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Evaluation of Empirical and Predictive Approach of Selection for Yield Improvement in Wheat

Research Article

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Abstract

The relative efficiency of empirical and predictive approaches was evaluated in identifying the suitability of early generation (F_2) selection criteria for yield improvement in wheat. It was concluded that (i) the identification of traits for selection in F_2 generation following simple correlation and regression approach is inefficient, (ii) the predictive approach was also poor in comparison to the empirical approach for the identification of traits for selection in F_2 generation and (iii) Correlation coefficients of grain yield of F_4 bulk progenies with grain yield of parent F_2 plants were not significant, making prediction in early generation difficult.

The correlation coefficients of grains per spike (r = 0.54**, 0.54** and 0.52**), tiller number (r = 0.79**, 0.83** and 0.55** and biological yield (r = 0.88**, 0.92** and 0.90**) with grain yield in F2 generation were high in all the three crosses. Thus the selection based on one or simultaneously on all three yield components viz: grain number, high tiller number and higher biological yield would result into high grain yield due to positive correlated response. Use of stepwise multiple regression approach may quantify and improve the efficiency of selection based on above traits in resulting generation.

Key words: Coefficient of determination; Empirical approach; Early generation selection; F_4 bulk progeny; Stepwise multiple regression

Introduction

In most wheat breeding programmes, the most important objective is to enhance the genetic potential for grain yield. A careful choice of parents and effective selection in the early segregating generations (F_2/F_3) are important steps leading to the development of superior yielding genotypes. Early generation selection for yield in wheat is desirable because a genotype possessing various desirable genes in both homozygous and heterozygous conditions do occur most often in the F_2 generation where frequency of heterozygous loci decline in subsequent generations.

In view that selection for yield potential using yield on single plants in early generations (F_2/F_3) within crosses has been reported ineffective [1-3], most often, the suggested criteria for early generation selection have been yield components or harvest index or a combination of the two. Walton using a multiple regression approach, reported an increase in yield with the selection for increase in number of heads per plant, kernels per plant and 1000 kernel weight. Despite the preponderance of evidence on the usefulness of the component approach to breeding, yield components in quantitatively indexed manner have been seldom used as selection criteria by plant breeders for improvement of yield. Frey assigns three reasons for this lack of interest: (i) the relationship between yield and yield components is often non-linear, (ii) the environment affects the relationship between yield and yield components, and (iii) collection of yield component data may be more expensive than collection data on yield [4].

The concept of early generation testing has been earlier advocated but its usefulness have also been questioned. Okolo examined the utility of early generation testing using harvest index concept but did not found any significant correlation between harvest index of selected F_2 plants and their F_3 or F_4 bulk yields [5]. The present investigation is an attempt to examine the effectiveness of empirical and predictive approaches in identifying the suitable early generation selection criteria for yield improvement in wheat.

Material and Methods

Two thousand plants of each of the F_2 populations derived from three different single crosses e.g., CPAN 1866/ HD 2009, CPAN 1866/ DL 153-2 and CPAN 1959/ DL 153-2 were raised in an un-replicated plot in 5 m rows with a plant to plant and row to row distance of 15 cm and 30 cm, respectively, at Research Farm, Department of Genetics and Plant Breeding, Ch. Charan Singh University, Meerut. Out of 2000 plants in each of the three F_2 populations, the data on 300 disease free plants were recorded on the following seven traits viz., grain yield (g), plant height (cm), grains per spike, 100 grain weight (g), tiller number, biological yield (g) and harvest index (%). Subsequent to recording of data, the selection in each of the three F_2 populations was carried out as follows: (i) the 20% plants each with high and low values for each of the seven traits were separately selected, (ii) 20% plants were selected on the basis of an index involving greater values of each of the seven traits than their means in the respective populations and (iii) 20% plants were randomly selected. Since several plants were selected based on these three criteria, a total of 272,274 and 275 plants were selected from out of 300 plants retained in each of the three F_2 populations of CPAN 1866/ HD 2009, CPAN 1866/ DL 153-2 and CPAN 1959/ DL 153-2, respectively.

