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ESTIMATES OF GENETIC VARIABILITY IN MUTATED POPULATIONS OF *TRITICUM AESTIVUM*

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Abstract

M_2 populations of four cultivars of Mexican origin (Mexipak-65, Nayab, Pak-70 and 6134 x C-271) and two locally bred cultivars (H-68 and C-591) of bread wheat, *Triticum aestivum* (2n = 6x = AA BB DD) derived from six irradiation treatments (gamma rays Co^{60}; 10, 15 and 20 kR and fast neutrons; 300, 600 and 900 RADS) were critically examined for spike length, spikelets per spike, grains per spike and grain yield.

Genotypes varied significantly ($p \geqslant 0.01$) for all the characters. Irradiation treatment were instrumental in creating significant variability for all the characters, indicating that varieties did not perform uniformly across different gamma rays as well as fast neutron treatments. In the M_2 generation there was a considerable increase in variance for all the four metrical traits. Comparisons were made between controls and treated populations. Mutagenic treatments shifted the mean values mostly towards the negative direction, but the shift was not unidirectional nor equally effective for all the characters. The differences in mean values and the nature of variability observed in M_2 indicated a possible preference of selection in M_3 generation. In general, estimates of genetic variability and heritability (b.s) increased with increasing doses of gamma rays and fast neutrons. Genetic advance also exhibited similar trend. The observed variability can be utilized in the evolution of new varieties.

Introduction

In series of experiments carried out in various autogamous crops it has been established that radiations when applied to plants induce mutations in polygenic characters (Brock, 1977; Siddiqui, *et al* 1979; Gaul, 1977; Gustafsson, 1954; Mac Key, 1954). Attempts have also been made to identify and evaluate radiation induced variation in quantitative characters and have estimated the progress that can be made by subsequent selection. Brock (1965) has put forward the hypothesis that random mutations are expected to increase the variance and shift the mean away from the direction of previous selection.

The present studies were designed to compare the relative effectivensss of gamma rays and fast neutrons for inducing improvement in yield and yield components of wheat

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cultivars having different histories of selection. The present paper also discusses the magnitude of induced changes with particular reference to heritabilities of different characters.

Material and Methods

Seeds harvested from M_1 generation of six cultivars of bread wheat, *Triticum aestivum* L. em. Thell. (2n = 6x = 42 = AA BB DD) viz., Pak-70, Nayab, Mexipak-65, 6134 x C-271, H-68 and C-591 were sown in the field of Botanical Garden of Sind Agricultural University, Tandojam in a split plot design with four replications during Rabi 1977-78. Each plot consisted of 5 rows 2.0 m long spaced at 30 cm apart. In each plot 105 seeds were planted with 21 seeds per row, while the plant to plant distance within a row was 10 cm.

Data on individual M_2 plants for four characters viz., spike length, spikelets per spike, grains per spike and grain yield per plant were collected and analysed. Estimates of broad sense heritability and expected genetic advance with a selection intensity of 5% were also computed. The broad sense heritability (h) of a character was estimated according to the method followed earlier by Larik (1975a,b):

$$\text{i.e } \%h = \frac{\sigma g^2}{\sigma t^2} \text{ X } 100$$

where σg^2 = induced genetic variance and σt^2 is the total phenotypic variance calculated from radiated populations. The statistical approach modified by Larik (1978) was used to estimate genetic advance (GA) at 5% selection intensity and computed by the following formula.

$$\text{G.A.} = (K)(\sigma)(H)$$

where σp = phenotypic standard deviation of the mean performance of radiated populations H = heritability coefficient and K = 2.06 constant for selection differential. The G.A. was expressed as percentage of the mean for the purpose of comparison.

Experimental results

Analysis of variance (ANOVA) for all the four metrical traits is presented in Table 1. ANOVA shows that the mean squares for varieties and treatements were significant at 1% level of probability except grains per spike where treatment effects were significant at 5% level of probability. This indicates that cultivars and treatments under study varied significantly for all the quantitative characters. Highly significant mean squares attributtable to genotypes also reveals that significant genetic variability existed among the cultivars. Varieties X treatment interaction mean squares were significant at %5 level of probability for spike length and spikelets per spike indicating that varieties did not perform uniformly across different gamma rays as well as fast neutron treatments. Non-significant

Table 1. Analysis of variance for four quantitative characters in M_2 populations of six hexaploid wheat genotypes under different radiation doses (1977-78).

