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Analysis of gene effects under normal and late sown irrigated condition for grain yield and its components in bread wheat (*Triticum aestivum L.)*

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ABSTRACT

An experiment consisting six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of four crosses of bread wheat (Triticum aestivium L .) viz. 'VL922 X LOK 1'; 'VL 922 X MP 4010'; VL922 X Sonalika' and 'VL922 X AKAW 3717', were evaluated in normal and late sown irrigated conditions during rabi season of 2014-15 at Gwalior (M.P.9. Results revealed that the significant χ^2 values of Joint scaling test, indicating the assumption of absence of epitasis, did not hold true and epitasis gene action played significant role in the inheritance of yield and its component characters under both normal and late sown irrigated situation. Under both normal and late sown irrigated condition, additive (d) as well as dominance (h) effects were significant in positive direction for grain yield in cross 'VL922 X LOK 1' and for biological yield in 'VL922 X Sonalika', thereby indicating contribution of both additive and non additive components in the inheritance of these traits. Fixable additive (d), additive X additive gene effects (i) were significant for grain yield in positive direction under both normal and late sown irrigated condition in cross 'VL922 X LOK 1' but in opposite direction for plant height in 'VL922 X MP 4010' and 'VL922 X Sonalika', peduncle length in 'VL922 X Sonalika' and 'VL922 X AKAW 3717,' spike / plant in 'VL922 X LOK 1' ; 'VL922 X Sonalika' and 'VL922 X AKAW 3717', days to 50% heading in 'VL922 X LOK 1' and 'biological yield in 'VL922 X Sonalika'. Both dominance (h), dominance X dominance gene effects (l) were significantly positive direction for grain yield in cross 'VL922 X LOK1', peduncle length in 'VL922 X MP 4010', flag leaf area in 'VL922 X Sonalika' and harvest index in 'VL922 X AKAW 3717' under both normal and late sown irrigated condition. The duplicate epitasis for most characters showed their complex nature of inheritance. Inbreeding depression was significant for all traits in all crosses. Crossing in promising segregating families and pure line selection in advance generation will be more effective for fixing allelic as well as epistemic additive X additive interaction for improving grain yield and its components in future breeding programme.

Keywords: Bread wheat, generation mean analysis, gene effects, heterosis,

INTRODUCTION

Wheat (*Triticum aestivium L.*) turns out to be most important cereal crop in the world due to its wider adaptation and diverse consumptions in the human nutrition; especially in developing countries. Wheat is the second most important grain crop after rice in India and recorded remarkable wheat productivity of 3093 kg/ha and achieved a record production of 93.50 m tones (Anonymous, 2016). There is a dire need of improving genotypes for high yield potential/unit area basis to raise overall wheat production vertically. This could be achieved by exploring the maximum genetic potential from the available germplasm of wheat. The main purpose of wheat breeding is to increase grain yield, however, yield is a complex character which is governed by polygenes and affects many genetic and non-genetic factors. The knowledge about nature of gene action is essential to increase the efficiency of selection. Varieties and advanced lines with different morphological and economic characteristics are now available as breeding stock. Generation mean analysis is very useful for the rapidly obtaining the overall information on the various genetic system for speedy gains in segregating generations. Although the presence of heterosis in wheat was earlier reported by Freeman (1919), its large scale exploitation had not been realized to recent past. Studies on heterosis would help for generating breeding strategies of hybrid wheat production. Overall information on various genetic system involved in segregating generations which may lead fixing of favorable gene action for speedy gains in well plan breeding programme. Therefore, the present study was carried out to obtain information about gene action on grain yield and its component traits.

MATERIALS AND METHODS

Wheat (*Triticum aestivium L.*) genotypes *viz.,*VL922 (resistant to multiple rust races i.e. Sr/31+, Lr/26+23 and Yr/9+), LOK 1, MP4010 and Sonalika (suitable for late sown irrigated condition) and AKAW 3717 (drought and heat tolerant) were used to develop six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of 4 crosses viz., 'VL922 X LOK 1'; 'VL922 X MP4010'; VL922 X Sonalika' and 'VL 922 X AKAW 3717'. Experiment consisting six generations of 4 crosses were sown in a randomized complete block design with two replications in normal (15, Nov, 2014) and late sown (15, Dec, 2014) condition during *rabi* season of 2014-15 at research farm, Rajmata Vijayraje Scindia Krishi Vishwa Vidyalaya, Gwalior (Madhya Pradesh). Generations consisting parents P_1, P_2 and F_1 were sown in 2 rows plot, BC_1 and BC_2 in 4 rows and F_2 in 8 rows plot in each cropping situation. Recommended agronomical practices were adopted to raise good crop. The observations were recorded on randomly selected plants for grain yield and yields attributing characters, 5 plants in parents and F_1s generation, 20 plants in backcross generation (BC_1 and BC_2) and 40 plants in F_2s generation. Generation mean data were subjected to joint scaling test to detect presence of epistasis as proposed by Cavalli (1952) and to estimates three-parameter (M, D, H) in absence of epistasis effects. Crosses showing presence of non–allelic interaction were further subjected to six parameters model to estimate direct gene effects and epistasis effects as proposed by Hayman (1958). Heterosis and inbreeding depression were estimated according to Mather and Jinks (1982).

