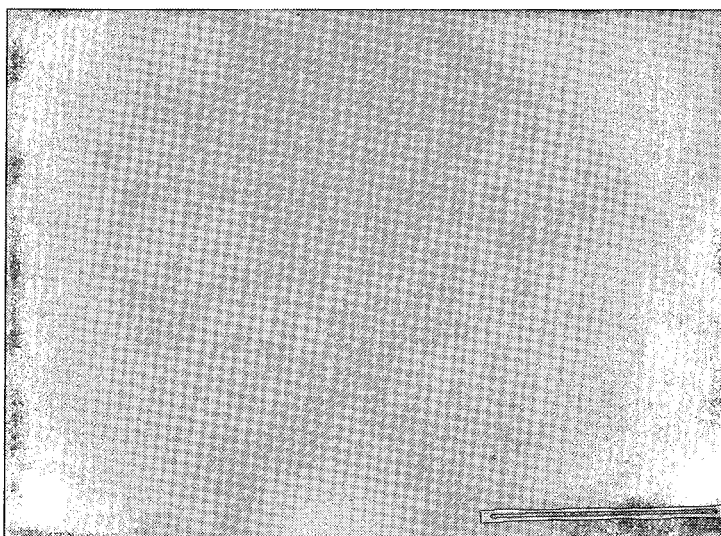


Fig. 1. Fluorescent photomicrograph of DAPI-stained chloroplasts in a mesophyll protoplast of *T. aestivum*. A big bright body at the lowest part is the nucleus. Reference bar; 10  $\mu$ m.

It was confirmed by a DNase digestion test that the material within chloroplasts stained by DAPI is really DNA. Chlorophyll autofluorescence showed no interference with fluorescent images of chloroplast DNA stained with DAPI. These fluorescent particles are rather regular in shape and are not located ubiquitously within chloroplast architecture as far as Fig. 1 shows.

The number of fluorescent particles of chloroplast DNA by DAPI per chloroplast is 18.5 on the average in mesophyll protoplasts released from the mature region of the first foliage leaves. Since a single chloroplast fluorescent dot appears to contain at least as much as  $120 \times 10^6$  daltons of DNA contained in  $T_4$  phage<sup>11)</sup>, it seems reasonable to say that the number of chloroplast DNA per chloroplast, i.e. the copy number is about 20 or more. About 135 chloroplasts are present in a single mesophyll cell in this species<sup>12</sup>. So, a single mature mesophyll cell appears to contain at least 2500 chloroplast DNA molecules. Chloroplast DNA of higher plants is a double-stranded, circular, covalently closed molecules with a contour length of 43-55  $\mu$ m and a molecular weight of  $85-100 \times 10^6$  daltons<sup>13)</sup>. The amount

of chloroplast DNA per cell is estimated to be at least  $5 \times 10^{-13}$ g, which is about 1% of the nuclear DNA amount.

It seems reasonable to suppose that DAPI-staining should permit detection of a single full sized chloroplast DNA molecule. The fluorescence microscopy for detecting chloroplast DNA *in situ* reported here is believed to be very useful to see details of the organization, replication and segregation, and relative amounts of DNA per chloroplast in the wheat genus and its related genus from ontogenetic and phylogenetic interests.

The study was partly supported by Grant Aids for Fundamental Scientific Research from the Ministry of Education, Science and Culture. The author wishes to thank Dr. H. NIEDDERER, Serva-Feinbiochemica, Heidelberg, Fed. Rep. of Germany, for his generous gift of DAPI.

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## Meiotic consequences of induced chromosomal anomalies in *Triticum aestivum* L.

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Investigations on the mechanism of chromosome breakages, types of aberrations and their genetic consequences form an integral part of the most of the studies on radiation genetics (BROCK 1977; KONZAK *et al.* 1977; LARIK 1975; SEARS 1977; SHARMA & FORSBERG 1977), covering a wide range of plants belonging to both wild and cultivated species. Mutations due to deficiency of genes with a dominant or epistatic effect occur in very high frequency (MAC KEY 1968) because the well buffered genomes of polyploids can tolerate losses of large chromosome segments and even of entire chromosomes (LARIK 1978a; LARIK & THOMAS 1979; LARIK *et al.* 1980a).

Extensive investigations on the effect of physical and chemical mutagens on the cytological behaviour of wheat and other plants have already been reported (GAUL 1977). However, cytological studies on the  $M_2$  and  $M_3$  populations are very limited (LARIK *et al.* 1980a). An attempt has been made in the present work to extend these studies. This paper presents an analysis of meiotic anomalies in  $M_3$  populations of bread wheat and discusses their significance with reference to genetics and plant breeding.

### Materials and Methods

$M_3$  populations of two cultivars (C-591 and Pak-70) of bread wheat *Triticum aestivum* L. em Thell ( $2n=6x=42=AABBDD$ ) derived from four irradiation treatments (gamma rays  $CO^{60}$ ; 10 and 20 kR and fast neutrons; 300 and 600 RADS) were sown through dibbling single seed per hole at 30.5 cm in randomized block design with five treatments, two varieties and four replications were critically examined for their meiotic behaviour. Seventy five seeds were planted in each plot with 15 seeds per row while plant to plant distance within a row was kept 10 cm.

Immature spikes from each irradiated treatments and control were fixed in Carnoy's (6:3:1) solution. Anthers were stained in alcoholic-hydrochloric acid carmine stain for 2 h at 60°C (SNOW 1963). Analysis of different stages of meiosis was done at MI and AI.

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## Results and Discussion

### Cytological observation in control plants

At metaphase I control plants regularly formed 21 bivalents, characteristic of diploid-like pairing reported in this species (RILEY 1974). Microsporocytes with two ring and rod bivalents were of normal occurrence. Pollen mother cells (PMCs) carrying chains and rings of four chromosomes were never encountered. Anaphase I in control plants revealed normal disjunction of 21:21 chromosomes on both the poles.

### Cytological observation in radiated plants

All the mutated populations revealed disturbed meiosis. We observed extensive irregular pairing (Table 1). Reciprocal translocations were either rings or chains of four chromosomes. They invariably resulted in adjacent type of segregation. The disjunction of ring quadrivalents was usually symmetrical i.e. one half going to one pole, the other half going to other, but there were few cells showing irregular separation as well. The most extreme types of associations were chain of 6-chromosomes+1<sub>IV</sub>(ring)+7<sub>II</sub>+18<sub>I</sub> and 1<sub>VI</sub>+18<sub>II</sub>. The occurrence of such associations indicates homology between more than four chromosome arms and the genotypes may thus be either doubly aneuploid or heterozygous for interchange. Other reason for such unusual type of associations may be allosyndetic pairing or heterozygosity for several translocations (KOUL 1964). In few cases chromosomes at MI appeared to be clumped. This can be attributed to the straight and narrow nature of the spindle.

Data in Table 1, indicate that fast neutrons were more efficient in producing aberrations. This may be interpreted to mean that more than one ionization was necessary to produce a break (LEA, 1955). However, a more critical examination of chromosomal

Table 1. The frequency of bridges (B), bridges+fragments (B+F), anaphase cells with normal separation and with laggards in mutated populations of *Triticum aestivum*

Treatment	PMCs analysed	ANAPHASE I						ANAPHASE II	
		21:21	20 1/1 20	19 2/2 19	18 3/3 18	B	B+F	B	B+F
<i>Fast neutron</i>									
C-591 (Control)	50	1.0	0	0	0	0	0	0	0
Pak-70 (Control)	50	1.0	0	0	0	0	0	0	0
C-591 300 RADS	50	0.74	0.18	0.08	0.03	0.10	0.03	0	0
C-591 600 RADS	50	0.59	0.28	0.12	0.06	0.12	0.04	0.01	0.02
Pak-70 300 RADS	50	0.50	0.31	0.06	0.04	0.09	0.02	0.01	0
Pak-70 600 RADS	50	0.48	0.26	0.10	0.08	0.15	0.06	0.02	0.04
<i>Gamma rays</i>									
C-591 10 kR	50	0.80	0.19	0.04	0.02	0.07	0.01	0	0
C-591 20 kR	50	0.90	0.14	0.06	0.04	0.09	0.02	0.01	0.01
Pak-70 10 kR	50	0.81	0.13	0.03	0.03	0.06	0.02	0	0
Pak-70 20 kR	50	0.86	0.18	0.08	0.03	0.11	0.04	0.02	0.03
Mean for categories		0.77	0.17	0.06	0.04	0.08	0.02	0.01	0.01

Table 2. Analysis of variance for meiotic anomalies in mutated population of *Triticum aestivum*

Source of variation	D.F.	S.S.	M.S.	F-ratio
Between Categories (C)	7	4.647	0.6638	125.16**
Between Treatments (T)	9	0.017	0.0019	N.S.
Error	63	0.454	0.0072	
Total	79	5.118		

\*\* Significant at 1% level of probability.

N.S.: Non-significant

Coefficient of variability (C.V.)

C.V.(C) = 18.73%

C.V.(T) = 20.94%

Difference between categories means

L.S.D. (.05) = 0.10

L.S.D. (.01) = 0.08

anomalies (Table 1) suggests that differences amongst various treatments of gamma rays and fast neutrons were not significant (Table 2). This may be due to the fact that the doses employed in the present experiment were selected on the basis of previous experience which aimed at the induction of an array of useful mutations (LARIK 1978b; LARIK *et al* 1980b). Selection of higher doses of gamma rays as well as fast neutrons are likely to create highly significant differences among treatments.

The results (Table 2) however, suggest that the differences amongst different categories of chromosomal anomalies were highly significant ( $P \geq .01$ ). Category 1 (21:21) was significantly different from all other categories at 1% level of significance. This is understandable as this category represents normal chromosome pairing and distribution. Category 2(20-20) was also significantly ( $P \geq .05$ ) different from all other categories (Table 1). The differences among other categories (from 3 to 7) gradually became diluted and consequently reached a non-significant level. The present analysis is perhaps the first critical analysis of chromosomal anomalies. Previous workers (NILAN *et al* 1962; LARIK 1975) have also reported similar anomalies but their experimental data were not subjected to proper statistical analysis and therefore were not amenable to meaningful inferences.

The occurrence of dicentric bridges accompanied by free acentric fragments were observed in many treated plants, suggesting that most of the individuals were heterozygous for paracentric inversions. First meiotic anaphase bridge results from dicentrics and should be lethal (DUBININ 1964). Laggards and unequal segregation at AI will give rise to aneuploid spores of uncertain viability (LARIK 1978a; LARIK & THOMAS 1979). Lagg- ing chromosomes arise from acentric fragments.