The three sets of F_3 progenies of the selected F_2 plants along with their parents and two national check cultivars (WL 711 and Sonalika) were evaluated in 1.5 m rows in three simple lattice design experiments with two replications at two diverse locations i.e. Meerut and Pantnagar. Data on grain yield per plot were recorded on the central 1 m row of each progeny after slashing 0.25 m on both ends. On the basis of grain yield data from each of the two locations, the selection of 10 % highest yielding F_3 progenies was carried out in each of the three sets of populations. This resulted in the retention of a total of 40,36 and 37 progenies from CPAN 1866/ HD 2009, CPAN 1866/ DL 153-2 and CPAN 1959/ DL 153-2 populations, respectively.

The above selected three sets of F3 progenies were evaluated as F_4 bulk progenies along with their parents and two national check cultivars in three separate randomized block design experiments with three replications at University Research Farm, Meerut. Each progeny was evaluated in plots of 5 rows of 4 m length with a row to row distance of 23 cm. The seed rate was kept at 100 kg/ha. Data on grain yield per plot was recorded on 3 central rows of 3 m length.

The three sets of F_4 progenies descended from 272, 274 and 275 selected F_2 plants belonging to CPAN 1866/ HD 2009, CPAN 1866/ DL 153-2 and CPAN 1959/ DL 153-2, respectively, were also evaluated along with their parents and two national check cultivars in three separate randomized block design experiments with two replications. Each progeny was assigned to a single row plot of 2 m length with a row to row distance of 23 cm. The seed rate was kept at 100 kg/ha. The grain yield data on each progeny was recorded on a plot of 1.5 m length.

The data recorded on individual plants (F_2) and plots (F_3/F_4) as well as pooled data were analyzed in each population separately as follows:

(i) The correlation analysis among the seven traits in F_2 populations.

(ii) The correlation of grain yield of F_4 bulk progenies with seven traits of parent F_2 plants. (iii) Simple and stepwise multiple regression analysis as per Panse and Sukhatme [6] and Draper and Smith [7], respectively

(iv) Using regression coefficient (b) from above analysis (ii), ten F_2 plants with highest grain yield potential estimates were identified.

(v) The F_4 bulk progenies selected from 10% highest yielding F_3 and F_4 populations were traced back to the selected parent F_2 plants and the selection patterns of F_2 plants were compared to determine the effectiveness of various selection criteria.

Results and Discussion

Mean values of plants selected for high (H) expression, low (L) expression and randomly selected (R) for the seven traits in the three F_2 populations are given in Table 1 which indicated that the mean of plants selected for high value (H) were much higher than the mean of low (L) expression and randomly selected (R) for all the seven traits in all the three crosses. The increase in H over L as % of H varied 51.6 to 58.6% for grain yield, 25.3 to 37.3% for plant height, and up to 58% increase for other traits over three crosses. This increase was remarkably high for grain/spike (46 to 56%) and tiller number (43-58%), moderate increase for 100 grain weight (27.6 to 35%) and low for harvest index (13 to 30%). Similarly, increase of H over mean of randomly selected (R) plants was 16 to 35% for grain yield, 17 to 19% for plant height, 21.8 to 43.9% for 100 grain weight 6 to 10% for harvest index and up to 44% for other traits.

However, The magnitude of correlation coefficient of three traits in F2 viz., grains per spike ($r = 0.54^{**}$, 0.54^{**} and 0.52^{**}), tiller number ($r = 0.79^{**}$, 0.83^{**} and 0.55^{**}) and biological yield ($r = 0.88^{**}$, 0.92^{**} and 0.90^{**}) with grain yield was high (Table 2). These are major yield components found in this study. Thus the selection based on one or all three traits viz: grain number, high tiller number and higher biological yield would result into high grain yield due to positive correlated response. Similar to the present results, Balyan and Verma [8] and Balyan and Singh [9,10] also reported high co-variability of grain yield with tiller number and biological yield in wheat.