RESULTS AND DISCUSSION

Results of generation mean analysis showed that significant x^2 values of Joint scaling test in 4 crosses of bread wheat *viz*., 'VL922 X LOK 1'; 'VL922 X MP4010'; 'VL922 X Sonalika' and 'VL922 X AKAW 3717' studied under both normal and late sown irrigated condition suggested the presence of non- allelic gene interaction for all traits of 4 crosses, thereby, evidenced the inadequacy of the additive-dominance model to understand gene effects. Hence, in present study, contributions of epistasis gene action were explained by using six parameters model as suggested by Hayman (1958).

Table 1: Estimates of gene effects for grain yield and its attributes in cross 'VL 922 X LOK 1' and 'VL922 X MP4010' under normal and late sown irrigated condition

Character	Sowing situation	'VL 922 X LOK 1'						'VL922 X MP4010'					
		m	d	h	i	j	l	m	d	h	i	j	l
Plant height	NS	109.8**	5.5**	-14.8**	-8.7**	3.0**	-2.0*	110.2**	4.3**	-22.3**	-17.9**	-1.4	23.2**
	LS	109.9**	4.6**	-10.8**	-13.0**	2.3**	16.2**	110.9**	6.7**	-28.9**	-26.7**	3.8**	22.2**
Peduncle	NS	40.6**	-2.0*	17.2**	11.9**	-0.3	-8.5**	43.1**	1.2	8.3**	6.1**	3.0**	-11.2**
length	LS	40.6**	-0.6	13.4**	11.6**	-2.0*	-12.6**	41.5**	-1.8	8.2**	9.4**	0.8	-15.5**
Tillers /	NS	13.0**	-3.2**	0.8	1.5	-3.3**	-2.6**	14.1**	-2.8**	-1.8	-3.1**	-3.2**	7.1**
plant	LS	12.7**	-2.9**	12.7**	7.0**	-3.0**	3.3**	14.2**	-0.7	0.5	-3.0**	1.4	11.1**
Spike	NS	11.7**	-0.1	3.1**	4.5**	-0.4	-5.0**	12.7**	-0.5	1.9	-0.5	0.1	7.6**
length	LS	11.1**	0.5	5.6**	6.7**	-0.8	-8.4**	12.5**	-0.6	-1.3	-0.2	-0.3	-4.3**
Spike /	NS	17.2**	4.8**	-1.2	-3.0**	3.5**	7.3**	17.4**	0.9	-0.5	-3.6**	-2.2**	12.4**
plant	LS	17.2**	5.0**	-3.5**	-3.0**	2.3**	4.3**	17.4**	4.0**	-2.9**	-1.1	2.4**	0.8
Grains /	NS	15.6**	-1.1	-3.0**	-4.6**	-0.4	13.6**	14.8**	-0.5	4.5**	1.3	0.0	7.2**
spike	LS	15.5**	-0.8	-0.8	-3.1**	0.0	8.6**	15.4**	0.1	0.0	-2.4**	0.3	15.3**
Days to	NS	82.7**	-2.1**	-2.2**	4.1**	6.2**	19.9**	82.8**	-0.6	-2.3**	4.5**	8.1**	20.6**
heading	LS	82.4**	-2.8**	6.2**	5.9**	-1.1	-6.9**	82.7**	-0.3	2.9**	3.5**	0.6	0.1
Days to	NS	113.0**	1.8	-6.2**	-6.2**	0.1	9.0	112.7**	3.0**	-3.3**	-3.7**	2.0*	7.6**
maturity	LS	113.1**	2.6**	-3.1**	-5.5**	1.3	9.7**	112.7**	1.2	-1.4	-3.4**	2.1**	4.8**
Flag leaf	NS	53.6**	-4.5**	3.2**	-0.2	-0.1	8.6**	54.3**	-6.4**	4.9**	2.2**	-4.7**	1.9
aria	LS	54.2**	-3.6**	0.7	-1.8	-2.2**	-4.7**	54.6**	-5.4**	7.7**	1.8	-2.9**	0.7
1000 grain	NS	50.8**	-5.0**	-4.4**	-4.2**	-7.5**	-8.7**	51.6**	-2.4**	-10.9**	-10.0**	-6.2**	4.8**
weight	LS	51.4**	-6.5**	-4.9**	-6.8**	-3.4**	14.6**	50.0**	-0.5	5.9**	2.0*	1.3	-0.2
Harvest	NS	43.1**	-0.9	11.0**	8.0**	-1.0	-8.9**	42.6**	-2.0*	7.5**	2.9**	-0.4	7.4**
index	LS	40.9**	3.0**	7.1**	8.5**	2.2**	-21.8**	45.9**	-1.3	-1.7	-1.6	0.6	13.2**
Biological	NS	104.3**	6.4**	-2.3**	-3.5**	3.2**	31.0**	103.2**	7.8**	-10.7	-2.5**	0.2	17.7**
yield	LS	103.5**	1.9	8.0**	4.9**	-4.5**	19.0**	102.8**	6.4**	-1.0	-4.3**	6.8**	14.4**
Grain yield	NS	44.7**	2.1**	10.6**	6.5**	0.8	5.6**	43.7**	1.5	1.7	0.8	-0.3	16.5**
/ plant	LS	42.1**	3.9**	11.2**	11.4**	0.3	-15.3**	46.9**	1.7	-2.8**	-4.1**	4.0**	21.5**

