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GENETIC ARCHITECTURE OF HARVEST INDEX IN TETRAPLOID WHEAT (*TRITICUM DURUM* DESF.)

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ABSTRACT

Gene effects were analysed using mean harvest index of 12 populations, viz., both parents, F_1, F_2, first backcross generations, BC_1 and BC_2, second backcross generations, BC_{11}, BC_{12}, BC_{21} and BC_{22} along with BC_{1s} and BC_{2s} derived by selfing BC_1 and BC_2 populations of three crosses involving six diverse cultivars of *Triticum durum* to determine the nature of gene actions governing harvest index through generation mean analysis under normal and late sown environments. The ten-parameter model was adequate in almost all cases to account for the variability in generation means. Epistatic effects, particularly trigenic type were predominant over additive and dominance effects under both normal and late sown environments. Duplicate epistasis was observed frequently under late sown environment only. Hybridization systems, such as biparental mating and/or diallel selective mating which exploit both additive and nonadditive gene effects, simultaneously could be useful in the improvement of harvest index in durum wheat.

Key words: Durum wheat, harvest index, nonallelic interactions, duplicate epistasis, hybridization system.

Harvest index (HI) measures the physiological efficiency of the plants [1]. Breeders have recognised the importance of a favourable harvest index in terms of partitioning of photosynthate to economically important plant part. According to Galunova [2], HI may be a reliable selection criterion for high productive genotypes in cereals. The phenomenal increase in wheat yield potential during the past few decades is attributed to increased levels of HI [3–5]. However, the genetics of HI by taking grain yield as an economic character was sporadically worked out in tetraploid wheat (*Triticum durum* Desf.). Thus, there is a greater need for genetic manipulations for increasing the HI to enhancing the productivity in this second important wheat species.

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Therefore, the present investigation was taken up to study the nature and magnitude of various kinds of gene effects (additive, dominance and epistatic) involved in the inheritance of HI. Thus, it would aid in the choice of effective and efficient breeding methods which are likely to accelerate the pace of genetic improvement for grain yield.

MATERIALS AND METHODS

The experimental material generated from six diverse parents, comprised three crosses, namely, Cocorit 71 x A-9.30-1 (P_2), HI 8062 x JNK-4W-128 and Raj 911 x DWL 5002. Twelve basic generations, viz., two parents, F_1 and F_2, first backcross generations with both parents (BC_1, BC_2), where BC_1 was the cross between F_1 x female parent and BC_2 was F_1 x male parent, their selfed progenies (BC_1 F_2, BC_2 F_2), and second backcross generations, i.e. the BC_1 and BC_2 plants again crossed with both original parents (BC_1 x female parent, BC_1 x male parent and BC_2 x female parent, BC_2 x male parent). All these populations were *raised* together in randomized block design with three replications at 30 x 15 cm spacing of under normal and late sown environments in the same cropping season at Research Farm of Agricultural Research Station, Durgapura, Jaipur, Rajasthan. Each parental and F_1 generation was represented by 2 rows, each backcross generation by 4 rows, and F_2 and the second cycle of backcrosses by 6 rows of 5 m length. Harvest index of 15 random plants in each parent and F_1, 30 plants in each backcross generation, and 60 plants in each F_2 and second cycle backcross was recorded under both environments. The biological yield of each sampled plant was recorded in grams and the HI was then calculated as:

$$\text{Harvest index (\%)} = \frac{\text{Total grain yield per plant}}{\text{Total biological yield per plant}} \times 100$$

The data of each population in both environments were analysed separately by the joint scaling test of Cavalli [6] to determine nature of gene action.

RESULTS AND DISCUSSION

The generation means of twelve population (Table 1) analysed by three, six and ten-parameter models showed trigenic interactions to be operative in all three crosses under both normal and late sown environments, except in the cross HI 8062 x JNK-4W-128 under timely sowing. The nonapplicability of the ten-parameter model in this cross does not preclude the absence of some higher order interactions. This indicates that harvest index is too complicated a property to be explained by simple and digenic models. Linkage of the interacting genes may also cause a bias in the estimates. In the cross HI 8062 x JNK-4W-128 (normal sown), the estimates of various gene effects were based on trigenic interaction model as only three, six and ten-parameter models were compared in this study. Thus, it was not possible to test the adequacy of the other better suited models to such data to explain higher order interactions.

Table 1. Gene effects for harvest index under two sowing dates in three crosses of durum wheat