The analysis of correlations and regressions of grain yield of F_4 bulk progenies with different traits of parent F_2 plants may be helpful in the identification of selection parameter in F_2 generation. Out of the three crosses, the grain yield of F_4 bulk progenies of only CPAN 1959/ DL 153-2 showed positive and significant association with plant height and biological yield and significant and negative association with harvest index (Table 3). However, in the pooled analysis the grain yield of F_4 bulk progenies showed positive and significant association with grain yield (0.13^{**}), plant height (0.12^{**}), tiller number (0.14^{**}) and biological yield (0.12^{**}) and significant and negative association with 100 grain weight (-0.10^{*}) and harvest index (-0.12^{**}) Contrary to the present results, Whan et al., [11] reported that the selection for yield by means of harvest index was no more effective than selection for yield itself. Similarly, Huel and Graf observed that spike harvest index was not correlated with either plot harvest index

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Table 1: Mean values of plants selected for high (H) expression, low (L) expression and randomly selected for the seven traits in the three F_2 populations.

F_2 population and trait	Mean values of selected F_2 plants				
	High expression (H)	Low expression (L)	Random (R)	$\frac{H-L}{H} X100 *^{a}$	$\frac{H-R}{H} X100 **^{a}$
CPAN 1866/HD 2009					
Grain yield (g)	27.45	11.37	18.55	58.58	32.42
Plant height (cm)	120.20	85.67	98.78	28.73	17.82
Grains per spike	72.55	34.65	61.72	52.23	14.93
100 grain weight (g)	4.45	2.89	3.95	35.06	11.24
Tiller number	21.15	8.77	11.85	58.53	43.97
Biological yield (g)	68.20	35.20	55.20	47.95	19.06
Harvest index	0.38	0.33	0.35	13.16	7.89
CPAN 1866/DL 153-2					
Grain yield (g)	38.53	18.65	32.25	51.59	16.04
Plant height (cm)	127.25	79.68	105.21	37.38	17.32
Grains per spike	78.28	42.25	65.77	46.03	15.98
100 grain weight (g)	4.34	3.14	3.90	27.65	10.14
Tiller number	23.75	13.55	18.57	42.95	21.81
Biological yield (g)	102.58	67.60	95.45	34.10	6.95
Harvest index	0.40	0.28	0.36	28.21	7.69
CPAN 1959/DL 153-2					
Grain yield (g)	41.18	17.58	26.65	57.30	35.28
Plant height (cm)	118.65	88.55	95.40	25.37	19.60
Grains per spike	85.20	37.38	68.55	56.13	19.54
100 grain weight (g)	4.38	3.12	4.05	28.77	7.53
Tiller number	21.72	9.75	14.70	55.11	32.32
Biological yield (g)	100.16	60.45	75.75	39.65	24.37
Harvest index	0.40	0.28	0.36	30.00	10.00

Table 2: Correlation coefficients among seven traits in three F2 populations as well as in pooled data of three populations.

Parameter	Cross	2	3	4	5	6	7
1. Grain yield (g)	1	0.27^{**}	0.54^{**}	0.16^{**}	0.79^{**}	0.88^{**}	-0.02
	2	0.33^{**}	0.54^{**}	0.18^{**}	0.83^{**}	0.92^{**}	0.26^{**}
	3	0.46^{**}	0.52^{**}	0.09	0.55^{**}	0.90^{**}	0.11
	Pooled	0.30^{**}	0.53^{**}	0.17^{**}	0.68^{**}	0.92^{**}	0.07
2. Plant height (cm)	1	-	-0.01	0.35^{**}	0.09	0.33^{**}	-0.17^{**}
	2	-	0.22^{**}	0.24^{**}	0.23^{**}	0.34^{**}	-0.02
	3	-	0.23^{**}	0.24^{**}	0.23^{**}	0.46^{**}	-0.09
	Pooled	-	0.19^{**}	0.11^{*}	0.21^{**}	0.35^{**}	-0.16^{**}
3. Grains per spike	1	-	-	0.01	0.32^{**}	0.42^{**}	0.13^{*}
	2	-	-	0.06	0.41^{**}	0.54^{**}	0.14^{**}
	3	-	-	-0.07	0.34^{**}	0.45^{**}	0.08
	Pooled	-	-	-0.04	0.37^{**}	0.49^{**}	0.08
4. 100 grain weight (g)	1	-	-	-	0.02	0.16^{**}	-0.02
	2	-	-	-	-0.04	0.08	0.18^{**}
	3	-	-	-	-0.01	0.02	0.08
	Pooled	-	-	-	-0.01	0.10^{*}	0.11^{*}
5.Tiller number	1	-	-	-	-	0.86^{**}	-0.31^{**}
	2	-	-	-	-	0.89^{**}	-0.04
	3	-	-	-	-	0.55^{**}	-0.06
	Pooled	-	-	-	-	0.71^{**}	-0.14^{**}
6. Biological yield (g)	1	-	-	-	-	-	-0.43^{**}
	2	-	-	-	-	-	-0.01
	3	-	-	-	-	-	-0.25^{**}
	Pooled	-	-	-	-	-	-0.22^{**}
7. Harvest index	1	-	-	-	-	-	-
	2	-	-	-	-	-	-
	3	-	-	-	-	-	-
	Pooled	-	-	-	-	-	-