**, **: significant at 5 and 1%, respectively; NS: Normal sowing, LS: Late sowings situation*

Assessment of estimates of gene effects estimated by six parameters model (Table1 and 2) showed that both additive (d) and dominance (h) main effects were significant in positive direction for grain yield in cross 'VL922 X LOK 1' and for 'biological yield in 'VL922 X Sonalika', under both normal and late sown irrigated condition thus revealed the contribution of both additive and non additive components in the inheritance of these traits, whereas, additive (d) as well as dominance (h) effects were in negative direction for 1000 grain weight in 'VL922 X LOK 1'. However, additive (d) as well as dominance (h) effects were significant in opposite direction for plant height in 'VL922 X MP 4010' and 'VL922 X Sonalika', spike / plant in 'VL922 X Sonalika' and 'VL922 X AKAW 3717' and flag leaf area in 'VL922 X MP 4010' under both normal and late sown irrigated condition, thus, cancelling or lowering fixable type of gene action. Only fixable gene action should be considered while planning the improvement for yield and its attributes. Similar results for different traits were reported by Zaazaa *et al.* (2012) and Hassan *et al.* (2014).

Table 2: Estimates of gene effects for grain yield and its attributes in cross 'VL 922 X Sonalika' and 'VL 922 X AKAW 3717' under normal and late sown irrigated condition

