Available Online at http://www.journalajst.com

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol.07, Issue, 04, pp.2698-2702, April, 2016

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

PREDICTED AND REALIZED GENETIC GAIN FOR YIELD AND ITS RELATED TRAITS IN COMMON WHEAT (*TRITICUM AESTIVUM* L.)

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ARTICLE INFO

Article History:
Received 23rd January, 2015
Received in revised form
18th February, 2016
Accepted 11th March, 2016
Published online 27th April, 2016

Key words:
Grain yield, Predicted response, Realized response, Sib-mating, selfing.

ABSTRACT

The predicted response (as per cent mean of checks) due to first cycle of selection for grain yield revealed the superiority of sib-mating over selfing in cross I as well as in cross II. The predicted response to selection for grain yield was manifold higher in sib populations than in the respective F3 populations. The magnitude of predicted correlated responses (ignoring the sign) for all characters except tiller number in cross I and days to heading in cross II were also relatively high in sib populations than in respective F3 populations. The average realized response to selection was higher under sib mating (50.64 % and 17.33 %) than under selfing (41.52 % and 14.59 %) in cross I and cross II. Further, the realized response to selection was positive for grain yield, plant height biological yield, harvest index and days to maturity in cross I and for grain yield and biological yield in cross II.

INTRODUCTION

The foremost objective of every crop breeding programme is the genetic improvement in yield potential. In wheat, considerable progress has been made on production front during the last three/four decades but much of this progress has largely been made due to the incorporation and manipulation of major genes which led not only to increase in production but also to stabilize the production. Further progress in yield improvement *per se* and yield component that are largely governed by polygenic systems had become slow because breeding methodology did not change much from the conventional pedigree method. Allard and Hansche (1964) attributed the slow progress to either inadequate initial variability or the existing use of single plant in early generation selection was inadequate to exploit the range of useful variability available. The traditional method of breeding has several drawbacks like reduced recombination and rapid fixation of genes. Some of the drawbacks of the above method of breeding may be overcome by attempting inter mating in early segregating generations which is most effective in breaking unfavorable linkages and in obtaining desirable recombinants (Hanson, 1959; Mackey, 1963; Joshi and Dhawan, 1966; Miller and Rawlings, 1967; Meredith and Bridge, 1971; Redden and Jensen, 1974; Verma *et al*., 1979; Mahalingam *et al*., 2011).

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The inter mating in F_2 segregants provides chances of finding superior recombinants in F_3 or later generations and a greater amount of concealed genetic variations particularly of the additive type would be released thereby improving response to selection (Moll and Robinson, 1967). The present study has been designed to study the response to selection (predicted and realized) for grain yield and its related traits in the populations derived through sib mating and selfing.

MATERIALS AND METHODS

The material for the present study comprised of two F_2 populations of wheat viz., Kundan/HD 2329 (cross I) and HW 3081/HD 2839 (cross II). In each F_2 population, 150 random plants were selfed and crossed in pairs (sib-mating) to obtain 150 F_3 selfs and 75 sib's. The F_3 and sib's progenies of each of the cross I and cross II were separately evaluated along with their respective parents in randomized block design (RBD) experiments with three replications at Research Farm of Kisan P.G. College, Simbhaoli (Hapur) during 2008-09. All the progenies (F_3 selfs and sib's) in each replication were evaluated in a single row plot of 2 m length with a distance of 30 cm and 15 cm between rows and plants, respectively. Natural selfing was allowed in each of F_3 and sibs progenies. The selection for grain yield in F_3 and SIB's populations was carried out following two methods of selection: (i) random selection method (R) based on individual plant merit, 5 percent plant were randomly selected and (ii) biased selection method (B): based on individual plant merit, 5 percent highest yielding plants were selected. After the first cycle of selection (random and biased) in each F_3 and sib's population resulted into four selected populations i.e. F_4 R, F_4 B, SIB (R) and SIB (B) in each of the cross I and cross II. Each of the four selected populations, two selected under selfed generation (F_4 R and F_4 B) and two selected under sib mating (SIB's R and SIB's B) of cross-I and cross-II along with their respective parents were separately evaluated in randomized block design experiments with three replications at Research Farm of Kisan P.G. College, Simbhaoli during 2009-10. All entries in each replication were raised in single row plots of 2 m length with distance of 30 cm between rows and 15 cm between plants. All the recommended cultural practices were adopted to raise the good crop. The data were recorded on all plants except border plants in each plot on the following ten characters viz., grain yield (g), plant height (cm), spikelets per spike, grains per spike, 100 grain weight (g), tiller number, biological yield (g), days to heading and days to maturity. Plot means were used for the different statistical analysis. The heritability in broad sense and coefficients of variation were estimated following Lush (1940) and Burton and De Vane (1953), respectively. The predicted response to selection (as percent mean of checks) for directly selected trait was calculated by using the following formula:

$$\text{Predicted selection response} = \frac{\text{GA}}{\text{Mean of checks}} \times 100$$

Predicted correlated selection response for unselected characters was calculated by using the following formula:

$$CR_y = k.hx.\ hy.\ r_{gxy}.\ \sigma p_y$$

The realized response to selection was calculated as a difference between the mean phenotypic value of the offspring of the selected plants and the parental generation before selection.

RESULTS AND DISCUSSION

The estimate of response to selection is helpful to the plant breeder in predicting the performance of the progeny of selected plants in subsequent generation. Selection response can be maximized either by selecting the best genotype available in the progeny or by increasing the rigor of selection. A very rigorous selection may not be desirable as it can eliminate some promising genotypes. The estimates of GCV were relatively high in the SIB populations than in the corresponding F_3 populations for all the characters in cross II and for grain yield, plant height, 100 grain weight, tiller number, biological yield and days to maturity in cross I (Table 1). The higher estimates of GCV for the above characters in the SIB populations indicated more variation. The increased variation in SIB populations for the above characters may be due to the presence of the repulsion phase linkages in the parents (Randhawa and Gill, 1978). The inter-crossing in segregating population may have broken such linkages and resulted into the concentration of the favorable genes in segregants. As shown above, this resulted into increased genetic variability and thus may lead to increased selection response. On the converse, for other characters such as spikelets per spike, grains per spike, harvest index and days to heading in cross I, the estimates of GCV were higher in F_3 than the SIB populations. This indicated the predominance of coupling phase, linkages for these characters in the parents. The sib-mating may have broken such linkages and consequently resulted into the decreased variability. The estimates of heritability were higher in the SIB populations than in corresponding F_3 populations for all the characters except harvest index, days to heading and days to maturity in cross I and for 100 grain weight in cross II (Table 2). In agreement with the above results, Randhawa and Gill (1978). Balyan and Singh (1983), Balyan and Singh (1997), Singh and Singh (2001), also reported high heritability for grain yield, plant height, tiller number and biological yield in the populations obtained following intercrossing in segregating generations. The high estimates of heritability for different characters, in general, are in agreement with the high coefficients of variability for these characters. Thus, the estimates of heritability and coefficients of variability in the two populations for different characters including grain yield suggested that the sib-mating in F_2 generation of cross I and cross II resulted into increased genetic variability. General shiftin the value of ranges for characters by following biparental approaches was also reported by Nematullah and Jha (1993) in wheat. As a consequence of increased genetic variability due to sib-mating the response to selection for grain yield was expected to be high in the SIB populations than in the F_3 populations. Anbu Selvam (2011) also concluded that intermating in F_2 segregants increased the mean performance in BIP's than F_3's in bhindi. In comparison to SIB populations of cross I and cross II, the differences between estimates of PCV and GCV for grain yield were relatively high in F_4 populations (Table 3 and 4).