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Table 3: Correlation coefficients of grain yield of F_4 bulk progenies with seven trait of parent F_2 plants in three crosses and pooled data.

Parameters of F_2 plants	Cross	Correlation coefficient (*b*)
1. Grain yield (g)	1	0.09
	2	-0.06
	3	0.07
2. Plant height (cm)	Pooled	0.13^{**}
	1	0.00
	2	-0.08
	3	0.14^{*}
3. Grains per spike	Pooled	0.12^{**}
	1	0.05
	2	-0.09
	3	-0.03
4. 100 grain weight (g)	Pooled	0.06
	1	0.04
	2	-0.05
	3	-0.11
5. Tilller number	Pooled	-0.10^{*}
	1	0.03
	2	-0.01
	3	0.08
6. Biological yield (g)	Pooled	0.14^{**}
	1	-0.05
	2	-0.05
	3	0.12^{*}
7. Harvest index	Pooled	0.12^{**}
	1	0.05
	2	-0.03
	3	-0.14^{*}
	Pooled	-0.12^{**}

Cross 1 = CPAN 1866/HD2009; Cross 2 = CPAN 1866/DL 153-2; Cross 3 = CPAN 1959/DL 153-2; *,** = Significant at P = 0.05 and P = 0.01 level, respectively.
N=272, 274 & 275 for cross 1, cross 2 & cross 3, respectively.

Table 4: Estimates of simple regression coefficients of F_4 bulk for grain yield and seven traits of parent F_2 plants in three crosses as well as in their pooled data.

Parameters of F_2 plants	Cross							
	CPAN1866/HD 2009		CPAN 1866/DL 153-2		CPAN 1959/DL 153-2		Pooled	
	b + S.E.	r^2 (%)	b + S.E.	r^2 (%)	b + S.E.	r^2 (%)	b + S.E.	r^2 (%)
1. Grain yield (g)	0.68 + 0.48	0.00	-0.33 + 0.31	0.00	0.37 + 0.32	0.00	0.75^{**} + 0.19	1.69
2. Plant height (cm)	0.01 + 0.24	0.00	-0.65 + 0.46	0.00	0.23^{*}+ 0.10	1.96	0.33^{**}+ 0.10	1.44
3. Grains per spike	0.22 + 0.26	0.00	-0.49 + 0.28	0.00	-0.13 + 0.27	0.00	0.29 + 0.17	0.00
4. 100 grain wt. (g)	4.24 + 7.29	0.00	-6.68 + 7.04	0.00	-10.83 + 6.16	0.00	-11.29^{**}+ 3.97	1.00
5. Tiller number	0.35 + 0.64	0.00	-0.08 + 0.67	0.00	0.95 + 0.75	0.00	1.67^{**} + 0.41	1.96
6. Biological yield(g)	–0.06 + 0.08	0.00	-0.10 + 0.11	0.00	0.23^{*} + 0.11	1.44	0.20^{**} + 0.06	1.44
7. Harvest index	0.31 + 0.42	0.00	-0.37 + 0.74	0.00	-1.31^{*} +0.55	1.96	-1.15^{**} +0.33	1.44

*,** = Significant at P = 0.05 and P = 0.01 levels, respectively.