The occurrence of fragments in cells carrying bridges were considered to be due either to the smallest of the fragments or its disappearance in earlier division or its origin from the achromatic portions. Multipolar anaphase could have caused misdivision of centromeres, leading to the formation of chromosome fragments (FEDAK 1979, 1980). Another interesting point was the absence or rare presence of micronuclei which normally originated from



acentric fragments. The association of bridges and fragments with the meiotic sequence suggests that their formation depends upon an event which occurs regularly at meiosis. The most obvious event of this kind is crossing over. Presence of fragments in Nf 600 RADS of Pak-70 at MI points towards the process of breakages and reunion is similar to one considered by REES (1962) in rye. Structural differences between chromosomes could also be inferred from the present study of AI and AII where bridges accompanied by fragments were observed.

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## Aneuploid analysis for resistance against stem rust race 21 in wheat variety Kalyansona

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Up until 1954, when SEARS reported the production of a complete series of 21 monosomic lines in the hexaploid wheat variety Chinese Spring, all the studies regarding the inheritance of rust resistance were confined to conventional genetic analyses. In wheat, so far in all, 34 stem rust resistance genes have been indentified.

By aneuploid analyses till to date, 29 different *Sr* genes (*Sr*=stem rust=black rust=*Puccinia graminis* Pers. f. sp. *tritici* Eriks & Henn) have been located on specific chromosomes of hexaploid wheat by various workers. In the present investigation, attempt has been made to locate rust resistance gene(s) on specific chromosome(s) of wheat variety Kalyansona against race 21 of stem rust.

### Materials and Methods

Wheat variety Kalyansona was selected for locating gene(s) conditioning seedling resistance against stem rust race 21. Race 21 is one of the most prevalent races of stem rust in India. For this purpose monosomic analysis was employed. The 21 monosomic lines of wheat variety PbC591 used were developed by SWAMINATHAN *et al.* (1968).

Monosomic ( $2n=41$ ) plants were identified cytologically in all the 21 aneuploid lines of PbC591 and were crossed with Kalyansona.  $F_1$  progenies were grown and monosomic  $F_1$  hybrids were identified in all the 21 lines.  $F_2$  seeds were collected from the monosomic  $F_1$  hybrids and grown in the glass house for testing against race 21 of stem rust. To serve as control, PbC591 ( $2n=42$ ) was crossed with Kalyansona, the  $F_1$  progeny grown and  $F_2$  seeds collected for testing against stem rust race 21.

The  $F_2$  seedlings were raised and inoculations were carried out with the stem rust race according to the technique described by STAKMAN *et al.* (1944). Observations were recorded on the infection type 15 to 25 days after inoculation and classified according to the scale devised by STAKMAN *et al.* (1962). The tests were carried out at a temperature ranging from 8°C to 22°C.

A chi-square test was applied to the segregation ratios of the resistant and the susceptible plants obtained in the  $F_2$  generation of the control cross and after selfing the monosomic

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F<sub>1</sub> hybrids, after infecting with the rust race. The control cross provided the data of the conventional genetic analysis and among the F<sub>2</sub>, derived from the monosomic F<sub>1</sub>'s, only those lines which deviated from the expected ratios were considered to be the critical lines (chromosomes on which the resistance genes are located).

### Results and discussion

The inheritance of resistance in Kalyansona to race 21 was studied in crosses of PbC 591 monosomic lines with Kalyansona. Kalyansona produced '0;' type of reaction to race 21, whereas PbC591 produced a highly susceptible reaction of '4' type to this race.

The F<sub>2</sub> data for race 21 showing the mode of segregation in different monosomic F<sub>2</sub> families, including PbC591 (disome) x Kalyansona are presented in Table 1. A good fit to a ratio of 3R:1S was obtained in the F<sub>2</sub> of the disomic cross (control) as well as in the 18 families of the monosomic F<sub>2</sub>'s (F<sub>2</sub> of monosomic 5B and 7D x Kalyansona could not be studied). In the cross involving chromosome 5A, expected monogenic segregation was not obtained. 29 plants out of 30, from the progeny of monosomic 5A showed resistant type of reaction (Table 1) thereby suggesting that the dominant resistance gene, which governs resistance against race 21, is located on this chromosome of Kalyansona.

Table 1. Segregation of F<sub>2</sub> seedlings (from 41 chromosome F<sub>1</sub> hybrids) from crosses between variety Kalyansona and the monosomic lines of PbC591 inoculated with race 21 of stem rust

Chromosome	Resistant		Susceptible		Total	X <sup>2</sup> (3R:1S)	P. value.
	Observed	Expected	Observed	Expected			
1A	35	31.50	7	10.50	42	1.70	.20 .10
1B	43	41.25	12	13.75	55	0.29	.95-.50
1D	37	39.00	15	13.00	52	0.40	.95-.50
2A	39	36.75	10	12.25	49	0.54	.50-.20
2B	46	45.75	15	15.25	61	0.13	.95-.50
2D	43	36.00	5	12.00	48	5.38	.05-.02
3A	43	39.00	9	13.00	52	1.65	.20-.10
3B	39	40.50	15	13.50	54	1.71	.20-.10
3D	42	40.50	12	13.50	54	1.71	.20-.10
4A	30	32.25	13	10.75	43	0.62	.50-.20
4B	39	36.00	9	12.00	48	1.00	.50-.20
4D	42	39.00	10	13.00	52	0.92	.50-.20
*5A	29	22.50	1	7.50	30	44.37*	<0.01
5B	Not tested	-	-	-	-	-	-
5D	13	12.75	4	4.25	17	0.02	.95-.50
6A	36	31.50	6	10.50	42	2.56	.20-.10
6B	21	18.75	4	6.25	25	1.06	.50-.20
6D	27	30.00	13	10.00	40	1.20	.50-.20
7A	22	23.25	9	7.75	31	0.26	.95-.50
7B	32	35.25	15	11.75	47	1.18	.50-.20
7D	Not tested	-	-	-	-	-	-
DxD	84	84.75	29	28.25	113	0.02	.95-.50

\* Critical line; DxD=Disome x Disome (control).

A perusal of literature has revealed that so far no stem rust resistance gene has been located on chromosome 5A in any variety. It is thus proposed that the major dominant gene in variety Kalyansona, which governs resistance against race 21 of stem rust is an undescribed gene, or a possible translocation of a small segment into chromosome 5A from some other chromosome.

#### Acknowledgement

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## Frost damage to winter cereals in northern Iraq

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In Iraq about 6 million donums (1.5 million hectares) of wheat and 3 million donums (750,000 hectares) of barley are annually planted. The country, which lies between 29°5' and 37°22' north latitudes and 38°45' and 48°45' east longitudes, could be divided into two major winter cereal zones. The northern zone, between 35° and 37° latitudes, characterised by rain fed agriculture, predominantly pastoral and range management, and the central mesopotomian plains between the rivers Tigris and Euphrates, characterised by irrigated agricultural production systems. The latter zone is characterised by saline soils and barley is the dominant winter cereal. Nearly 80% of the total production of cereals are from the northern zone. The national productivity levels of wheat and barley are rather low at 600 to 800 kg per hectare more due to low levels of management than to ravages by pests or diseases. In the north the productivity levels fluctuate because of its dependency on rainfall. Besides, rarely occurring frost damage could be a contributing cause. The present note describes one such incidence.

During the crop season of 1979-80, frosty weather prevailed in the northern parts, in the Nineveh governorate (which accounts for 50% of the wheat and 25% of the barley area in the country), on the night of the 16 April, 1980, when the wheat and barley crops were in the late flowering to early dough stage. The damage was of the 'head frosting' type. Whole ears or sections of ears turned white and failed to develop further (Fig. 1). Developing grains were found shrivelled. Younger heads although with no apparent damage, had pronounced sterility. Glumes opened up with a translucent appearance with water soaked tissues. An average visual estimate of the damage could be placed at 50% of grain loss. Since the area affected was fairly large, this would imply a substantial reduction in wheat production this year. Although infrequent in occurrence the potential nature of this threat to wheat production is obvious, and should be taken into account in the cereal production systems of northern Iraq, and assess feasible protection measures, if any.

The meteorological conditions that favour frost are clear, cold, dry and calm atmosphere, into which there is an influx of dry cold air mass. When the temperature of the invading air mass is above the freezing point, there is a net loss of radiant energy from the plants and soil resulting in the rapid fall of temperatures of the plant body and soil. When the vapour pressure of the crop surface exceeds that of the surrounding air, there is a quick loss of heat by evaporation. The net result of these events is the formation of ice in the intercellular spaces, and this is lethal to the plant tissues. The affected parts take on a wilted appearance. Thus the climatological variables in the predisposition to frost

Table 1. Some climatological elements in four selected locations in northern Iraq and one central Iraq

Location	Mosul		Kirkuk		Sulaimniya		Salahdhin		Baghdad		
Period	1941-1970		1941-1970		1971-1977		1967-1977		1941-1970		
Months	March	April	March	April	March	April	March	April	March	April	
<i>Elements</i>											
I. Temperature °C											
i. Minimum mean											
	6.3	10.2	8.5	13.0	5.4	10.3	5.4	10.1	9.6	14.6	
	highest	9.8	12.9	11.2	16.5	8.1	12.8	7.1	13.2	13.7	16.6
	lowest	2.3	7.6	4.4	9.3	3.7	8.2	3.0	7.2	6.3	11.9
Extreme highest											
	16.6	23.3	19.7	23.7	12.4	17.2	13.7	19.0	21.2	25.0	
	lowest	-3.9	-1.6	-5.6	1.0	-6.5	2.9	-1.5	1.0	-2.8	1.2
ii. Maximum mean											
	19.0	25.4	19.3	25.5	15.3	20.5	13.3	18.7	22.7	28.7	
	highest	23.1	29.5	24.1	29.6	18.0	24.0	14.8	22.0	26.3	32.4
	lowest	14.0	21.3	14.7	21.6	12.0	18.8	10.5	15.4	18.6	25.6
Extreme highest											
	30.6	40.0	34.4	39.6	23.5	29.8	24.0	29.1	36.1	43.3	
	lowest	3.8	11.1	5.0	10.0	0.5	7.8	1.7	6.0	10.7	15.8
II. Surface wind											
speed m/s mean											
	2.3	2.4	3.0	3.1	2.7	2.0	3.2	3.0	3.6	3.5	
	highest	4.2	4.3	5.1	4.7	3.6	2.8	4.2	4.5	4.6	5.3
	lowest	1.1	1.0	2.1	1.6	1.9	1.5	2.5	1.9	2.0	2.8
III. Vapour											
pressure mb mean											
	10.0	12.2	9.3	10.8	7.6	9.6	7.1	9.2	9.4	11.2	
	highest	12.9	14.9	11.8	13.5	8.9	12.2	11.3	13.2	12.4	14.4
	lowest	7.5	9.2	6.9	7.8	6.4	7.9	6.1	8.8	7.3	8.9
Extreme highest											
	18.4	27.1	19.0	22.6	-	-	-	-	19.3	23.6	
	lowest	2.5	3.9	1.4	2.5	-	-	-	-	2.7	2.0

Source: Iraqi Meteorological Organisation, Climatological Normals, Publication 15. (1979-80)

are, (i) the temperature gradient between the plant and its environment, (ii) the corresponding vapour pressure gradient, and (iii) the wind speed over the plant surfaces.