This suggested that the role of environment and genotype x environment interaction in the expression of grain yield was substantially more in F_4 populations than in SIB populations. Further, in comparison to the F_4 populations, estimates of GCV were high in SIB populations for days to heading, plant height and 100 grain weight following random selection method and for days to maturity and grains per spike following biased selection method in cross I. However, the estimates of GCV were relatively higher in SIB populations for almost all the characters following biased selection method in comparison to their estimates in F_4 populations. Similar to the present results, high estimates of GCV were also reported by Srivastava *et al*. (1989); Kaushik *et al*.(1996) and Singh and Singh (2001). Further, a comparison of the estimates of heritability in the selected populations (F_4's and SIB's) revealed that for plant height and days to heading following random selection method and for spikelets per spike and 100 grain weight following biased selection method the estimates of heritability were higher in SIB's populations than their estimates in corresponding F_4 populations of cross I. However in cross II, except for grains per spike, tiller number and harvest index following random selection method and except for plant height, spikelets per spike and days to maturity the estimates of heritability were higher in SIB's populations than the estimates in corresponding F_4 populations (Table 5). Similar to the present results, high estimates of heritability were also reported by Shoran (1995); Patel and Jain (2002) and Kumar and Shukla (2002). The predicted response to selection (as percent mean of checks) for grain yield and correlated responses for above nine characters in cross I and cross II are presented in Table 6. A perusal of the results

Table 1. Estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for ten characters in F_3 and SIB's populations in cross I and cross II

S.No.	Characters	Cross I				Cross II			
		F_3		SIB		F_3		SIB	
		GCV	PCV	GCV	PCV	GCV	PCV	GCV	PCV
1.	Grain yield (g)	17.77	37.46	24.19	28.82	14.65	27.56	19.54	26.79
2.	Plant height (cm)	8.15	10.36	15.35	16.90	5.33	7.92	7.82	10.30
3.	Spikelets per spike	8.87	15.45	8.81	12.14	6.54	12.63	7.68	10.02
4.	Grains per spike	8.09	13.86	5.97	8.84	6.22	11.53	8.43	13.07
5.	100-grain weight (g)	5.21	11.37	8.05	11.11	6.35	11.29	7.89	16.05
6.	Tiller number	10.03	34.35	36.71	44.34	29.55	44.11	34.55	42.19
7.	Biological yield (g)	15.55	29.87	16.80	22.58	9.58	20.20	15.87	17.99
8.	Harvest index (%)	6.54	11.32	2.26	12.80	6.65	11.77	9.38	13.18
9.	Days to heading	4.55	5.52	4.22	5.58	3.42	5.01	8.27	9.38
10.	Days to maturity	3.02	3.62	3.97	5.26	2.00	3.00	4.16	4.70

Table 2. Estimates of heritability (broad sense) for ten characters in F_3 and SIB population of cross I and cross II

S.No.	Characters	Cross I		Cross II	
		F_3	*SIB's*	F_3	SIB's
1.	Grain yield (g)	0.224	0.704	0.281	0.622
2.	Plant height (cm)	0.618	0.825	0.452	0.576
3.	Spikelets per spike	0.331	0.528	0.268	0.587
4.	Grains per spike	0.340	0.456	0.291	0.416
5.	100 grain weight (g)	0.208	0.500	0.316	0.236
6.	Tiller number	0.085	0.685	0.449	0.668
7.	Biological yield (g)	0.275	0.554	0.224	0.777
8.	Harvest index (%)	0.335	0.032	0.319	0.506
9.	Days to heading	0.680	0.570	0.467	0.777
10.	Days to maturity	0.695	0.518	0.442	0.784

Table 3. Estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for ten characters in F_4 and SIB's populations selected following random (R) and biased (B) selection methods in cross I

S.No.	*Characters*	F_4				SIBs			
		R		B		R		B	
		GCV	PCV	GCV	PCV	*GCV*	PCV	GCV	PCV
1.	Grain yield (g)	20.17	25.78	15.42	20.92	12.70	19.40	12.47	16.91
2.	Plant height (cm)	4.34	5.58	5.84	6.58	5.97	7.49	4.87	5.87
3.	Spikelets per spike	6.74	9.84	0.17	8.88	0.17	8.49	0.17	8.77
4.	Grains per spike	12.47	14.19	10.12	12.27	8.59	11.89	10.80	13.21
5.	100-grain weight (g)	7.28	9.98	11.98	19.15	8.32	15.89	9.83	15.38
6.	Tiller number	20.60	29.94	18.31	26.51	13.99	24.50	13.63	20.12
7.	Biological yield (g)	17.60	21.42	16.76	18.25	11.08	21.70	9.14	12.62
8.	Harvest index (%)	9.86	13.00	7.07	9.26	5.08	9.67	6.03	9.88
9.	Days to heading	4.23	5.25	5.09	5.76	4.82	5.83	4.18	5.17
10.	Days to maturity	3.76	5.07	3.06	3.51	2.30	3.36	3.25	3.97