Table 5: The F_4 bulk progenies derived from F_2 plants selected for highest regression coefficient (b) indicating grain yield potential estimate and their selection group patterns in F_2 populations in three crosses.

F_4 bulk progeny	F_4 bulk progeny yield(g per plot) no.	Parent plant selected in F_2 generation on the basis of					
		Grain yield (g)	Plant height (cm)	100 grain weight	Tiller number	Biological Yield (g)	Harvest index
CPAN 1866/HD 2009							
259	282.50	O	O	O	O	O	L
330	277.50	H	O	O	H	H	O
097	237.50	O	O	L	O	O	L
077	225.00	O	O	L	O	O	O
Selection group totals		1	-	2	1	1	2
CPAN 1866/DL 153-2							
033	405.00	O	O	O	O	O	L
044	402.50	H	O	O	O	O	O
261	395.00	O	O	L	H	H	O
156	385.00	O	O	L	H	O	O
078	337.50	O	O	O	O	O	L
Selection group totals		1	- 2	2	1	2	
CPAN 1959/DL 153-2							
001	382.50	O	O	L	O	O	O
182	325.00	H	O	L	O	O	O
330	320.00	H	O	O	O	O	O
236	315.00	O	O	O	O	H	O
246	295.00	H	O	O	O	O	O
Selection group totals		3	- 2	-	1	-	

High, low and non-selected are designated by H, L and O, respectively.

Table 6: Ten highest yielding F_3 selected F_4 bulk progenies and the selection group patterns of their parent F_2 plants in three crosses.

F_4 bulk progeny no.	F_4 bulk progeny yield (g per plot)	Parent plant selected in F_2 generation on the basis of								
		GY (g)	PHT (cm)	G/S	GW (g)	TN	BY (g)	HI	Random selection	Index selection
CPAN 1866/HD 2009										
330	946.67	H	O	O	O	H	H	O	O	O
234	941.67	O	O	L	O	O	O	O	O	O
144	935.00	O	O	O	O	H	H	O	O	O
097	928.33	H	O	H	O	O	H	O	O	O
237	916.67	O	O	O	H	O	O	O	O	O
015	886.67	H	O	O	O	O	H	O	O	O
172	861.67	H	O	H	O	O	H	O	O	O
219	853.33	O	O	H	O	O	O	O	R	O
092	853.33	O	O	H	O	O	H	O	R	O
290	843.33	O	O	O	O	O	O	L	O	O
Selection group totals		4	-	5	1	2	6	1	2	-
CPAN 1866/DL 153-2										
275	876.67	O	O	L	O	O	O	O	O	O
304	843.33	H	O	H	O	H	H	O	O	O
044	835.00	H	O	H	H	O	H	O	O	O
061	831.67	H	O	H	O	H	H	O	R	O
172	818.33	O	O	O	H	O	O	H	O	O
085	796.67	H	O	O	H	H	H	H	O	O
187	786.67	H	O	H	O	H	H	O	O	O
111	786.67	O	O	O	O	O	O	O	R	O
078	785.00	L	O	L	L	O	L	L	O	O
114	770.00	H	O	O	O	H	H	O	R	O
Selection group totals		7	-	6	4	5	7	3	3	-
CPAN 1959/DL 153-2										
167	951.67	H	O	O	O	H	H	O	O	O
140	870.00	O	O	O	O	H	H	O	O	O
161	866.67	O	O	O	H	H	H	O	O	O
182	863.33	H	O	H	O	O	H	H	R	O
330	856.67	H	O	H	O	H	H	O	O	O
081	856.67	O	O	O	O	O	O	O	R	O
087	853.33	H	O	O	O	O	O	H	O	O
219	846.67	O	O	O	O	O	O	O	R	O
144	841.67	O	O	O	H	O	O	O	O	O
303	773.33	L	O	L	O	L	L	O	O	O
Selection group totals		5	-	3	2	5	6	2	3	-

GY: Grain yield; PHT: Plant height; G/S: Grains per spike; GW: 100 grain weight; TN: Tiller number; BY: Biological yield; HI: Harvest index; High, low, non-selected and random groups are designated by H,L,O and R, respectively.