In Table 1 are presented some climatological data for some selected locations in northern Iraq (Mosul, Krikuk, Sulaimaniya, and Salahdhin) as also for one of central Iraq (Baghdad). It will be seen from these data how the predisposing elements for a frosty weather prevail in the northern parts. It is possible that in the past there have been fortuitous frosty events in this region, but of so localised a nature as to escape notice, or of serious consequence. The present report of wide spread damage indicates the potential nature of the threat to the winter cereals of this area.

In the wheat growing regions of the world damage by frost is not unknown. For instance, heavy losses caused by frost to the wheat crop has been reported in Australia during the 1959 season (ANONYMOUS 1959) and during the 1970-71 season (GROSS 1971). The main characteristics of this damage is that it is infrequent, unpredictable, but can be severe if wide-spread. It is the spring season frost that causes the most damage, since the crop is at its active reproductive or grain filling stage, which are the most susceptible

stages in the wheat plant growth. It has been noticed that early season frost could be tolerated by varieties having cold tolerance, like the winter wheats, but late season or spring frost damages all varieties alike (SINGLE 1968). In this regard winter and spring wheat varieties do not differ appreciably since cold tolerance in the early vegetative stage is not linked with cold tolerance in the reproductive stages (MARTINIC 1974).

From the above observations arises considerations for possible protective measures that can be undertaken. From the view point of varietal manipulation, there are no spring wheat varieties specifically bred for resistance to late frost and are also suitable for Iraqi conditions. The only possible step, in this regard, is to recommend late maturing varieties, which might escape frost injury or recover from it. Even this step is of limited scope for Iraq due to the rapid increase in the summer temperatures during the months of May and June is not very favourable for grain filling. An operational protective measure is to irrigate the crop, if frosty weather could be forecast 2-3 days in advance (LANDRES & WITTE 1967). Sprinkler irrigation rather than flood or gravity irrigation is recommended. But in northern Iraq where the cereals are raised as rainfed crops scope for protective irrigation is very limited. Even if available, it would perhaps be more economical to protect plantation or vegetable crops than the cereals. Low lying areas are more prone to frost damage by the influx of air mass. Consequently, avoiding planting of low lying areas with wheat or barley will minimize the loss. Likewise, planted areas in neighbourhood of timbers or tall trees are more affected by frost and are to be avoided. Good seed bed preparation also helps in reducing frost damage on account of the good moisture holding capacity of the soil. Thus, the pre-planting protective measures to be taken in frost-prone areas are:

- i. good seed bed preparation;
- ii. Correct time of planting: if the variety planted is of the early maturing type avoid very early planting, or alternatively, plant late maturing types; both these steps facilitate recovery from frost damage, thus avoiding total failure of the crop;
- iii. avoid planting wheat or barley in low lying areas;
- iv. avoid planting in the vicinity of timber or tall trees;

When a standing crop of wheat or barley, planted in the hope of a normal season, has been overtaken by unexpected frosty weather, there is little that can be done as a protective measure. The few that are available depend for their effectiveness in the ability of the farmer to recognise frost injury immediately after the occurrence of frost. This is difficult since the symptoms can often be mistaken for those of fungal diseases. The following are a few of the hints to recognise frost injury. If one runs a hand back and forth brushing the plants damaged stalks usually bend at the point of injury. Stripping off the leaf sheath will expose injured nodes and internodes. Developing ears appear water soaked and flabby. Emerged ears, when affected have glumes gaping, or appear white and bleached. Frost injury can affect the central or basal spikelets in the ear and can thus be distinguished from the injury by hot, dry winds that affect the terminal spikelets. Once the frost

injury has been recognised, and the extent damage assessed, the steps to be taken in the treatment of the frosted crop, depend on the economic evaluation of the alternative choices, which are as below:

- i. irrigate, preferably by sprinkler irrigation:
- ii. cut for hay, or silage, or even graze off:
- iii. leave the crop untreated in the hope of some recovery.

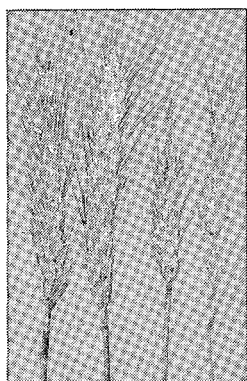


Fig. 1. (Left) Wheat variety Mexipak: two ears on the left normal, two ears the right frost damaged.

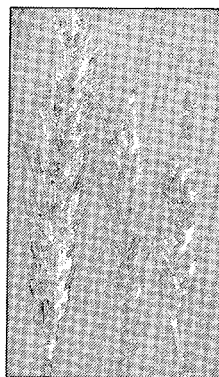


Fig. 2. (Right) Wheat variety Mexipak: normal ear (left) and frost damaged ears, middle and right: note aborted spikelets with empty glumes, and naked spike rachis.

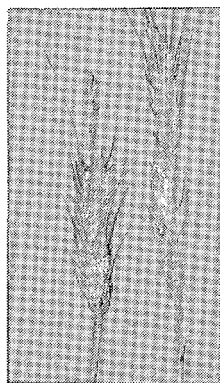


Fig. 3. (Left) Two frost damaged ears of Mexipak wheat: note differential top and bottom ear abortion depending on stage of ear development at frost incidence.

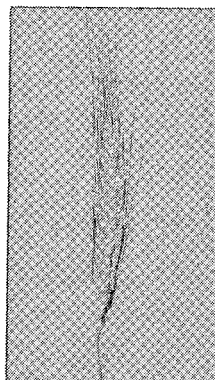


Fig. 4. (Right) Whitish ear of Italian wheat variety completely devoid of grains due to frost damage.

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## Gene action for earliness, plant height and spike characteristics in wheat

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The developmental of vigorous hybrid required a considerable time and efforts, thus, it is desirable to do estimation of heterosis and combining ability as earlier time of the breeding program. Moving target in the breeding procedure should be initiated by a good understanding of the mode of inheritance of quantitative genes affecting the desirable characters. The nature of genetic variability determines which type of selection will be the most effective in producing genetic advantageous. The variance due to average gene effects contributes fully to selection response whatever the type of selection applied. Genetic variance due to dominance and non-allelic interactions involving dominance are fully utilized in the future selection among  $F_1$  crosses of homozygous lines but are completely non-existent among the homozygous themselves.

This investigation based on five parent diallel cross. Such technique has been adopted extensively by many investigators in self and cross-pollinated crops in order to provide satisfactory introduction of the genetic mode of actions and genes that governing a particular quantitative characters. These studies have been commonly used with  $F_1$  hybrids only.

This investigation was conducted to evaluate five parents and 10  $F_1$ 's hybrids combinations in order to detect the amount of heterosis and combining ability in earliness, plant height and spike characteristics.

### Materials and Methods

A diallel cross involving five cultivars of wheat from diverse regions were utilized in this investigation. These cultivars were: Super X (Mexican), Hinta Madeni (Local), Giza 155 (Egypt), Arz (Mexican) and one triticale called Arabian (Mexican).

10  $F_1$ 's hybrids seeds (excluding reciprocals) along with five parents were planted in 1980 season in Jiffy pots (one seed per pot) and kept in the greenhouse. Three weeks later seedling were transplanted into the field after ideal preparation to the plots of land. The experiment were laid out at Faculty of Agriculture (Olisha), Riyadh University.

The experimental design was a randomized complete block with four replications. Each entry was represented by a row of 10 plants spaced 40 cms. apart and 30 cms. between rows.

Observations were recorded on five metric traits, namely days to heading, plant height (cm), spike length (cm), number of spikelets per spike and spike density.

$$\text{Spike density} = \frac{\text{No. of spikelets per spike}}{\text{Length of spike axis in mm}} \times 100$$

The data obtained for each trait on the basis of single plants and were analyzed on a plot mean basis by the analysis of variance. Significance differences was determined by F-test.

Percentage of mid-parent heterosis (MP) was computed as  $\frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$ . Similarly,

percentage of high-parent mean heterosis (HP) was determined as  $\frac{\overline{F_1} - \overline{HP}}{\overline{HP}} \times 100$ .

Estimates of general and specific combining ability were obtained by employing partial modified diallel cross method developed by MATZINGER and KEMPHORNE (1956) in which one set of  $F_1$ 's are included.

### Results and Discussion

Heterosis:

Heterosis percentages, deviation of the  $F_1$  means from the mid-parent values as well as over better parent was used to estimate the preponderance of dominant gene effects, acting in one direction, at loci by which the parental complements differ. The data for different traits based on means of midparent (MP) and higher parents(HP) are shown in Table 1.

Observable heterosis significant mean a sets of genes indicates dominance of the individual genes preponderantly in the same or in reverse direction; but no significant or zero heterosis does not necessarily mean absence of dominance.

Days to heading and spike density in the  $F_1$  showed a highly significant tendency to be lower than the parental mean value and heterosis percentage -3.51 for days to heading and -3.59 for spike density. Thus amongst the parents of the diallel there were present gene sets for controlling heading date and spike density at a loci by which the parents are differed.

For the characters plant height, spike length and number of spikelets per spike the mean  $F_1$  value was either greater than or equivalent to the parental mean. An analysis of variance for grain yield in the  $F_1$  was carried out (AL-SAEAL & GAMIL) which indicated significant differences between lines, both parental and  $F_1$ , for its expression.

It can be concluded from the previous results that there are no useful heterosis observed in these materials or, at least, was not of economical usefulness.

Similar results was obtained for days to heading by ROSENQUIST (1931), CLARK & HOOKER (1926), JOHNSON *et al.* (1966), AMAYA *et al.* (1972), and BHATT (1972). The results of plant height are in agreement with that reported by GRANHALL (1946), GANDHI *et al.* (1961), STUBER *et al.* (1962), JOHNSON *et al.* (1966) and AMAYA *et al.* (1972).

Regarding to spike length GRANHALL (1946), SIKKA *et al.* (1959), GANDHI *et al.* (1961) and JOHNSON *et al.* (1966) came up to similar trend of findings. PAL & NEK ALAM (1938), SIKKA *et al.* (1959) and HASSANIEN *et al.* (1974) found similar results in number of spikelets per spike.

Table 1. Expression of heterosis in F<sub>1</sub> over mid (MP) and higher (HP) parents in percentage for the traits studied in 5-parent diallel cross in wheat.