Source of variation	D.F.	Spike length (cm)		Spikelets per spike		Grains per spike		Yield per plant (gm)	
		M.S.	F-value	M.S.	F-value	M.S.	F-value	M.S.	F-value
Replicates	3	0.60		0.65		3.76		5.17	
Varieties (Factor A)	5	17.06	28.91**	12.44	10.54**	1042.91	48.28**	687.63	157.71**
Error (a)	15	0.59		1.18		21.60		4.36	
Treatment (Factor B)	6	21.73	103.47**	8.83	15.22**	6.61	1.93*	51.60	26.59**
A X B Interaction	30	0.34	1.61*	0.99	1.70*	0.88	0.25 ns	0.88	0.45 ns
Error (b)	108	0.21		0.58		3.42		1.94	
Total	167								

*Significant at 5% level of probability
**Significant at 1% level of probability
ns = Non-significant

interaction for grains per spike and yield per plant indicates a consistency in performance of each variety across different irradiation treatments.

Radiation in general reduced the length of spike and spikelets per spike (Table 2 & 3). In all the genotypes fast neutron treatments displayed progressive decrease with the increase of radiation dosage whereas gamma rays treatments reduced the spike length and spikelets per spike in all the cases except 15kR treatment where the characters showed some improvement over the control. While comparing the control and irradiated populations in each of the varieties significant ($p \geqslant 0.01$) reduction for spike length was observed at Nf 900 RADS and 20kR treatment whereas Nf 600 RADS significantly reduced ($p \geqslant 0.01$ and 0.05) spike length only in varieties Nayab, C-591, 6134 x C-271 and H-68. Gamma rays 10kR was also effective in reducing spike length for varieties C-591 and H-68. Among all the radiation treatments Nf 900 RADS and 20kR treatment were found to be more effective to reduce spike length and spikelets per spike in all the genotypes to the extent of 1.50 to 3.00 cm. and 3.41 spikelets per spike, respectively.

Highest genotypic coefficient of variation (18.02%). heritability (82.97%) and genetic advance (33.80%) for spike length was shown by variety Mexipak-65 at 20kR treatment and lowest genetic estimates for this trait were shown by variety Nayab at Nf 300 RADS. On the contrary variety Pak-70 showed the highest genetypic coefficient of variability (17.81%) for spikelets per spike at Nf 900 RADS which also had the highest heritability estimates (65.95%) and (29.78%) genetic advance.

Grains per spike and yield per plant in each treatment (Table 4 & 5) were not significantly altered from that of controls. In comparison between controls and irradiation treatments grains per spike were significantly reduced ($p \geqslant 0.01$) in all the six cultivars at Nf 900 RADS and 20kR. The other gamma ray and fast neutron treatments were found less effective in reducing grains per spike and yield per plant. Non-significant increase was noticed in 15kR treatment for all the six genotypes. Mexipak-65 was the most susceptible to irradiation whereas, the most resistant varieties were Pak-70 and Nayab. While comparing the mean yields of individual varieties over all the treatments, variety Pak-70 was found high yielding.

Highest genotypic coefficient of variability (13.15%), heritability (58.53%) and genetic advance (20.51%) for grains per spike was given by variety Pak-70 at Nf 600 RADS, whereas variety 6134 X C-271 had shown the highest genotypic coefficient of variability for yield per plant with heritability estimates (60.43%) and (17.48%) genetic advance.

Discussion

Spike length and spikelets per spike are the most important yield components, as they determine the ultimate crop yield (Larik, 1979; Siddiqui *et al*, 1979). Both the radiation sources displayed negative effects upon these characters. Every additional dose of radiation progressively reduced the number of spikelets per spike and spike length

Table 2. Estimates of mean values, genotypic coefficient of variability, heritability (b.s) and expected genetic advance with selection intensity (k*) of five percent for spike length in M_2 generation of six hexaploid wheat genotypes (1977-78).