Table 4. Estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for ten characters in F_4 and SIB's populations selected following random (R) and biased (B) selection methods in cross II

S.No.	*Characters*	F_4				SIBs			
		R		B		R		B	
		GCV	PCV	GCV	PCV	*GCV*	PCV	GCV	PCV
1.	Grain yield (g)	16.84	26.39	8.54	15.10	10.72	15.77	17.57	26.80
2.	Plant height (cm)	4.31	5.41	7.32	7.82	5.66	6.40	8.75	10.24
3.	Spikelets per spike	5.73	10.74	10.40	13.74	0.17	8.99	8.39	14.88
4.	Grains per spike	10.55	13.08	8.33	11.78	8.82	11.16	9.91	12.65
5.	100-grain weight (g)	0.88	12.53	8.69	16.02	15.21	23.18	13.41	19.04
6.	Tiller number	24.75	30.93	11.87	18.70	12.65	20.84	20.07	26.80
7.	Biological yield (g)	13.55	18.44	8.00	13.77	16.56	19.98	13.94	20.01
8.	Harvest index (%)	9.13	12.88	5.29	8.84	8.04	11.44	7.00	10.69
9.	Days to heading	4.23	5.12	5.95	6.46	5.08	5.72	6.53	7.04
10.	Days to maturity	2.96	3.64	3.23	3.62	3.25	3.69	3.44	5.05

indicated that the predicted response to selection for grain yield and the correlated responses for other nine characters (except tiller number in cross I and days to heading in cross II) were manifold higher in sib populations than in the F_3 populations.

In agreement with the present results for grain yield selection in wheat, the high predicted responses were reported by several workers (Randhawa and Gill, 1980; Balyan and Singh, 1983; Balyan and Verma, 1985, Singh and Singh, 2001).

Table 5. Estimates of heritability (broad sense) for ten characters in F_4 and SIB's populations selected following random (R) and biased (B) selection methods in cross I and cross II

S.No.	*Characters*	Cross I				Cross II			
		F_4		*SIB's*		*F_4*		*SIB's*	
		F_4R	*F_4B*	*SIB R*	SIB B	F_4R	*F_4B*	SIB R	SIB B
1.	Grain yield (g)	0.643	0.543	0.429	0.543	0.407	0.319	0.461	0.429
2.	Plant height (cm)	0.605	0.786	0.636	0.689	0.635	0.878	0.780	0.731
3.	Spikelets per spike	0.857	0.175	0.345	0.462	0.281	0.572	0.423	0.317
4.	Grains per spike	0.773	0.688	0.521	0.668	0.650	0.500	0.624	0.614
5.	100-grain weight (g)	0.542	0.391	0.274	0.419	0.005	0.294	0.430	0.489
6.	Tiller number	0.473	0.477	0.326	0.462	0.637	0.403	0.368	0.659
7.	Biological yield (g)	0.676	0.843	0.551	0.524	0.540	0.337	0.688	0.485
8.	Harvest index (%)	0.576	0.504	0.276	0.373	0.502	0.359	0.493	0.428
9.	Days to heading	0.650	0.782	0.682	0.654	0.681	0.848	0.791	0.860
10.	Days to maturity	0.551	0.759	0.468	0.669	0.659	0.799	0.777	0.661

Table 6. Predicted response for ten characters as % mean of checks in the F_3 and SIB population of cross I and cross II.

S.No.	Characters	Cross I		Cross II	
		F_3	*SIB's*	F_3	SIB's
1.	Grain yield (g)	18.37	64.03	16.64	40.62
2.	Plant height (cm)	1.49	2.89	2.18	2.63
3.	Spikelets per spike	1.09	2.60	0.49	3.15
4.	Grains per spike	0.90	31.28	0.60	3.38
5.	100 grain weight (g)	-0.13	-1.05	-0.75	-2.92
6.	Tiller number	-24.02	4.93	0.55	5.67
7.	Biological yield (g)	1.72	4.99	1.97	6.25
8.	Harvest index (%)	1.31	4.08	-0.07	3.88
9.	Days to heading	0.82	-1.89	-1.09	-0.56
10.	Days to maturity	0.52	-2.14	-0.83	-1.19