Traits	Days to Heading	Plant Height	Spike Length	No. of Spikelets /Spike	Spike Density
F <sub>1</sub>	82.5	63.8	11.2	43.8	43.0
Range of F <sub>1</sub>	79.0-87.7	57.9-69.5	10.1-12.2	40.6-50.6	37.6-51.1
Mid-parent	85.5	61.7	10.7	43.3	44.6
Range of parents	83.3-91.8	58.5-66.8	9.7-12.1	40.1-50.1	38.1-53.1
High-parent	91.8	66.8	12.1	50.1	53.1
(MP) heterosis %	-3.51**	3.40**	4.67**	1.15	-3.59**
LSD 0.05	1.0	1.9	0.2	2.0	1.2
LSD 0.01	1.3	2.5	0.3	2.6	1.6
(HP) heterosis %	-0.96	-4.49	-7.44**	-12.57**	-5.91*
LSD 0.05	1.9	3.6	0.5	3.8	2.3
LSD 0.01	2.5	4.8	0.7	5.0	3.1

Significant level in this table and all tables are: -

\* 0.05%

\*\* 0.01%

Table 2. Mean squares for F<sub>1</sub> hybrids, general (GCA) and specific (SCA) combining ability for the traits involving 5-parent diallel cross of wheat.

Traits	Mean Squares of			GCA/SCA
	F <sub>1</sub>	GCA	SCA	
Days to heading	38.74**	64.10**	38.52**	1.66:1
Plant height	67.47**	94.92**	45.51**	2.09:1
Spike length	1.52**	2.57**	0.68	3.78:1
No. of Spikelets/spike	42.68**	42.05**	43.18**	0.97:1
Spike density	88.47**	142.20**	45.48**	3.13:1

#### Combining Ability:

The results appeared that there are highly significant differences in F<sub>1</sub> hybrids for all measured traits. Comparisons of general combining ability (GCA) versus specific combining ability (SCA) indicated that GCA was greater in magnitudes than SCA for all traits studied except number of spikelets per spike. The estimates of GCA and SCA were positive and highly significant for all traits with the exception of spike length even though there are insignificant differences in SCA for this trait. It can be concluded from the results obtained in this study that the differences among the hybrids are due to general as well as specific combining ability for all traits except spike length which showed that a large portion of the total genetic variability was a result of GCA. The results obtained for days to heading and plant height are in agreement with that obtained by KRONSTAD and FOOTE (1964), GYAWALI *et al.* (1968), SOOMRO and AKSEL (1976), and EL-HADDAD and ALI (1979). However, BROWN *et al.* (1966), and WIDNER & LEBSOCK (1973) found only highly significant general combining ability for plant height. The results concerned with spike length agreed with that obtained by JOHNSON *et al.* (1966). While, JAIN & SINGH (1976)

and EL-HADDAD & ALI (1979) found that both general and specific combining ability estimates were highly significant in the effect on this trait. Regarding to number of spikelets per spike WALTON (1971) and JAIN & SINGH (1976) reached to the same results, contradicted the findings of HASSANIEN *et al.* (1974). However, KRONSTAD & FOOTE (1964) and EL-HADDAD & ALI (1979) obtained highly significant differences in only GCA. Gene Action:

Variances of general ( $\sigma_G^2$ ) and specific ( $\sigma_S^2$ ) combining ability and gene action estimation measured in terms of additive ( $\sigma_A^2$ ) and dominance ( $\sigma_D^2$ ) genetic variance are presented in Table 3 and Table 4.

Table 3. Estimates of variance components for general ( $\sigma_G^2$ ) and specific ( $\sigma_S^2$ ) combining ability for five traits in  $5 \times 5$  diallel cross in wheat.

Traits	Variance Components	
	$\sigma_G^2 \pm SE$	$\sigma_S^2 \pm SE$
Days to heading	2.13 $\pm$ 3.53	8.79* $\pm$ 5.15
Plant height	4.12 $\pm$ 5.00	8.39* $\pm$ 6.13
Spike length	0.16* $\pm$ 0.13	0.10* $\pm$ 0.10
No. of Spikelets/spike	-0.09 $\pm$ 2.79	9.73* $\pm$ 5.78
Spike density	8.06* $\pm$ 7.14	9.88* $\pm$ 6.09

Table 4. Estimates of additive ( $\sigma_A^2$ ) and dominance ( $\sigma_D^2$ ) genetic variance for five traits studied in  $5 \times 5$  diallel cross in wheat.

Traits	Additive & dominance variances	
	$\sigma_A^2 \pm SE$	$\sigma_D^2 \pm SE$
Days to heading	4.26 $\pm$ 7.06	8.79* $\pm$ 5.15
Plant height	8.24 $\pm$ 9.99	8.39* $\pm$ 6.13
Spike length	0.32* $\pm$ 0.25	0.10* $\pm$ 0.10
No. of Spikelets/spike	-0.18 $\pm$ 5.28	9.73* $\pm$ 5.78
Spike density	16.12* $\pm$ 14.27	9.88* $\pm$ 6.09

The results obtained in this study indicated that the variance of general combining ability ( $\sigma_G^2$ ), i.e. additive gene action ( $\sigma_A^2$ ) estimates were only significant for spike length and spike density. Whereas, significant specific combining ability components ( $\sigma_S^2$ ), i.e. nonadditive genetic variance, have been reported for all traits, in comparing the relative magnitudes of general ( $\sigma_G^2$ ) versus specific ( $\sigma_S^2$ ) combining ability genetic variance components for all traits except spike length had higher ( $\sigma_G^2$ ) than ( $\sigma_S^2$ ). These results suggest that a large part of the total genetic variability associated with days to heading, plant height and number of spikelets per spike was a result of nonadditive gene action. However, additive as well as dominance genetic variance are responsible for the inheritance of spike length and spike density.

The results of days to heading since only significant dominance genetic variance are in agreement with that reported by JOHNSON *et al.* (1966), contradicted that findings obtained by BHATT (1972) and ALI & EL-HADDAD (1978). However, AMAYA *et al.* (1972) found that early genotypes may be attainable only with a system that can exploit both additive and nonadditive genetic effects. AMAYA *et al.* (1972) came up to similar conclusion regarding plant height, while ABO EL-ENEIN & GOMMA (1977) found only highly significant additive gene action. The results of spike length are in agreement with that obtained by ALI & EL-HADDAD (1978). Similar findings have been reported in number of spikelets per spike by HASSANIEN *et al.* (1974), while ALI & EL-HADDAD (1978) found that this trait had higher and highly significant additive gene action in relation to nonadditive types.

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**A dominant gene of dwarfism located on chromosome 4D  
in *Triticum aestivum* cv. 'Ai-bian 1'**

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Reduction of plant height is one of the main subjects in modern wheat breeding, and dwarf or semi-dwarf genes have been identified in common wheat (reviewed by KONZAK 1975; GALE & LAW 1978; GOTOH 1977). There are three major genes genetically well analysed. Norin 10 has two major recessive semi-dwarfing genes, *Rht-1*, and *Rht-2* (ALLAN *et al.* 1968; FICK & QUALSET. 1973), which has been used as a donor parent to introduce modern semi-dwarf cultivars. These genes were identified to be located on chromosome 4A (GALE and MARCHALL 1976) and on 4D (GALE *et al.* 1975), respectively. On the other hand, a variety 'Tom Thomb' has a semi-dominant dwarf gene, *Rht-3*, located on 4A (MORRIS *et al.* 1975).

Plant height is a quantitative character affected considerably by aneuploid condition, which have made it difficult to determine the number of dwarfing gene involved or the type of gene action. To avoid these difficulties, the insensitivity test to gibberellic acid was employed (ALLAN *et al.* 1959; GALE *et al.* 1975), which clarified the characteristics of dwarf genes.

Recently, a very short stature variety, 'Ai-bian 1' (winter wheat) had been bred at Genetics & Breeding Institute of Shei-Bei Agricultural Academy (San-Shi, China), and the seeds were sent to Dr. H. KIHARA (Kihara Institute, Yokohama, Japan) for research study. The authors would like to express their sincere thanks for their supplying the seeds of 'Ai-bian 1' for the present study. The study was carried out to identify the characteristics of the dwarf gene in 'Ai-bian 1'.

#### Materials and Methods

Plant characters of 'Ai-bian 1' were compared with those of 'Chinese Spring' (tall variety) and 'Norin 10' (semi-dwarf). Plant height, spike length, number of tillers, leaf length, internode length, and seed-set were examined with twenty plants for each line.

'Ai-bian 1' was crossed as the male parent with monosomic lines and normal disomics of 'Chinese Spring'. The  $F_1$  plants were grown in the greenhouse, and monosomics were selected cytologically. The selected  $F_1$  plants were selfed for obtaining  $F_2$  progeny. The  $F_2$  obtained were sown in pots and vernalized at 5°C for 4 weeks. Subsequently, they were transplanted in a randomized block design with three replications in the field during spring, 1981 at the experimental field of Obihiro Univ., Obihiro, Japan. Some  $F_2$  families were restricted in the population size and 6D group was not obtained because of dry cultivation condition at transplanting.

The measurement were conducted on the individual basis. The population was classified into two groups, short and tall, by using 50 cm as the criterion. Chi-square test was applied to ascertain whether the segregation of each group fits to 3:1 ratio.

### Results and Discussion

Table 1 indicates that 'Ai-bian 1' has very short stature and leaf length, but has normal number of tillers, spike length and number of floret in comparison with other two. All three variety has 4.2 internodes in average. This indicates that the dwarfness of 'Ai-bian 1' is due to short internode length but not to the reduction of internode number. 'Ai-bian 1' has relatively small stamens (2 mm in length) and it flowers without completion of head emergence. The pollen fertility and seed-set of 'Ai-bian 1' are normal except that the late tillers tend to have less seed-set.

The 33 F<sub>1</sub> plants examined showed almost similar height to each other and the F<sub>2</sub> family segregated into short and tall with 3:1 ratio, suggesting that the dwarfism of 'Ai-bian 1' is controlled by a single dominant gene (Fig. 1, Table 2).

Chi-square test, carried out on each F<sub>2</sub> monosomic group, showed that all groups except one in 4D group fit to 3:1 ratio for the gene action of a single dominance (Table 2). On the other hand, 4D group had significant different segregation from 3:1 ratio, and, also, had the

Table 1. Comparison the main chcracters of Chinese Spring, Norin 10 and Ai-bian 1.

	Plant height (cm)	Spike length (cm)	No. of tiller	No. of internode	No. of floret	Internode length* (cm)				Leaf length* (cm)		
						1	2	3	4	1	2	3
C.S.	82	6	9	4	11	37	24	9	5	26	21	15
Norin 10	56	8	22	4	13	21	15	7	4	20	20	16
Ai-bian 1	23	7	22	4	16	7	5	2	2	12	12	9

\* Internodes and leaves from the top of mian tillers.