or grain yield [12]. This un-effectiveness of selection based on HI is reported due to presence of genotype x environment interactions that decreased the reliability of harvest index as a selection criterion [13]. However, increased HI in dwarf wheat has been back bone for yield improvement and lodging resistance in wheat programmes in India. The negative correlation of HI with grain yield may happen when the variability exhaust among dwarf wheat e.g., crosses among 4-gene dwarf wheat varieties. Under such situation selection when response to single yield component plateaus, selection for higher biological yield coupled with high HI is used as the advance selection criteria for improving the grain yield The low magnitude of above significant associations of grain yield of F_4 bulk progenies with other traits scored on parent F_2 plants may be attributed to (i) high degree of heterozygosity in the F_2 populations which will further segregate and will not breed true as genetic principle, (ii) the high genotype x year interaction since selected plants are compared with their progenies in different years and (iii) inter-genotypic competition.

The simple regression analysis of the grain yield of F_4 bulk progenies on the seven traits of parent F_2 plants confirmed the result of correlation analysis. The grain yield of F_4 bulk progenies in only one cross: CPAN 1959/ DL 153-2 showed significant regression coefficient (*b*) of F4 bulk progenies over parent F_2 plants for plant height, biological yield and harvest index. In the pooled analysis of data, the grain yield of F_4 bulk progenies showed significant associations for grain yield, plant height, tiller number, 100 grain weight, biological yield and harvest index of parent F_2 plants (Table 4). Similar to the correlation analysis, the coefficient of determination (r^2) of simple regression analysis of grain yield of F_4 bulk progenies on various traits of parent F_2 plants ranged from 1.00 to 1.96% which is very low and so non--reliable for determining performance of F4 progenies based on early generation F2 mean due to segregation, depletion of heterosis due to reduction in heterozygosity on selfing, selection in F3 and GxE interactions due to comparison in different years Following the use of appropriate regression equations involving each of the seven traits of parent F_2 plants, ten F_2 plants with highest regression coefficient (*b*) generated F_4 bulk grain yield potential were identified in each of the three crosses. A comparison of the ten F_4 bulk progenies derived from the above identified plants with the ten

Table 7: Ten highest yielding F_4 selected F_4 bulk progenies and the selection group patterns of their parent F_2 plants in three crosses.

F_4 bulk progeny no.	F_4 bulk progeny yield (g per plot)	Parent plant selected in F_2 generation on the basis of								
		GY (g)	PHT (cm)	G/S	GW (g)	TN	BY (g)	HI	Random selection	Index selection
CPAN 1866/HD 2009										
205	335.00	O	O	O	O	O	O	H	O	O
186	290.00	O	O	H	O	O	O	O	R	O
259	282.50	O	O	H	O	H	H	O	O	O
330	277.50	H	O	O	O	H	H	O	O	O
172	265.00	H	O	H	O	O	H	O	O	O
113	252.50	O	O	O	O	O	O	H	R	O
097	237.50	H	O	H	O	O	H	O	O	O
202	232.50	O	O	O	H	O	O	O	O	O
005	232.50	H	O	H	H	H	H	O	O	O
077	225.00	O	O	O	O	H	H	O	O	O
Selection group totals		4	-	5	2	4	6	2	2	-
CPAN 1866/DL 153-2										
018	455.00	H	O	H	H	O	H	O	O	O
304	425.00	H	O	H	O	H	H	O	O	O
033	405.00	H	O	H	H	H	H	O	O	O
044	402.50	H	O	H	H	O	H	O	O	O
261	395.00	O	O	O	O	H	H	O	O	O
085	385.00	H	O	O	H	H	H	H	O	O
156	385.00	O	O	O	O	H	O	O	R	O
187	365.00	H	O	H	O	H	H	O	O	O
176	342.50	O	O	H	O	O	O	O	R	O
078	337.50	L	O	L	L	O	L	L	O	O
Selection group totals		7	-	7	5	6	8	2	2	-
CPAN 1959/DL 153-2										
167	385.00	H	O	O	O	H	H	O	O	O
001	382.50	O	O	H	O	O	O	O	R	O
182	325.00	H	O	H	O	O	H	H	R	O
330	320.50	H	O	H	O	H	H	O	O	O
236	315.00	O	O	O	O	H	H	O	O	O
151	302.50	O	O	O	H	O	O	H	O	O
257	297.50	O	O	O	L	O	O	O	R	O
246	295.50	H	O	H	H	O	O	H	O	O
221	287.50	O	O	O	O	H	H	O	O	O
189	280.00	H	O	O	O	H	H	O	O	O
Selection group totals		5	-	4	3	5	6	3	3	-