Genetic Estimates	Control	TREATMENTS 300 RADS	600 RADS	900 RADS	10kR	15kR	20kR
				PAK - 70			
Mean	13.20	13.00	12.60	11.10**	12.90	13.30	11.05**
C.V (p) %	9.85	15.54	17.92	16.53	12.42	10.92	12.82
C.V. (g) %		12.21	14.67	12.01	7.68	5.32	5.95
Heritability %	-	61.76	68.90	52.83	38.29	23.76	21.52
G.A. % of means	—	19.74	25.43	17.97	9 77	5.53	5.67
				NAYAB			
Mean	13.00	12.80	12.10**	10.80**	12.90	13.00	10.00**
C.V. (p) %	8.69	8.[illegible]7	8.92	8.68	6.43	6.92	8.70
C.V. (g) %		4.00	5.00	14.19	12.33	11.23	15.80
Heritability %		20.00	26.67	70.13	71.59	68.08	71.39
G.A. % of means	-	3.00	5.31	24.46	.49	19.09	27.86
				C 591			
Mean	12.80	12.00*	11.20**	10.60**	11.50**	12.20	10.00**
C.V (p) %	7.50	7.58	8.57	9.34	7.91	10.33	15.20
C.V. (g) %	-	11.39	15.25	16.08	11.89	6.62	11.31
Heritability %		66.61	76.02	74.22	67.37	41.04	55.37
G.A. % of means		19.08	27.40	28.54	20.27	18.73	17.34
				H - 68			
Mean	11.50	11.10	10.68*	9.50**	10.00**	11.70	9.00*
C.V. (p) %	7.71	8.02	8.30	9.25	9.20	9.27	8.22
C.V. (g) %	-	14.42	15.52	17.32	16.67	9 91	24.44
Heritability %		76.81	76.57	76.10	77.03	58.92	72.65
G.A. % of means		26 94	27.97	31.21	30.47	15.66	28.93
				6134 X C 271			
Mean	11.80	11.50	10.90*	10.80*	11.40	11.90	9 00*
C.V. (p) %	7.54	7.45	8.32	8.16	7.79	7.87	9.89
C.V. (g) %		14.43	15.93	15.96	14.08	13.02	18.52
Heritability %	-	76.08	76.60	76.50	76.07	73.22	77.82
G.A. % of means	-	25.90	28.74	28.94	25.01	22.95	33.66
				MEXIPAK - 65			
Mean	12.00	11.60	11.00	10.00**	11.60	12.10	9 80**
C.V. (p) %	6.67	6.72	7.91	8.38	6.84	6.78	9.59
C.V. (g) %		13.61	15.36	16.23	11.41	12.77	18.02
Heritability %		79.80	81.66	81 94	75.57	78.59	82.97
G.A. % of means		25.05	28.60	30 22	21.74	23 33	33 80

*,** denote significance at 5% and 1% level of probability respectively, K 2 06 5%

Table 3. Estimates of mean values, genotypic coefficient of variability, heritability (b.s) and expected genetic advance with selection intensity (K)* of five percent for spikelets per spike in M_2 generation of six hexaploid wheat genotypes (1977-78).