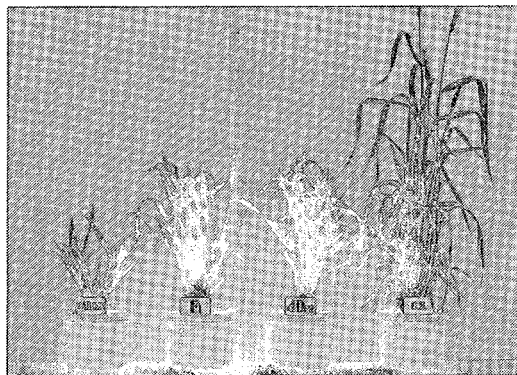


Fig. 1. A dwarf variety, 'Ai-bian 1' and its hybrids with 'Chinese Spring'; (from left to right) 'Ai-bian 1', F<sub>1</sub> (Chinese Spring × Ai-bian 1), F<sub>2</sub> (monosomic 4D × Ai-bian 1), and Chinese Spring.



least standard deviation and mean height among  $F_2$  monosomic groups (Fig. 2, Table 2). 4D group had only one tall plant (55 cm), which might be nullisomic because it had narrow leaves, less tiller number and low fertility. These results indicate that the dwarf gene of 'Ai-bian 1' locates on chromosome 4D.

Except 4D group, the 530  $F_2$  monosomic progeny were examined, and the culm length frequency had two peaks at 40-44 cm and 65-69 cm, so that  $F_2$  monosomic progeny could be classified into two groups if divided at 50 cm. This segregation gives a good fit to 3:1 ratio with Chi-square test. This result indicates, also, that 'Ai-bian 1' had a single dominant gene of dwarfism.

The distribution of plant height in  $F_2$  family of 1A showed a different shape from others (Fig. 2), where the peak was at the shortest column (20-24 cm) and the frequency tended to down along the height went up (Fig. 2). The plant height of 5D group was the highest with the largest standard deviation among the  $F_2$  groups. MORRIS *et al.* (1972) reported the similar phenomena in the monosomic analysis with "Tom Thumb" to the present observations. One of the semi-dwarf genes in 'Norin 10' *Rht-2* was reported to locate on chromosome 4D (GALE *et al.* 1975), where the dwarf gene of 'Ai-bian 1' was involved in. However, the present data indicate the gene action of dwarfism in 'Ai-bian 1' is different from that of *Rht-2* in 'Norin 10'. The preliminary observation suggested the dwarfness of 'Ai-bian 1'

Table 2. Mean height, standard deviation of height, number of short and tall groups with Chi-square tests for 3:1 segregation.

	Mean height (cm)	Standard deviation (cm)	Number of plant		Probability (%) with Chi-square (3:1)
			Short	Tall	
C.S.	73	11	0	27	
Ai-bian 1	19	3	31	0	
$F_1$	33	4	20	0	
$F_2$	38	16	6	2	100
1A	36	12	32	7	30-50
2A	47	16	3	3	10-20
3A	44	19	27	10	70-80
4A	42	19	23	7	80-90
5A	47	19	16	6	80-90
6A	42	19	28	12	30-50
7A	41	16	22	7	90-95
1B	45	19	28	12	30-50
2B	43	15	9	3	100
3B	41	22	6	2	100
4B	37	14	16	1	5-10
5B	45	20	3	2	30-50
6B	44	16	27	12	30-50
7B	36	15	37	7	10-20
1D	43	17	24	10	50-70
2D	38	17	21	6	70-80
3D	39	12	24	3	5-10
4D	35	8	33	1	0.1 -1
5D	48	24	26	14	10-20
6D	-	-	-	-	-
7D	43	15	22	12	10-20

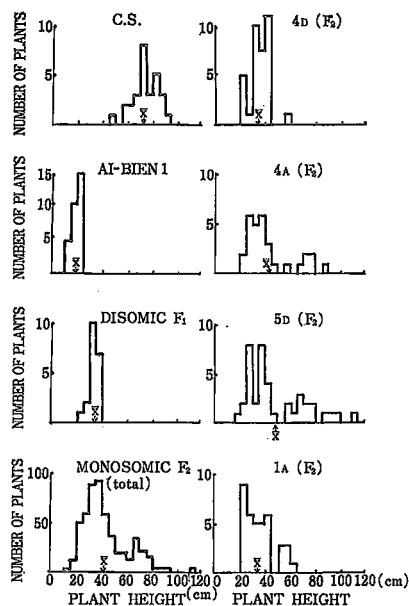


Fig. 2. Frequency distribution of plant height in 'Ai-bian 1', Chinese Spring, and their disomic and monosomic hybrids.

was insensitive to  $GA_3$ . The further study will be conducted with sufficient population size on the interactions of this gene with other semi-dwarf genes as well as detail analysis on gibberellin sensitivity.

The present study points out that the dwarf gene of 'Ai-bian 1' is completely dominant which has not been studied in the past, and that its dwarfing effect is distinct without sacrifice of fertility in comparison with other dwarf genes.

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## Heterosis in wheat (*Triticum aestivum* L.)

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Heterosis, the increased vigor of  $F_1$  over the mid and better parents is the result of allelic or non-allelic interaction of genes under the influence of a particular environment. One of the most important developments in plant breeding of recent times has been the extension of the use of heterosis to many crop plants including wheat for increased yield. Continued attention has been given for the possible use of heterosis from intervarietal hybrids of wheat to advantages in yield and stability of performance for genetically diverse population. Recently, however, numerous investigators have engaged themselves with new enthusiasm to determine heterosis in wheat. Many scientists have established the fact that heterosis does occur with proper combination of parents.

TSUNEWAKI (1970) reported heterosis for plant height in geographically & distantly related varieties, whereas, significant heterosis was reported by SINGH (1978) for plant height character. CHOWDHRY *et al.* (1972) reported significant heterosis for number of tillers per plant. Strongest heterosis for number of tillers per plant was reported by POPOVIC (1976). HRASKA (1975) reported heterosis for spike length, kernels per spike, and plant height exceeding 10 percent over the mid parental value and SINGH (1978) reported significant heterosis to mid and better parental value for this character.

BITZER & FU (1972) reported heterosis for number of kernels per spike exceeding 5 percent over the better parent, whereas, positive and significant heterosis for this character was also reported by SINGH (1978). GRANT (1970) reported 25–36 percent increase in grain yield, whereas, SHABESKI (1970) reported heterosis exceeding 30–50 percent over the better parent in grain yield. HASSANAIEEN *et al.* (1974) observed heterosis increasing 8–94 percent and 2–62 percent over the mid and better parental value respectively. CREGAN & BUSH (1978) reported 5 to 58 percent increase in grain yield over the mid parental value.

### Materials and Methods

The experimental material used for the study comprised of ten wheat varieties viz: Pak 70, Chenab 70, C 591, C 273, H 23–42, LU 75, Mexi-pak 65, Cajemo, Tobari and Torum and ten crosses viz. (i) Pak 70 × Torim, (ii) Cajemo × Pak 70, (iii) Torim × C 591, (iv) H 23–42 × Tobari, (v) LU 75 × Chenab 70, (vi) LU 75 × Mexipak 65, (vii) LU 75 × C 293, (viii) Mexipak 65 × Chenab 70, (ix) Mexipak 65 × C 273 and (x) C 273 × Chenab 70.

Hand crossing were made in 1977 and the  $F_1$  seed thus obtained was sown in the field alongwith their respective parents in the following year in randomized complete block

design, one row for each line with three replications. The seeds were dibbled in rows three meters long and 30 centimeters apart. The distance between the two plants was kept at 20 centimeters. All cultural treatments were provided. Non-experimental border rows were also grown.

A total of 10 plants from each cross and from each parental variety was taken for observation from each replication. The data on different plant characteristics was recorded in the following manner.

Table 1. Mean squares for the parents.

	Plant height (cms.)	Number of tillers per plant	Spike length (cms.)	Number of kernels per spike	100 kernel weight (gms.)	Yield per plant (gms.)
Blocks	0.10 N.S	0.04 N.S	0.36 N.S	0.66 N.S	3.11*	0.05 N.S
Varieties	956.20**	4.22**	8.12**	367.84**	0.70**	134.17**
Error	0.91	0.28	0.39	1.85	0.02	0.89

N.S. = Non Significant

\*\* & \* = Significant at 5 and 1% levels.

Table 2. Mean squares for crosses

	Plant height (cms.)	Number of tillers per plant	Spike length (cms.)	Number of kernels per spike	100 kernel weight (gms.)	Yield per plant (gms.)
Blocks	3.17 N.S	2.55 N.S	0.40 N.S	0.60 N.S	0.02 N.S	0.42 N.S
Crosses	183.24**	36.80**	7.48**	322.02**	0.95**	144.16**
Error	1.88	0.83	0.27	0.87	0.10	0.41

N.S = Non Significant

\*\* = Significant at 1%.

Table 3. Percentage increase (+) or decrease (-)

Sr. No.	Crosses Parents	Plant Height		Tiller Number	
		Mid	Better	Mid	Better
1.	Pak 70 × Torim	+18.65	- 3.35	-17.16	-22.40
2.	Cajemo × Pak 70	- 1.45	-13.26	+53.27	+44.80
3.	Torim × C 591	+ 6.00	-21.01	+24.85	+18.08
4.	H 23-42 × Tobar	+ 4.37	+ 2.38	+30.01	+29.77
5.	LU 75 × Chenab 70	+15.68	+ 0.26	+39.82	+29.10
6.	LU 75 × Mexipak 65	+30.32	+22.91	+72.07	+55.14
7.	LU 75 × C 273	+26.14	+ 7.13	+64.10	+52.51
8.	Mexipak 65 × Chenab 70	+10.48	+ 0.96	+11.00	+ 8.15
9.	Mexipak 65 × C 273	+36.89	+22.04	+59.10	+53.96
10.	C 273 × Chenab 70	+16.43	+13.64	+41.42	+40.33
Average		+15.68	+ 6.78	+37.68	+35.81

*Plant height.*

Plant height of the central tiller was noted in centimeters from the base up to the earhead excluding awns.

*Number of tillers per plant.*

The number of fertile tillers borne by the plant were counted a few days before harvesting.

*Spike length.*

Spike length of three randomly taken spikes was measured in centimeters from the base to the tip excluding awns and then averaged.

*Number of kernels per spike.*

The total number of kernels were manually counted of three randomly taken spikes per plant and then averaged.

*100 Kernels weight.*

One hundred kernels from the produce of the individual plant was randomly taken and their weight in grams was recorded.

*Grain yield per plant.*

Yield of grains per plant was recorded in grams with torsion balance.

The entire data was processed according to Fisher's method for analysis of variance on average values.

### Results and Discussion

Recently many plant breeders have suggested that heterosis does occur in bread wheat and if proper combination of parents is ascertained, it can be used commercially in hybrid wheat breeding programmes.