Table 7. Realized response to selection (%) for ten characters in selected population of cross I and cross II

S.No.	*Characters*	Cross I				Cross II			
		F_4		*SIB's*		*F_4*		*SIB's*	
		F4R	*F_4B*	*SIB R*	SIB B	F_4R	*F_4B*	SIB R	SIB B
1.	Grain yield (g)	37.86	45.18	41.78	59.51	6.11	23.07	9.13	25.53
2.	Plant height (cm)	5.40	7.75	4.17	6.40	-3.54	-1.03	-4.08	-0.51
3.	Spikelets per spike	1.14	3.75	-9.20	-5.85	-3.38	-0.20	-14.55	-12.39
4.	Grains per spike	-9.35	-1.67	-5.59	9.20	-11.55	-6.75	-14.37	-12.46
5.	100-grain weight (g)	-12.14	-15.71	6.66	4.92	-15.29	-14.35	-3.17	-4.76
6.	Tiller number	56.83	64.29	-0.82	46.62	37.51	53.32	-9.62	2.27
7.	Biological yield (g)	1.22	11.47	16.97	36.01	9.31	19.47	12.88	26.16
8.	Harvest index (%)	36.18	37.82	21.20	17.29	-3.07	3.15	-3.33	-0.50
9.	Days to heading	-0.86	-0.17	5.13	5.78	-5.73	-4.94	4.96	5.56
10.	Days to maturity	4.86	4.79	0.70	0.83	-4.70	-2.56	-6.75	-6.42

Due to first cycle of selection the predicted response for grain yield and the correlated responses for other characters revealed that the estimate of selection response for grain yield, plant height, spikelets per spike, grains per spike, biological yield and harvest index were relatively high in SIB's populations than in the F_3 populations of cross I and cross II. The predicted response for grain yield and other characters were; however, lower than the realized response to selection (Table 6 and 7). Similar to the present results for grain yield selection in wheat, the realized response was reported to be high than the predicted response by several earlier workers (Randhawa and Gill, 1980; Balyan and Singh, 1983; Balyan and Verma 1983; Singh and Balyan, 1997; Singh and Singh, 2001). Mahalingam *et al*. (2011) also inferred that two or more cycles of intermating among the selected segregants might not only break undesirable linkages if any, but also allow accumulation of favourable alleles resulting into increased means of traits of interest. This discrepancy in the predicted and realized response due to first cycle may be attributed to the biased estimates of genotypic variance and heritability and also some extent to genotype x environment interaction. Further, it is proposed by Robertson (1977) and Nishida and Abe (1974) that in the instance of positive skewness of genotypic distribution and the negative skewness of environmental distribution for a character, the realized response to selection is expected to be high than the predicted response. Both the selection methods (random and biased) were highly effective in improving the grain yield under selfing and sib mating. Similar to the present results, Verma and Mani (2000), reported that biased selection gave higher means than the random selection in F_2, but the differences got dissipated in the next generation. The estimates of selection differential were, in general, positive and high for biased selections than for corresponding random selections. All the progenies derived from the biased selection gave very high selection differential but the realized selection responses were negative for grains yield which indicated that the phenotypic selection could be misleading and unstable. In cross I, the average realized response was 50.64% and 41.52% under sib mating and selfing, respectively. In cross II, the average realized response was 17.33% and 14.59% under sib mating and selfing, respectively (Table 6 and 7). Thus in cross I and cross II, the average realized selection response due to first cycle of selection was greater under sib mating than under selfing and it may be attributed to increased genetic variation due to recombination that may have taken place due to intercrossing and to relatively high inbreeding depression in selfing. In agreement with the present results, Mackey (1963), Joshi and Dhawan (1966), Jenson (1970), Randhawa and Gill (1978), Balyan and Verma (1985), Kaushik et al. (1996), Singh and Singh (2001) and Mahalingam et al.(2013) also recommended the use of inter-crossing in early segregating generations in self pollinated crops such as wheat and rice to break undesirable linkages and to retain more variability for several cycles of selection.

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