Genetic Estimates	TREATMENTS						
	Control	300 RADS	600 RADS	900 RADS	10kR	15kR	20kR
				PAK 70			
Mean	21.70	21.60	20.50	20.30	21.70	21.75	20.10
C.V. (p) %	13.69	15.60	17.20	16.94	13.89	12.68	13.95
C.V. (g) %	-	10.14	15.20	17.81	6.36	7.93	13.62
Heritability %	–	42.25	60.97	65.95	22.55	31.73	53.37
G.A. % of means	–	13.56	25.09	29.78	6.21	9.20	20.48
				NAYAB			
Mean	22.90	22.80	22.40	22.00	22.90	23.10	22.20
C.V. (p) %	10.50	11.70	12.38	13.65	11.50	12.00	13.00
C.V. (g) %	–	5.28	5.00	5.39	2.84	2.02	3.14
Heritability %	–	37.29	33.99	25.85	14.81	8.47	16.67
G.A. % of means	-	6.72	6.00	5.83	2.25	1.70	2.64
				C - 591			
Mean	23.51	23.40	22.60	21.00**	23.40	24.00	20 10**
C.V. (p) %	8.46	8.56	9.24	9.19	10.00	10.50	14.58
C.V. (g) %	–	4.38	5.95	5.50	6.00	6.20	12.21
Heritability %		29.07	41.39	31.26	40.32	41 50	70.18
G.A. % of means		4.87	7.88	6.95	8.10	9.10	21.07
				H - 68			
Mean	24.40	22.50	22.10	22.00	21.50	22.70	22.00
C.V. (p) %.	7.90	8.89	9.05	10.09	8.11	9.13	9.86
C.V. (g) %	–	5.44	5.72	7.14	5.22	6.02	7.35
Heritability %	–	37.87	40.00	50.08	35.93	43.58	55.10
G.A. % ofmeans	–	6.89	7.45	10.41	6.44	8.19	11.53
				6134 XC – 271			
Mean	23.00	22.80	22.50	22.00*	23.00	23.50	22.60
C.V. (p) %	6.87	7.06	8.76	8.27	6.55	6.75	8.50
C.V. (g) %	-	5.53	7.54	6.21	4.72	4.93	7.25
Heritability %		61.41	74.23	69.78	54.35	57.28	72.87
G.A. % of means		8.93	13.38	11.89	7.85	8:10	12.75
				MEXI PAK - 65			
Mean	23.10	23.20	22.80	22.60	23.00	23.20	22.70
C.V. (p) %	7.10	7.58	8.73	8.50	7.04	7.33	7.45
C.V. (g) %		6.23	7.54	7.00	5.53	6.00	6.50
Heritability %	-	67.63	73.74	65.53	61.83	65.00	68.35
G.A. % of means	–	18 90	13.43	10.00	8.96	10.00	11.50

*,** denote significance at 5% and 1% level of probability, K = 2.06 5%.

Table 4. Estimates of mean values, genotypic coefficient of variability, heritability (b.s) and expected genetic advance with selection intensity (K)* of five percent for grains per spike in M_2 generation of six hexaploid wheat genotypes (1977-78).

Genetic Estimates	TREATMENTS						
	Control	300 RADS	600 RADS	900 RADS	10kR	15kR	20kR
			PAK - 70				
Mean	57.01	56.90	57.01	56.60	56.95	57 10	56.10
C.V. (p) %	13.19	13.73	21.20	14.24	15.93	16.00	16.85
C.V. (g) %	-	7.59	13.15	7.95	5.98	6.45	7.88
Heritability %	-	30.55	58.53	32.75	15.58	20.95	29.83
G.A. % of means	--	8.63	20.51	9.95	7.32	8.10	9.68
			NAYAB				
Mean	54.10	54.20	54.00	54.10	54.05	54.60	54.70
C.V. (p) %	12.65	13.93	14.08	14.01	12.80	13.35	14.23
C.V. (g) %	--	6.53	6.68	6.45	5.50	5.85	6.04
Heritability %		43.88	45.13	40.08	30.23	31.19	38.34
G.A. % of means	--	8.90	9 10	8.50	5.80	6.32	7.78
			C 591				
Mean	59.20	59.21	59.00	58.80	59.00	59.50	58.00
C.V. (p) %	9.31	9.85	9.95	9.10	7.85	8.13	13.60
C.V. (g) %		5.74	7.39	6.97	4.10	5.30	10.23
Heritability %		48.77	60.80	58.83	24.10	29.18	74.19
G.A. % of means	-	8.30	11.87	10.97	6.78	7.53	18.16
			H – 68				
Mean	56.80	56.90	56.10	55.70	56.70	57.00	56.00
C V. (p) %	9.07	9.38	8.98	9.50	8.66	9.45	9.51
C.V. (g) %		5.87	5.10	5.89	4.83	5.97	5.93
Heritability %	--	39.14	37.10	38.45	29.15	40.27	35.36
G.A. % of means		4.28	5.70	7.25	5.25	8.10	6.38
			6134 XC - 271				
Mean	57.20	57.00	56.90	56.50	57.10	57.50	56.00
C V. (g) %	7.52	7.68	9.12	8.83	7.02	7.63	8.46
C.V. (g) %	-	3.85	5.81	5.35	5.28	5.65	6.08
Heritability %	--	16.19	40.59	35.76	34.01	40.01	41.28
G.A. % of meansm	--	2.82	7.62	6.03	5.14	7.01	7.38
			MEXI PAK - 65				
Mean	72.00	71.40	71.00	70.00	71.50	72.10	69.00*
C.V. (p) %	7.78	8.01	9.34	7.79	7.42	7.51	7.62
C.V. (g) %		3.95	6.13	5.14	4.36	4.93	5.37
Heritability %		24.38	43.12	29.85	20.73	28.41	33.10
G.A. % of means		4.02	8.29	5.04	3.08	4.04	5.12