As it is seen from Table 1 and 2, mean squares for parents and for crosses were highly significant for all the characters including grain yield.

*Plant height.*

Nearly all the hybrids showed positive heterosis, except one hybrid to better parental of F1 hybrid over the mid parent or better parent.

Spike Length		Kernels Per Spike		100-Kernel Weight (mgs)		Grain Yield (gms.)	
Mid	Better	Mid	Better	Mid	Better	Mid	Better
+ 6.69	+ 6.59	+ 2.93	+ 2.17	+11.85	+ 5.45	+ 1.71	+ 0.89
+17.51	+14.36	+ 8.71	+ 6.63	+15.06	+ 7.14	+39.44	+37.11
+ 7.25	+05.84	+10.79	+ 9.01	+16.03	+ 8.45	+35.45	+18.17
+ 7.22	-12.20	+16.11	+ 2.83	+ 3.62	-10.00	+22.34	+ 6.25
+33.11	-26.73	+26.17	+ 6.41	+48.60	+24.87	+40.27	+34.05
+64.18	+37.99	-22.90	-31.73	+41.41	+39.23	+38.34	+18.50
+50.19	+37.44	+ 4.93	- 0.49	+36.01	+27.06	+14.59	+ 2.83
+ 2.30	-10.26	+ 5.67	-19.17	+56.15	+29.58	+54.72	+37.86
+29.15	+17.38	+ 7.66	- 8.94	+61.51	+48.18	+36.58	+29.53
+31.56	+26.51	+23.32	+ 8.89	+35.38	+21.20	+51.61	+42.75
+23.64	+21.40	+ 7.46	+ 2.22	+31.85	+22.85	+33.24	+31.16

value. As regards the mean performance, the hybrids were 15.68 percent taller than the better parent. Cross LU 75 × Mexipak 65, showed highest increase of 22.91 percent and 30.32 percent to better and mid parental value respectively.

The results obtained are in confirmation with those of HRASKA (1975), who reported 10 percent increase over mid parent.

#### *Number of tillers per plant.*

This is an important component of yield in wheat. As it is clear from table 3, all the hybrids expressed heterosis for this character except one hybrid of cross Pak-70 × Torim, which showed a negative heterosis of 22.4 and -17.16 percent as compared with their respective superior and mid parents. On the basis of over all mean performance, the hybrids bore 37.68 percent and 35.81 percent more tillers than the mid and superior parents respectively.

The results are in agreement with those obtained by CHOUDHRY *et al.* (1974), who reported significant heterosis to this character.

#### *Spike length.*

Spike length is another yield component as in many cases it results in increased number of grains per spike and eventually the increased yield per plant. The most outstanding hybrid in respect to this character was LU 75 × Mexipak 65, which exhibited heterosis of 37.99 percent and 64.18 percent for superior and better parental values respectively.

The average increase in spike length for all the hybrids has been found to be 21.64 percent and 23.64 percent as compared to the respective better and mid parental values.

The results are in accordance with those obtained by HRASKA (1975) who reported 10 percent increase over the mid parental value for this character. Also, SINGH (1978), reported significant heterosis for this character as well.

#### *Number of kernels per spike.*

Another important yield component under study was the number of kernels per spike. A considerable amount of vigour has been exhibited by the hybrids in respect of their mid parental value. The over all mean performance of the hybrids has been found to be 2.22 percent and 7.46 percent, though the result of cross Torim × C591 was very encouraging, showing a high increase of 9.01 percent and 10.79 percent as compared to its respective better and mid parental value.

The results obtained agree with those reported by HRASKA (1975), who observed heterosis exceeding 10 per cent over the mid parental value. SINGH (1978), reported significant and positive heterosis of 3.94 to 31.00 per cent with respect to superior parent.

#### *100-kernal weight.*

All the hybrids exhibited a high degree of heterosis for this character. Hybrid Mexipak 65 × C273 showed the highest heterosis of 48.18 percent and 61.51 percent as compared to their respective superior and mid-parental value. The mean performance of the hybrids exceeded in kernel weight by 22.85 percent and 31.85 percent respectively for superior and mid-parental values.

The results are in agreement with those obtained by HRASKA (1975) who reported heterosis exceeding 33.7 percent and 10 percent to the better and mid parental values respectively. SINGH (1978) reported an increase of 5.9 to 11.91 percent over the mid-parental value.

#### *Grain yield per plant.*

The grain yield per plant has a prime importance in any breeding programme. It is seen from the table that all the hybrids exhibited a marked superiority over respective mid and superior parental value. The most out-standing hybrid was of the cross C 273 × Chenab 70, which out-yielded the better parent by 42.75 percent and the mid parent by 51.61 percent. Regarding the mean performance, the F<sub>1</sub> hybrids surpassed in yield by 33.24 percent and 31.16 percent to the mid and better parental values.

The results are in accordance with those obtained by MAKENZIE and GRANT (1970) who obtained the hybrids with 25.36 percent increase in grain yield, SHEBESKI (1970) who reported heterosis increasing 30.50 percent over the better parent. HASSNAIEN *et al.* (1974) reported heterosis increasing 8.94 percent over the mid parental value and 2.62 percent over the better parent. CREGAN & BUSCH (1978) obtained hybrids exceeding 5 to 58 percent over the mid parent in grain yield.

All the hybrids exhibited an average increase over the better parent by 6.78, 35.81, 21.40, 2.22, 22.85 and 31.16 percent respectively for plant height, number of tillers per plant, spike length, number of kernals per spike, 100-kernel weight and grain yield per plant.

The most promising of all the hybrids was of the cross C 273 × Chenab 70, which transgressed the better parent by 42.15 percent in grain yield, 40.33 percent in number of tillers per plant, 26.51 percent in spike length, 21.20 percent in 100-kernel weight, 19.33 percent in plant height and 8.89 percent in number of kernels per spike.

In order of merit, the yield components such as number of kernels per spike, number of tillers per plant and spike length contributed towards grain yield. However 100-kernel weight showed lowest variation.

Finally, it was also observed that the crosses which involved the high yielding parents with diverse and geographically distant origin exhibited the greater hybrid expression.

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## Correlation, multiple correlation and path coefficient analysis of yield components in wheat (*Triticum aestivum* L.)

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The knowledge of interrelationships of factors influencing yield which is a complex phenomenon, is a prerequisite for designing an effective plant breeding programme (WORLEY *et al.* 1976). Although information about the correlation of agronomic and morphological characters with yield is helpful in the identification of the components of this complex character, yet, these do not provide precise information on the relative importance of direct and indirect influences of each of the componential character (LARIK 1978). With increasing number of variables it becomes necessary to measure the contribution of these variables to the observed correlation and hence partition the correlation coefficients into components of direct and indirect influence (PANDEWY & GITTON 1975). Path coefficient analysis provides an effective means of partitioning correlation coefficients into unidirectional pathway and alternate pathways. This analysis thus permits a critical examination of specific factors that produce a given correlation and could be successfully employed in formulating an effective selection strategy. This technique has been extensively used by conventional breeders (BHATT 1973; LYRENE & SHANDS 1975).

The present study with a wheat variety 6591 was therefore conducted to provide information on interrelationship of grain yield with some important yield components and partition the observed phenotypic correlations into their direct and indirect effects in order to identify characters of utmost importance which may be used as selection criteria in a wheat breeding programme.

Simple correlation coefficient ( $r$ ) and regression coefficient ( $b$ ) were calculated after SNEDECOR (1956) and multiple correlation was calculated by using the formulae of STEEL & TORRIE (1960). Phenotypic correlations were partitioned into path coefficient using the technique outlined by DEWEY & LU (1959). This technique involves partitioning of correlation coefficient to determine direct (unidirectional path-ways ('P')) and indirect influence through alternate pathways (Pathway 'P' $\times$  correlation coefficient 'r) of various variables over grain yield per plant. Grain yield was considered as the resultant variable and the others as causal variables.

### Results and Discussion

Simple correlation coefficient (phenotypic) between all possible combinations were estimated (Table 1). Results reveal that all the characters exhibited a strong positive



correlation ( $P \geq .01$ ) with their possible combinations. The correlations reported by BHATT (1973), VARIK & VERMA (1972) and LARIK (1978) also reveal similar associations. This indicated that selection for these characters can be effective in the search of high yielding wheat varieties.

Multiple correlation has been worked out between five yield components and grain yield per plant. Multiple correlation (Table 2) was found to be 0.6392251 which indicated that about 71 percent of total variability in grain yield was due to the variation in the four independent variables. Highly significant multiple correlation coefficient was observed from the mean squares.

The pathways through which the four yield components operate to produce their phenotypic association with grain yield reveal direct and indirect contributions (Table 3) and are demonstrated diagrammatically in Fig. 1. The path coefficient analysis showed that the direct effect of spike length on grain yield was low and negative. The indirect effect via spikelets and spike yield was positive but very low in magnitude. Total correlation coefficient (0.4778) between spike length and grain yield was mainly due to its effect through seeds per spike (0.361158), which was high and positive and formed 75.59% of

Table 1. Phenotypic correlation among all possible combinations of five different quantitative characters.

Characters correlated	Spike length (1)	Spikelets per spike (2)	Seeds per spike (3)	Spike Yield (4)	Yield per plant.
Spike length	1.00	0.680**	0.620**	0.560**	0.478**
Spikelets per spike		1.00	0.780**	0.690**	0.680**
Seeds per spike			1.00	0.710**	0.780**
Spike yield				1.00	0.650**
Yield per plant					1.00

\*, \*\* Denote significance at 5% and 1% respectively.

Table 2. Multiple correlation between yield and yield components, spike length, spikelets per spike, seeds per spike and spike yield.

Source	Symbolic		
	D.F.	S.S.	M.S.
Regression on four variables.	4	8.9017218	2.225436
Residual	55	5.024078	0.0913468
		Subtraction	
Total	59 $\Sigma y^2$	13.9258	

Degrees of freedom = 55

Multiple correlation coefficient = 0.6392251

Estimated standard error = 0.302238

$Y = 1.505999 - 0.043122X_1 + 0.048684 X_2 + 0.03179 X_3 + 0.197784X_4$

Table 3. Direct and indirect influence of spike length, spikelets per spike, seeds per spike and spike yield on grain yield per plant.