Character	Sowing situation	'VL 922 X Sonalika'						'VL 922 X AKAW 3717'					
		m	d	h	i	j	l	m	d	h	i	j	l
Plant	NS	111.3**	2.8**	-35.2**	-29.4**	0.7	27.6**	107.1**	1.6	-15.3**	-14.2**	-3.7**	33.7**
height	LS	110.7**	3.0**	-30.3**	-38.6**	3.2**	59.6**	108.5**	3.4**	-22.2**	-28.5**	3.2**	45.2**
Peduncle	NS	35.4**	-3.1**	32.4**	28.6**	-1.5	-26.7**	40.0**	-3.4**	15.0**	11.3**	-0.8	-4.1**
length	LS	37.5**	-4.0**	22.0**	20.9**	-1.9	-18.6**	40.1**	-2.7**	12.2**	14.0**	-2.2**	-20.0**
Tillers /	NS	12.4**	0.7	10.9**	8.3**	1.0	-4.6**	12.1**	1.2	12.8**	11.0**	1.0	-8.5**
plant	LS	12.4**	-1.2	15.1**	10.0**	0.7	-2.4**	12.9**	-0.3	8.0**	4.2**	1.3	2.9**
Spike	NS	10.8**	-1.6	6.6**	7.7**	-1.7	-9.0**	11.2**	0.2	6.2**	6.6**	-0.3	-4.5**
length	LS	10.3**	-1.3	8.4**	9.9**	-0.5	-15.0**	11.5**	-0.1	4.5**	5.7**	0.1	-4.4**
Spike /	NS	17.8**	5.1**	-5.1**	-5.5**	2.3**	6.9**	18.0**	5.2**	-2.9**	-4.8**	4.0**	8.5**
plant	LS	18.0**	4.5**	-3.3**	-5.1**	3.5**	12.2**	18.4**	4.7**	-4.7**	-6.2**	3.9**	9.4**
Grains /	NS	15.9**	1.2	-0.6	-5.3**	1.6	20.4**	17.1**	1.9	-6.5**	-11.4**	3.7**	28.7**
spike	LS	15.4**	1.4	0.5	-1.0	0.5	13.4**	16.9**	1.5	-7.9**	-12.9**	3.6**	27.6**
Days to	NS	82.6**	1.6	-3.4**	3.5**	10.0**	23.1**	82.8**	0.4	6.7**	4.5**	1.0	0.4
heading	LS	83.0**	1.0	2.7**	3.3**	1.9	-3.4**	83.1**	-0.4	-0.9	0.5	2.7**	6.2**
Days to	NS	113.7**	1.4	-9.1**	-9.1**	1.9	12.2**	13.9**	0.7	-1.3	-0.8	0.4	-2.5**
maturity	LS	112.2**	2.6**	-2.7**	-2.3**	0.9	-1.3	112.7**	2.7**	-2.3**	-1.1	1.7	-1.8
Flag leaf	NS	53.3**	-1.0	4.6**	1.5	-1.2	10.4**	52.5**	0.0	8.2**	9.3**	1.3	-5.6**
aria	LS	53.8**	0.9	8.8**	5.2**	2.8**	5.9**	54.7**	-3.4**	3.6**	5.0**	-0.8	-6.9**
1000 grain	NS	50.7**	-2.7**	-3.4**	-5.9**	-6.8**	1.3	51.0**	0.6	2.2**	-3.0**	-3.9**	-6.3**
weight	LS	50.6**	-4.3**	-0.5	-2.8**	-3.6**	4.9**	51.9**	-1.0	-6.2**	-8.1**	-0.8	12.9**
Harvest	NS	46.6**	-5.4**	-5.6**	-5.9**	-3.2**	10.5**	38.6**	3.7**	8.3**	9.5**	-0.4	-11.7**
index	LS	43.5**	0.0	-4.4**	-1.9	-0.8	17.0**	43.9**	-2.3**	2.6**	2.2**	-4.8**	5.9**
Biological	NS	102.5**	28.9**	54.8**	52.5**	25.8**	-76.4**	117.3**	6.5**	-41.2**	-48.2**	3.7**	75.0**
yield	LS	103.4**	4.6**	12.3**	-0.1	4.4**	7.2**	103.4**	4.9**	11.3**	8.6**	5.3**	-7.6**
Grain yield	NS	47.5**	-2.3**	-1.2	-2.8**	-1.3	18.0**	40.5**	6.6**	11.2**	9.5**	1.3	-0.4
/ plant	LS	44.6**	2.1**	1.1	-2.4**	1.0	21.7**	45.0**	0.1	7.1**	5.3**	-2.2**	4.2**

, :significant at 5 and 1% , respectively; NS: Normal sowing, LS: Late sowings situation*

Allelic and non-allelic interaction revealed that both additive (d), additive X additive gene effects (i) were significant in positive direction for grain yield in cross 'VL922 X LOK 1' but in opposite direction for plant height in 'VL922 X MP 4010' and 'VL922 X Sonalika', peduncle length in'VL922 X Sonalika' and 'VL922 X AKAW 3717,' spike / plant in 'VL922 X LOK 1''VL922 X Sonalika' and 'VL 922 X AKAW 3717', days to days to 50% heading in 'VL922 X LOK 1' and 'biological yield in 'VL922 X Sonalika' under both normal and late sown irrigated condition. For grain yield, both additive and additive X additive epistatic components enhanced additive variances and for rest of the traits it was in apposite sign and cancels or lowers down the contribution of additive variances. Whereas, additive (d), additive X additive components was in negative direction for 1000 grain weight in 'VL922 X LOK 1' and 'VL922 X Sonalika' revealed that alleles responsible for less value of 1000 grain weight were dominants over alleles controlling high value. The significant role of additive gene effects was also reported by Sonia *et al.* (2005), Kavr *et al.* (2007) and Mohamed and El-Said (2014).