*Significant at 5% level of probability, K 2.06 - 5%

Table 5. Estimates of mean values, genotypic coefficient of variability, heritability (b.s) and expected genetic advance with selection intensity (K)* of five percent for yield per plant in M_2 generation of six hexaploid wheat genotypes (1977-78).

Genetic Estimates	Control	300 RADS	600 RADS	900 RADS	10kR	15kR	20kR
			TREATMENTS				
			PAK – 70				
Mean	40.48	40.30	40.10	38.00	40.10	40.70	37.80**
C.V. (p) %	15.49	19.75	19.78	17.98	16.98	17.00	17.20
C.V. (g) %		9.32	9.35	9.41	7.87	9.91	11.93
Heritability %		22.27	22.85	20.64	13.88	22.48	27.43
G.A. % of means		9.03	9.13	8.70	6.93	10.53	12.15
			NAYAB				
Mean	32.60	32.40	32.00	30.00**	32.50	32.80	29.95**
C.V. (p) %	8.16	11.64	10.73	10.92	8.83	9.91	12.35
C. V. (g) %		7.19	7.74	7.81	4.34	5.54	8.56
Heritability %	–	36.67	40.52	41.13	15.13	20.15	37.30
G.A. % of means	–	8.06	10.14	11.03	4.04	5.17	10.38
			C – 591				
Mean	29.00	28.70	28.00	27.00	28.80	27.10	25.80**
C.V. (p) %	8.34	9.40	9.00	8.61	9.79	9.41	11.69
C.V. (g) %		4.03	4.61	4.00	6.90	6.41	9.71
Heritability %	-	25.04	29.41	20.27	45.70	46.31	55.26
G.A. % of means	–	4.15	5.15	3.72	8.00	8.98	13.36
			H – 68				
Mean	28.00	27.60	27.00	25.50**	27.80	28.10	24.91**
C V. (p) %	9.19	9.93	9.48	10.12	10.20	11.30	13.33
C.V. (g) %	-	6.09	6.89	9.70	9.58	9.31	10.34
Heritability %		23.92	27.76	39.59	43.48	38.96	40.83
G.A. % of means	–	6.14	7.47	10.56	12.84	11.93	12.00
			6134 xC - 271				
Mean	26.06	25.70	25.00	23.00**	25.60	26.10	22.80**
C.V. (p) %	10.01	10.70	11.92	12.15	10.81	11.20	12.83
C.V. (g) %		7.45	8.83	8.93	6.80	7.91	11.13
Heritability %	-	47.84	54.95	50.00	35.55	50.15	60.43
G.A. % of means		10.62	13.49	12.00	7.56	11.41	17.48
			MEXI PAK - 65				
Mean	31.40	31.00	30.50	28.00**	31.00	31.50	27.00**
C.V. (p) %	10.21	10.34	11.08	11.91	10.50	10.81	11.61
C.V. (g) %	-	6.63	8.06	8.50	5.85	6.08	8.09
Heritability %	–	31.92	40.20	41.01	20.36	26.15	28.71
G A. % of means	–	7.72	10.53	10.83	4.81	5.13	7.31

*Significant at 1% level of probability, K 2.06 = 5%.

except in 15kR treatment of gamma rays. The decline was however non-significant in Nf 300 RADS and 600 RADS and in 10kR. In such treatments it is difficult to select desirable plants with respect to spike length and spikelets per spike. Depressing effects of radiation on these traits have also been reported by Viglasi (1967) and Larik (1978).