Path ways of associations	Direct effect		Indirect effect		Correlation Coefficient. (r)
	Path coefficient. (P)	%	Path coefficient. P×r	%	
1. Spike length					
(a) Direct effect (P <sub>1Y</sub> )	-0.091883	19.1			
(b) Indirect effect via					
Spikelets per spike (P <sub>2Y</sub> r <sub>12</sub> )			0.1145494	23.97	
Seeds per spike (P <sub>3Y</sub> r <sub>13</sub> )			0.361158	75.59	
Spike yield (P <sub>4Y</sub> r <sub>14</sub> )			0.0839508	17.57	
(c) Total effect					0.478
2. Spikelets per spike					
(a) Direct effect (P <sub>2Y</sub> )	0.168455	24.77			
(b) Indirect effect via					
Spike length (P <sub>1Y</sub> r <sub>21</sub> )			-0.0624804	09.19	
Seeds per spike (P <sub>3Y</sub> r <sub>23</sub> )			0.4543601	66.82	
Spike yield (P <sub>4Y</sub> r <sub>24</sub> )			0.121235	17.83	
(c) Total effect					0.680
3. Seeds per spike					
(a) Direct effect (P <sub>3Y</sub> )	0.58455	74.94			
(b) Indirect effect via					
Spike length (P <sub>1Y</sub> r <sub>31</sub> )			-0.0569674	7.303	
Spikelets per spike (P <sub>2Y</sub> r <sub>32</sub> )			0.1313949	16.84	
Spike yield (P <sub>4Y</sub> r <sub>34</sub> )			0.1247491	15.99	
(c) Total effect					0.780
4. Spike yield					
(a) Direct effect (P <sub>4Y</sub> )	0.175703	27.03			
(b) Indirect effect via					
Spike length (P <sub>1Y</sub> r <sub>41</sub> )			-0.0514544	7.92	
Spikelets per spike (P <sub>2Y</sub> r <sub>42</sub> )			0.1162339	17.88	
Seeds per spike (P <sub>3Y</sub> r <sub>43</sub> )			0.4133842	63.63	
(c) Total effect					0.650
5. Residual effect (P <sub>XY</sub> )					0.7132

phenotypic correlation. This showed that selection for the character spike length would not be realized in increased grain yield (LARIK 1979).

The direct effect of spikelets on grain yield was positive but not so pronounced. The indirect effect through spike length was low, whereas through seeds per spike was (0.4543601), which was highly positive and formed 66.82 percent of the total correlation coefficient and via spike yield (0.121235) was negligible. The total effect of spikelets on grain yield was 0.680 which was mainly due to its indirect effect through seeds per spike. Hence the spikelets can not be regarded as a reliable source of getting high yields in wheat.

The direct effect of yield per spike on grain yield per plant was positive but nonsignificant (0.175703). Total correlation coefficient, 0.650, between grain yield per plant and grain yield per spike was mainly due to its indirect effect through seeds per spike. Therefore selection for spike yield cannot guarantee for high yields in wheat.

In contemporary model of yield (WORLEY *et al.* 1976) seed is recognised as the basic unit of yield. The direct effect of seeds per spike on grain yield was very high and significant

(0.58455) and formed about 74.94 percent of total phenotypic correlation. The indirect effect through spike length was very low and negative, through spikelets per spike and spike yield was positive but not so pronounced. Total correlation coefficient 0.780 between grain yield per plant and seeds per spike was mainly due to its own direct effect which supports the hypothesis of LARIK (1979). However, indirect effect via spike length (-0.0569674) have somewhat deluded the direct effect. A number of complex and interlocking systems (WALTEN 1969), contribute to the expression of a quantitative character like yield. The high residual effect observed in the present studies (Fig. 1) suggest that the path coefficient obtained within the constraint of the construct do not reflect the influences of the second order components.

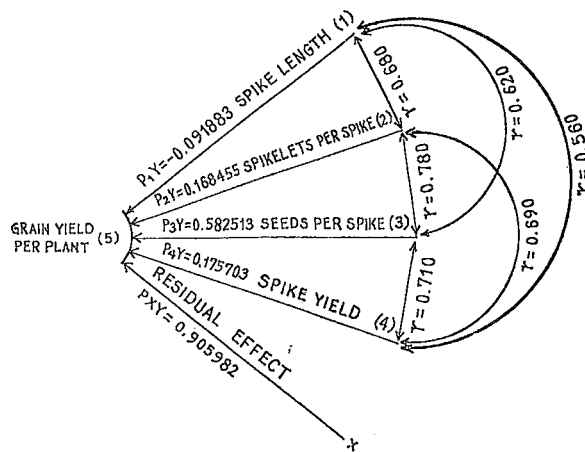


Fig. 1. Diagrammatic representation of direct and indirect influences of independent variables on dependent variable

It is clearly understood from the present study that the character of most influence on grain yield per plant was seeds per spike. This is also confirmed by SIDWELL *et al* (1976). SMOCEK (1977) also gave same idea for the character seeds per spike as reliable criterion for getting high yields in wheat plants.

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## Wheat improvement by induced mutations

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Induced mutations, a method of generating genetic variability have played a significant role in the evolution of tribe *Triticeae* (LARIK 1975a, b; 1976; 1977). In recent years induced mutations have been successful for the genetic modifications of many crop plants particularly bread wheat (*Triticum aestivum* L.) The philosophy and achievements of mutation breeding are indeed too well known (SIGURBJORNSSON and MIKE 1974; BOROJEVIC 1979). Stable mutants have been isolated from contemporary varieties of bread wheat with respect to various quantitative traits (LARIK 1978a, b) including disease resistance (SIDDIQUI and SIDDIQUI 1974), lodging resistance (LARIK *et al.* 1980a) and improved protein content and quality (SIDDIQUI *et al.* 1975).

Our main objective of wheat improvement however, is the induction and accumulation of positive variation associated with the advancement of grain yield and its effective components. Phenotypically stable wheat mutants were compared with a commercial variety (Pak-70) which covers the major wheat growing areas in Pakistan. However, this variety is susceptible to rusts and is showing considerable genetic deterioration with the passage of time. The present paper discusses the evolution of different mutants which are superior to existing commercial variety in grain yield and other useful agronomic traits.

### Materials and Methods

Phenotypically stable mutants of three hexaploid wheat cultivars viz., Pak-70, Nayab and 6134 × C-271 were evaluated in  $M_8$  generation and compared with a commercial variety during Rabi 1979-80 at Tandojam, Sind, Pakistan. Seeds of these mutants and mother cultivars were planted in 5 rows, 3 m long with 30 cm distance between rows in a randomized complete block design with 4 replications.

Analysis of variance for yield and other metrical traits was carried out separately. The pertinent mean squares and parameters estimated in each analysis were as follows:

Source of variation	Mean squares	Mean square expectations
Genotypes (Strains)	MSP	$\sigma_e^2 + r\sigma_p^2$
Error	MSE	$\sigma_e^2$

where  $\sigma_e^2$ , is the error variance,  $\sigma_p^2$  is the component variance due to genetic difference among strains and  $r$  is the number of replications. The selection parameters such as

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genotypic variance among strains ( $\sigma_p^2$ ), heritability ( $hw$ ) and genetic gain expected from selection ( $G_s$ ) were determined similar to GHAFOOR ARAIN (1973) as under:

$$i) \sigma_p^2 = \frac{MSP - MSE}{r}$$

$$ii) hw = \frac{\sigma_p^2}{\sigma_{ph}^2}, \text{ where } \sigma_{ph}^2 = \sigma_p^2 + \frac{\sigma_e^2}{r}$$

$$iii) G_s = hwS, \text{ where the selection differential}$$

$$S = k \times \sigma_{ph} = 2.06 \times \sigma_{ph}$$

### Results and Discussion

The variance analysis for all the nine metrical traits is given in Table 1. Genotype mean squares for these polygenic traits were significant at 1% and 5% level of probability (except 1000-kernel weight) which provided the evidence for the significant genetic variability for these traits among the genotypes. Among varieties/mutants, mutant 35-Nayab, 115-Nayab, A-6 and B-6 took significantly ( $P \geq .01$ ) lesser time to flowering as compared to Pak-70 and other mutant strains (Table 2). Rest of the mutant strains do not show significant genetic variation for heading duration. Heading date which directly influences the maturity is a polygenic character, under present investigation is altered by induced mutation. Early maturity in wheat is associated with escape from pests, drought, heat and other stress injuries that occur late in the growing season (EDWARDS *et al.* 1976).

Plant height (Table 2) in all the mutant strains have generally displayed non-significant reduction over Pak-70. However, mutant 35 and 115-Nayab are even taller than the mother cultivar Nayab. It is obvious from the data that all the mutants which are nearly equal to the height of check variety Pak-70 or even taller than the mother cultivars have produced significant yield than did relatively shorter ones. This situation is well supported by LAW and WORLAND (1973) and SHAKOOR *et al.* (1977). They demonstrated that taller wheat had larger grains as compared to shorter ones. Height reduction through

Table 1. Mean squares for different quantitative traits of wheat genotypes grown in field during 1979-80.

Source of variation	D.F	Heading date (days)	Plant height (cm)	Tillers per unit area	Spike length (cm)	Spikelets per spike	Grains per spike	Grain yield per spike (gm)	1000-kernel weight (gm)	Grain yield (gm/plot)
Replicates	3	1.00	16.74	50.86	0.28	0.46	12.29	0.18	12.78	93288.03
Genotypes	9	36.01**	21.25 <sup>n.s</sup>	26.02**	5.23**	4.79**	65.19**	0.27**	13.75 <sup>n.s</sup>	52289.11**
Error	27	1.65	9.98	5.81	0.23	0.14	3.02	0.05	7.44	16234.70
Total	39									

\*, \*\* Significant at 5% and 1% level of probability respectively

n.s = Non-significant

Table 2. Characteristics of improved genotypes and induced mutant lines of hexaploid wheat.

Genotype/Pedigree	Days to heading	Plant height (cm)	Tillers per unit area	Spike length (cm)	Spikelets per spike	Grains per spike	Grain yield per spike (gm)	1000-kernel weight (gm)	Grain yield (gm/plot)
Nayab (Control)	76.25	94.40	26.50	10.09	19.96 <sup>++</sup>	48.10 <sup>++</sup>	1.85	38.10	900.73
35 Nayab 30 kR	69.75 <sup>++</sup>	95.80	28.50	13.10 <sup>**</sup>	24.30 <sup>**</sup>	55.90 <sup>**</sup>	1.90	41.00	1025.32*
115 Nayab	74.00 <sup>++</sup>	99.30	40.85 <sup>**</sup>	12.99 <sup>**</sup>	20.86	51.10	1.82	41.40	1095.26*
Nf 600 RADS									
Pak-70 (Control & Check)	78.00	99.50	25.50	10.63	21.08	51.60	1.82	37.18	800.10
A-6/Pak-70 10 kR	72.25 <sup>++</sup>	96.95	30.40*	9.89 <sup>+</sup>	20.00 <sup>++</sup>	51.99	1.90	39.22	1058.81*
B-6/Pak-70	74.00 <sup>++</sup>	96.85	27.50	10.85	22.09 <sup>**</sup>	59.93 <sup>**</sup>	2.34 <sup>**</sup>	40.10	852.80
Nf 450 RADS									
6134 × C-271 (Control)	76.75	94.10	22.00	11.85 <sup>**</sup>	20.70 <sup>+</sup>	52.20	2.46 <sup>**</sup>	42050	950.39
B-33/6134 × C-271 20 kR	78.50	97.10	26.90	12.60 <sup>**</sup>	23.06 <sup>**</sup>	59.51 <sup>**</sup>	2.38 <sup>**</sup>	41.50	1110.03*
C-43/6134 × C-271 10 kR	77.25	93.08	29.50	10.75	22.94 <sup>**</sup>	54.55 <sup>**</sup>	2.16*	40.06	898.56
D-28/6134 × C-271 Nf 450 RADS	77.25	96.05	24.95	12.18 <sup>**</sup>	22.69 <sup>**</sup>	56.53 <sup>**</sup>	2.35 <sup>**</sup>	42.50	985.00*
LSD (.05)	1.86	NS	3.50	0.70	0.50	2.52	0.33	NS	184.00
LSD (.01)	2.51	NS	4.72	0.95	0.74	3.41	0.45	NS	-

\*, \*\* = mean values significantly higher than commercial variety (Pak-70) at 5% and 1% level of probability respectively.