Gene effect	Cocorit 71 x A-9-30-1		HI 8062 x JNK-4W-128		Raj 911 x DWL 5002	
	normal sown	late sown	normal sown	late sown	normal sown	late sown
(m)	23.6 ± 1.9**	28.4 ± 2.6**	45.3 ± 2.2**	25.4 ± 2.4**	43.4 ± 2.2**	46.2 ± 2.4**
(d)	7.8 ± 1.9**	6.6 ± 1.9**	- 1.9 ± 1.4	- 4.5 ± 2.1*	8.7 ± 1.6**	- 2.8 ± 1.7
(h)	5.4 ± 3.8	11.2 ± 3.7*	2.3 ± 2.8	17.3 ± 4.1**	- 4.8 ± 3.2	- 36.9 ± 3.5**
(i)	19.2 ± 3.2**	- 18.3 ± 7.6*	- 0.8 ± 7.0	11.1 ± 5.4	12.1 ± 6.5	9.4 ± 7.2
(j)	4.0 ± 9.3	27.5 ± 7.8**	- 19.2 ± 6.5*	15.1 ± 9.8	6.0 ± 6.7	19.4 ± 9.1
(l)	24.0 ± 13.8	- 73.6 ± 26.7**	- 34.1 ± 23.4	- 48.1 ± 2.2	15.7 ± 23.1	124.0 ± 25.2**
(w)	- 12.0 ± 6.2	3.5 ± 7.8	- 1.0 ± 5.3	2.7 ± 7.9	- 44.0 ± 6.6*	22.4 ± 6.0**
(x)	52.9 ± 16.1**	- 101.2 ± 32.8**	- 20.0 ± 29.9	- 33.8 ± 25.9	38.8 ± 28.6	149.8 ± 31.4**
(y)	36.4 ± 15.7**	30.8 ± 14.7*	- 40.1 ± 13.9**	32.8 ± 22.6	41.0 ± 13.3**	- 29.8 ± 24.7
(z)	- 19.1 ± 26.1	114.8 ± 36.5**	72.6 ± 33.7*	76.0 ± 37.8*	5.1 ± 34.5	- 100.9 ± 44.0**
χ^2 for 10-parameter model	0.4 (2)	5.4 (2)	23.8** (2)	1.4 (2)	3.8 (2)	0.7 (2)

*,**Significant at 5 and 1% levels, respectively.

Note. Degree of freedom for χ^2 test given in parentheses.

Both additive (d) and dominance (h) gene effects were operating but their relative significance and magnitude changed with the crosses as well as with the sowing dates. Since none of the gene effects was significant in the cross HI 8062 x JNK-4W-128 under normal sown condition, the role of higher order interactions in the inheritance of harvest index can not be ruled out (Table 1). The results further indicated that digenic interactions were significant in all the crosses under both the sowing dates except the crosses Raj 911 x DWL 5002 under late sown and HI 8062 x JNK-4W-128 under normal sown. The digenic interactions had high value in most of the cases where additive (d), nonadditive or both gene effects were significant. The trigenic interactions were significant in all the three crosses in both sowing dates. Among the trigenic interactions, additive x dominance x dominance (y) interaction was more frequent than other epistatic interactions. However, the relative importance and magnitude of these epistatic interactions changed drastically with the crosses as well as change in the sowing environments. Thus, it is suggested that nonallelic interactions, particularly of trigenic nature, were responsible for the inheritance of harvest index in durum wheat.

The parameters (h), (l) and (z) were significant in the crosses Cocorit 71 x A-9-30-1 and Raj 911 x DWL 5002 under late sown condition, and there signs indicated a duplicate epistasis between three genes. However, in other cases the type of epistasis could not be ascertained as either (h), (l) or (z) was nonsignificant. Duplicate epistasis may restrict the expression of a character in early segregating generations. Thus, it is suggested that selection intensity should be mild in early generations and intense in later ones, especially under late sown environment, which could be more effective in the improvement of harvest index.

The analysis of total epistatic effects (Table 2) revealed that second order interactions [(w) + (x) + (y) + (z)] were much greater in magnitude than the main effects and the first order interactions [(i) + (j) + (l)] in all the cases. Thus, it is evident that epistatic interactions,

Table 2. Abstract table showing main effects, total of the first and second order epistatic effects, fixable and nonfixable gene effects for harvest index under different sowing dates in durum wheat

Cross	Sowing date	Main effects		Epistatic effects		Total gene effects	
		(d)	(h)	I order	II order	fixable	nonfixable
Cocorit 71 x A-9-30-1	Normal	7.8	5.4	47.2	120.5	39.1	141.9
	Late	6.6	11.2	119.3	250.3	28.4	359.1
HI 8062 x JNK-4W-128	Normal	-1.9	2.3	54.1	133.7	3.7	188.2
	Late	-4.5	17.3	74.3	145.3	18.3	223.2
Raj 911 x DWL 5002	Normal	8.7	-4.8	33.8	98.9	34.8	111.4
	Late	-2.8	-36.9	152.9	303.0	34.7	460.9

particularly trigenic, had a greater role in the inheritance of the harvest index. The results support the findings of Dindsa and Bains [7]. Results further indicated that as a consequence of higher magnitude of nonallelic interactions, total nonfixable gene effects [(h) + (j) + (l) + (x) + (y) + (z)] were of much greater magnitude then fixable gene effects [(d) + (i) + (w)] in all the three crosses under both sowing dates. This indicates a greater role of nonadditive gene effects in controlling the inheritance of the harvest index. Other studies also [8–10] led to similar conclusion.

Under this situation diallel selective mating could be followed in improvement of harvest index through exploitation of nonfixable components of genetic variance. However, biparental mating and/or mating between selected plants from early segregating generations would also help in developing wheat populatitons with high harvest index which could ultimately help in the improvement of the yield potential in durum wheat.

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