Non-significant increase in the number of spikelets per spike was observed at 15kR gamma rays in all the genotypes. This increase may be ascribed to the increased frequency of supernumerary spikelets as a consequence of shortened spikes. Supernumerary spikelets have also been reported earlier (Mac Key, 1954; Sears, 1956; Larik, 1976). Mac Key believes that these are non-heritable recessive mutation. The degree of expression depends to a large extent on the environment. All the genotypes showed promising increase in genotypic variability, heritability and genetic advance for these traits, indicating that these chracters can be transmitted to future generations and a potential gain could possibily be achieved through selection in early generations. Gamma rays 15kR could successfully be used for creating genetic variability and ultimately the selection of mutants with longer spikes and increased number of spikelets per spike be made.

Number of grains per spike is a reliable measure of yielding ability (Borojevic & Borojevic, 1972) as the frequncy of induced changes in subsequent generation depends on the number of seeds which transmit them. Heritability estimates for number of seeds increase from one to four times in the treated populations in comparison to the controls and selection for this character will be more effective if it is applied in later generations (Borojevic & Borojevic, 1972).

Radiation affects the vitality of individuals. Poor seed set is amongst other factors a manifestation of an impaired fertility; transmitted from the afflicted embryos, through organogenesis, with the ultimate depression in seed yield per inflorescence. Mean values for this character have shown non-significant shifts towards negative direction and exhibited an increase in the genotypic variance. This could be due to low yielding treated populations. Similar conclusions have also been drawn by Gaul (1977) and Siddiqui & Arain (1974). Heritability estimates and genetic advance showed considerable increase indicating that the character could be transmitted to future generations and significant gain could possibly be achieved through selection in early generations.

Yield is a dependent character, and is the result of all the biological processes going on during the growth and development of plant (Scarascia-Mugnozza, 1964). The general trend of reduced yield among the mutagenic treated material could be due to pleiotropic effects (Brock, 1965; Gaul, 1977) on other characters. However, the present results suggest that the lower doses of fast neutrons and gamma rays in general and 15kR treatment in particular can be useful from breeding point of view for selecting higher yielding plants in early generations. The non-significant increase in mean and C.V. observed during present studies in mutagenized culture (15kR) of M_2 generation in comparison to the control may be related to the effect of selection (Gregory, 1965). The success of selection, however, will be greater in subsequent generations when there will be increased recombination and elimination of cytological variants (Kumar, 1972). From practical breeding point of view increased variation assumes greater significance. Frey (1969) reported that mutagen derived variability for quantitative characters in crop plants is heritable and that the response to selction is good. The relative value of this source of variaability for use in crop improvement, therefore, depends almost entirely upon the nature of phenotypic expression caused by the mutations induced at polygenic loci.

Mean yield per plant in M_2 generation has shown a shift towards the negative side (except 15kR) which is in agreement with findings arrived at by many workers (Borojevic, 1969; Brock, 1965; Ehrenberg *et al,* 1965; Gaul, 1977). It is only neccessary to know if such deviation from the mean is identical and unidirectional for all the yield components. The results indicated that the changes in the mean is not always unidirectional and is effective for all the characters. It may also depend on the nature of mutagen and its mode of action (Abrams & Frey, 1964). The evidence of genetic advance presented in this paper suggests that any of the genes, each with a small effect remain concealed in heterozygous form in this generation and their interaction is incomplete. The reliability of selection would therefore be more in M_3 *because of* stabilization.

The symmetry of the induced genetic variation and the shift of the mean depend very much on the character itself and of course on its previous selection history. Brock (1965) stated that the more highly selected or adapted character brings a greater shift in the mean and a greater asymmetry in the distribution. It woudl be tempting to suggest from the present investigations that there has been a greater shift in the mean in the well-adapted varieties of wheat H-68, Pak-70 and C-591 than in less adapted variety 6134 X C-271. Even in quantitative characters for fitness the number of plus and minus effects are essentially equal, a view suggested by Gregory (1965) and refuting the conclusions of Bateman (1959) and Oka *et al* (1958) that the induced genetic changes are unidirectional and negative. The better the symmetry of distribution the greater the chances of adaptatin. In the present experiment the distribution of the characters such as spike length, spikelets per spike, grains per spike and yield per plant are mostly symmetrical. This symmetry can thus be exploited advantageously for further improvement of the cultivars used in the present investigation.

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