†, ++ = mean values significantly less than the commercial variety (Pak-70) at 5% and 1% level of probability respectively.

induced mutations generally also results in a reduced grain weight (KONZAK 1973). Mutant 115-Nayab and A-6 produced significantly more number of tillers per unit area than the commercial variety Pak-70 (Table 2). Some of the mutants though produced more number of tillers per unit area but the differences were statistically non-significant. Increase in the number of tillers per unit area is desirable character from breeders point of view because of its direct influence on crop yield (LARIK *et al.* 1980b).

Evidence of the modification of spike characteristics is presented in Table 2. Significant ( $P \geq .01$ ) increase in spike length, spikelets per spike, grains per spike and grain yield per spike were observed in mutant strains 35-Nayab, B-6, B-33, C-43 and D-28 when compared with their respective controls and check variety Pak-70. These results are in confirmation with SIDDIQUI *et al.* (1978) and LARIK (1979a). These authors have observed positive shift in the mean values for these characters. These components have made effective contribution in enhancing grain yield.

Grain yield performance of all the mutants and mother cultivars is depicted in Table 2. These results further confirm the yield superiority of all the mutant strains over Pak-70 and their mother cultivars. These mutants have theoretical and practical significance as they produce higher yields than the mother cultivars under fertilizer stress condition (SIDDIQUI

1976). The genetic modification of allopolyploids (SIDDIQUI 1972) offered varied opportunities of redesigning of crop ideotypes for the changing agricultural environments. The high productivity of these mutants under tight supplies of fertilizer (SHIELDS 1975) might be due to induced genetic alterations with respect to nitrogen fixation (DOBEREINER 1977).

Mutants 35 and 115-Nayab are early maturing and produced amber coloured grain whereas, mother cultivar Nayab is red grained. This means that loci determining red grain colour and earliness on 3D chromosome were simultaneously mutated on both the chromosomes (SAWHNEY *et al.* 1971). Simultaneous mutation of two copies of genes is expected to be a rare event since two hit events are unexpected with gamma rays and fast neutrons. Mutants which are simultaneously changed for grain colour and maturity, could be due to pleiotropic effects of a single mutation although such effects are unlikely. The radiation has also removed a major defect such as apical sterility of mother cultivar Nayab. The isolation of amber seeded mutant with early maturity is of great interest because of plant type now produced could economically be used to enlarge the areas of cultivation.

Response to selection for quantitative characters is directly proportional to the function of its heritability and its genotypic variance. Heritability enables a plant breeder to recognise the genetic differences among strains and genotypic variance indicates the potential for the improvement of a population. Keeping in view these points the estimates of genotypic variance, heritability and genetic gain expected from selection were obtained separately for each quantitative character and are shown in Table 3.

Table 3. Estimates of genotypic variance ( $\sigma_p^2$ ), heritability ( $h_w$ ) values and genetic gain expected from selection (Gs) of different quantitative characters of wheat mutants.

Genetic parameters	Heading date (days)	Plant height (cm)	Tillers per unit area	Spike length (cm)	Spikelets per spike	Grains per spike	Grain yield per spike (gm)	1000-kernel weight (gm)	Grain yield (gm/plot)
$\sigma_p^2$	8.5900	2.4950	5.0525	1.2500	1.1625	15.5475	0.0550	1.5775	9013.60
$h_w$	0.9542	0.5304	0.7767	0.9560	0.9708	0.9540	0.8148	0.4589	0.6895
$G_s$	5.8977	3.6062	4.0808	2.2520	2.1884	7.9337	0.4361	1.7527	162.3966

All the metrical traits have displayed considerable increase in genotypic variance, heritability and genetic gain expected from selection. All the mutant strains exhibited highest genotypic variance for yield. This could be due to large number of high yielding mutants (Table 2). Similar conclusions have been drawn by LARIK (1979b) and LARIK *et al.* (1980a). They noticed that  $M_2$  families derived from six hexaploid wheat cultivars after irradiation treatments showed an increase of mean values and genotypic variance. The heritability ( $h_w$ ) and genetic gain expected from selection (Gs) displayed almost the same tendency as the genotypic variance ( $\sigma_p^2$ ). This indicates that greater gain from



selection for yield are anticipated in the mutant strains derived from different cultivars. While studying the magnitude of genotypic variance and heritability estimates for yield among randomly selected EMS-treated lines of barley cultivars with diverse yields and adaptation patterns at individual sites in  $M_4$  generation, GHAFOR ARAIN (1973) reached the similar conclusion.

It is therefore imperative from breeders point of view to select the yield components traits showing high heritability values among the mutated material. Thus, improvement of bread wheat, like any other crop, essentially depends on the induction and fixation of positive variation in a given agricultural environment. Mutation breeding is only one of the current methods of wheat improvement and can produce desirable results when combined with selection or with other methods of manipulating genetic variation (BROCK 1977).

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## Hybrid necrosis in wheat

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Hybrid necrosis in wheat is one of the major barrier encountered by plant breeders in bringing together desirable genes of different cultivars. Some of the Indian varieties like C 306, X 286, C 273 and NP 890 have been reported to give complete or partial necrosis in crosses with the genes present in Mexican germplasm (NARULA *et al.* 1966; GILL *et al.* 1969, 1972; ANAND *et al.* 1969). Much work on this aspect has been reported by HERMSEN (1963), and ZEVEN (1965, 1976). Based on these studies, it has been suggested that two complementary genes  $Ne_1$  and  $Ne_2$  when brought together causes necrosis in wheat, the degree of necrosis in the  $F_1$  plants varying considerably due to multiple allelism (s, m and w) of  $Ne_1$  and  $Ne_2$ . The present investigation adds further information in this direction which will be of interest to wheat breeders.

Buring the year 1979-80, with a view to transfer drought/rust resistance, a crossing programme was initiated at this centre, in which four standard wheat varieties namely; C 306, WH 147, Kalyansona and Sonalika were crossed with a number of varieties having drought/rust resistance in a line x tester analysis. Variety C 306 is tall growing, possesses bold amber grains and is a best available variety for rainfed conditions. Sonalika is a single dwarf and recommended for late sown conditions, while WH 147 and Kalayansona are double dwarf and recommended for normal sown high fertility conditions. During the following year, all the  $F_1$  s were grown in the field. Among these crosses, seedlings of nine crosses (Table 1) were very weak from the initial stage. They started yellowing at 2-3 leaf stage and finally died at 4-6 leaf stage without producing any ear showing the characteristic symptoms of severe necrosis of grade 7 as described by HERMSEN (1963). The different

Table 1. Morphological characteristics of different  $F_1$  hybrids.

Cross	No. of leaves on main shoot	Plant height (cm)	No. of tillers
1. C 306 × MP 823 A	5.0	43.0	6.0
2. C 306 × Raj. 939	4.4	39.0	3.6
3. C 306 × HD 2278	4.0	30.0	3.0
4. C 306 × K 7526	4.5	14.2	2.5
5. C 306 × HD 2037	5.0	30.0	2.0
6. C 306 × P 48-B	4.5	34.9	3.9
7. C 306 × P 118-1	5.4	46.6	3.6
8. C 306 × Ageti Kalayan	5.4	50.4	4.5
9. C 306 × E 8682	5.6	19.8	3.5

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

Ne <sub>1</sub> carrier	Ne <sub>2</sub> carrier	Non-carrier of Ne <sub>1</sub>	Non-carrier of Ne <sub>2</sub>
C 306	MP 823 A Raj. 939 HD 2278 K 7256 HD 2037 P 48-B P 118-1 Ageti Kalayan E 8682	C 281 Narbada 4 NP 875 Girja Pb-9 D D 134 Pictic 62 IWP 72 HS 74 NP 846	WL 711 UP 154 WH 157 P 195 WH 129 Raj. 1482 WL 410 HD 2160 IWP 72 HD 1949 N 7231

morphological characteristics of the seedlings in different F<sub>1</sub> hybrids have been given in Table 1.

As it has been reported that variety C 306 carries strong allele(s) of Ne<sub>1</sub> gene (GILL *et al.* 1969, 1972; ANAND *et al.* 1969), therefore, rest of the varieties (MP 823A, Raj. 939, HD 2278, K 7526, HD 2037, P 48-B, P 118-1, Ageti Kalyan and E 8682) are supposed to be the carrier of Ne<sub>2</sub> gene, thereby giving severe necrosis. The present findings support the report of ZEVEN (1966) on geographical distribution of Ne<sub>1</sub> gene. He had proposed that varieties from India are carrier of Ne<sub>1</sub> gene while the Mexican germ plasm carries Ne<sub>2</sub> gene. Based on the observations made from these crosses, varieties possessing/not-possessing Ne<sub>1</sub> or Ne<sub>2</sub> gene have been listed in Table 2. These informations will be of importance to breeders/geneticists.

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## II. Editorial Remarks

### Announcement for Future Issues

WIS No. 54 will be planned for publication in March 1982. Manuscripts for this issue are most welcome and accepted any time, not later than January 30, 1982.

WIS is open to all contributions regarding methods, materials and stocks, ideas and research results related to genetics, breeding and cytology of *Triticum*, *Aegilops*, *Secale*, *Haynaldia* and related genera. Manuscripts should be typewritten (double-space) in English, and submitted with duplicates. One article should not exceed five printed pages, including one textfigure (smaller than  $7 \times 7$  cm<sup>2</sup>). 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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*The Managing Editor*

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### *Explanation of the Figure on the Cover*

Flourescent photomicrograph of DAPI-stained chloroplasts in a mesophyll protoplast of *T. aestivum*. See the article by T. IKUSHIMA in page 2.

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