GY: Grain yield; PHT: Plant height; G/S: Grains per spike; GW: 100 grain weight; TN: Tiller number; BY: Biological yield; HI: Harvest index; High, low, non-selected and random groups are designated by H,L,O and R, respectively.

Table 8: Stepwise multiple regression analysis of F_4 bulk grain yield vs. seven parameters of parent F_2 plants in the pooled data of three crosses.

Intercept	b_1	b_2	b_3	b_4	r^2 (%)	Maximum contribution of the character to R^2 value
200.17	0.23^{*} + 0.10 (Plant height)	0.83^{**} + 0.20 (Grain yield)	-12.98^{**} + 3.89 (100 grain weight)	-0.94^{**} + 0.34 (Harvest index)	5.24	37.29 (Grain yield)

*, ** = Significant at P = 0.05 and P = 0.01 levels, respectively.

highest yielding F_4 bulk progenies in each of the three crosses revealed that with the help of regression approach only four, five and five high yielding F_4 bulk progenies of CPAN1866/HD 2009, CPAN 1866/DL 153-2 and CPAN 1959/DL 153-2, respectively could be retained (Table 5). Among these progenies the maximum number (3) of high yielding F_4 bulk progenies (CPAN 1959/DL 153-2) were derived from F_2 plants selected for high grain yield potential estimate on the basis of regression equation involving grain yield *per se.* Further, two high yielding F_4 bulk progenies in each of the three crosses were derived from F_2 plants selected for high grain yield potential estimate on the basis of regression equation involving 100 grain weight. The selection of F_2 plants with high grain yield potential on basis of regression equations involving plant height, tiller number, biological yield and harvest index either resulted in the retention of two or none of the high yielding F_4 bulk progenies in any of three crosses (Table 5). Thus, following simple regression approach, none of the trait of parent F_2 plants showed high effectiveness in terms of selecting high yielding F_4 bulk progenies.

A comparison of the results of regression approach with the results obtained following empirical approach also revealed a poor relationship. In the empirical approach, the highest number of high yielding F_4 bulk progenies were derived from plants selected for high biological yield followed by plants selected for high grain yield *per se*, while the response to selection of F_2 plants based on 100 grain weight, harvest index and also the selection at random was poor (Table 6 &7) as also reported by Alexander et al., [14]. The poor response of regression approach in the retention of high number of high yielding F_4 bulk progenies on the basis of biological yield, grain yield *per se* or any other trait of parent F_2 plants was not unexpected due to very low estimates of coefficients of determination (r^2) of simple regression analysis (Table 4).

The stepwise multiple regression analysis of the pooled data of the three crosses indicated an increase in the coefficient of determination (r2) for F_4 bulk yield when several variables were fitted (Table 8). The R^2 value was 5.24 percent for the multiple regression analysis while r^2 value varied from 1.00 to 1.96 percent for the simple regression analysis. On the basis of the result of multiple regression analysis, it may be argued that potential of grain yield may be improved following selection in F2 and F3 based on the four traits viz., higher grain yield, higher plant height in dwarf population,100 grain weight and harvest. Mc Vetty and Evans suggested, the biological yield and peduncle length as the most important trait for selecting F_2 plants with the high grain yield potential. As peduncle length was not recorded here, the role of other traits which are not the part of this study may also contribute to grain yield. The results of the empirical approach of present study also identified biological yield with other trait combination as the important trait for selecting plants in F_2 generation for recovering high yielding genotypes in dwarf x dwarf varietal croes of wheat as reported by Singh and Balyan also [15].

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