Under both normal and late sown irrigated condition, both non additive dominance (h), dominance X dominance gene effects (l) were significantly positive for grain yield in cross 'VL922 X LOK1', peduncle length in 'VL922 X MP 4010', flag leaf area in 'VL922 X Sonalika' and harvest index in 'VL922 X AKAW 3717'. Whereas, both gene action were significant in opposite direction for plant height in 'VL922 X MP 4010' 'VL922 X Sonalika' and 'VL922 X AKAW 3717',tillers / plant and harvest index in 'VL922 X Sonalika', spike length in 'VL922 X LOK 1', 'VL922 X Sonalika'; and 'VL922 X AKAW 3717',spike / plant in, 'VL922 X Sonalika'; and 'VL922 X AKAW 3717',grains / spike in 'VL922 X AKAW 3717', days to 50% heading in 'VL922 X LOK 1'and 'VL922 X Sonalika', flag leaf area ,1000 grain weight and biological yield in 'VL922 X AKAW 3717' under both normal and late sown irrigated condition. Significant and opposite signs of 'h' and 'l' gene effects signify duplicate epitasis as complex nature of inheritance may be barrier for improvement. Similar results were reported by workers Dobariya *et al.* (2010) Chhagan *et al.* (2013) and Hassan *et al.* (2014).

Table 3: Significant estimates of heterosis and inbreeding depression for grain yield and its attributes in 4 crosses of wheat under normal and late sown irrigated condition

Character	Sowing situation	'VL 922 X LOK 1'			'VL922 X MP4010'			'VL 922 X Sonalika'			'VL 922 X AKAW 3717'		
		MP	BP	IBD	MP	BP	IBD	MP	BP	IBD	MP	BP	IBD
Tillers	NS	-4.83**	-5.19**	-88.86**	9.49**	6.38**	-79.00**	18.44**	15.97**	-57.48**	12.41**	10.88**	-57.63**
/plant	LS	40.14**	39.16**	-43.98**	25.55**	9.55**	-65.21**	35.44**	19.88**	-44.75**	28.00**	15.03**	-55.62**
Spike	NS	-10.11*8	-11.70**	-85.38**	18.34**	12.95**	-66.10**	-8.49**	-9.05**	-79.00**	-3.12**	-6.59**	-71.90**
length	LS	-7.91**	-16.53**	-81.99**	-9.33**	-11.17**	-105.37**	-12.29**	-17.49**	-85.24**	-8.71**	-10.01**	-78.45**
Spike	NS	10.84**	2.79**	-74.94**	18.37**	0.50	-65.54**	2.41**	-12.37**	-87.71**	11.31**	3.89**	-77.69**
/plant	LS	-3.23**	-16.24**	-87.74**	-9.75**	-16.92**	-91.36**	9.60**	3.74**	-73.51**	9.20**	3.95**	-81.46**
Grains	NS	9.72**	15.13**	-71.64**	20.51**	16.77**	-59.72**	29.38**	26.22**	-56.29**	30.03**	16.67**	-60.31**
/spike	LS	14.95**	8.81**	-72.51**	13.95**	12.94	-60.88**	8.26**	2.70**	-62.05**	33.33**	16.47**	-65.30**
Biological	NS	1.09	-1.77	16.87**	-7.42**	-13.38	1.40	2.12**	-0.72	18.28**	6.45**	3.77**	13.91**
Yield	LS	2.79**	97.14**	19.98**	3.22**	3.62**	8.80**	12.48**	12.20**	18.43**	2.54**	2.10**	10.59
Grain Yield	NS	8.61**	5.54**	-35.56**	1.86	-1.86	-41.13**	3.17**	1.02	-41.00**	3.85**	-7.26**	-42.05**
/Plant	LS	-0.62	-7.94**	-52.18**	2.69**	-1.83	-41.25**	7.32**	4.90**	-37.68**	3.68**	-1.01	-41.06**

**, ** significant at 5 % and 1 % probability levels, respectively; MP= Mid parent; BP= better parent and ID =Inbreeding depression, NS: Normal sowing, LS: Late sowings situation*

Considering results over sowing situations, it is apparent that most of the characters were found to be under the control of both additive and non-additive gene effects, thus, establishing the importance of epistatic types of gene action in the inheritance of wheat traits under study and cannot be ignored when plan a new breeding programme to improve wheat population for economic traits. The presence of duplicate epitasis for most characters showed their complex nature of inheritance. Further, magnitude of heterosis over mid-parents and better parents showed significant in positive direction only for biological yield in cross 'VL922 X LOK 1' and 'VL922 X AKAW3717', tillers / plant and grains / spike in'VL922 X Sonalika' and 'VL922 X AKAW3717' and spike / plant in'VL922 X AKAW3717' under both normal and late sown irrigated condition (Table 3).Whereas, inbreeding depressions were significant for all traits. There was significant difference between F_1s and F_2s, which suggested that either heterosis was associated with epistasis in F_1s, that F_2s experienced out breeding depression or that both phenomena occurred. The relationship between the amount of inbreeding depression and heterosis supports the theory that the phenomenon of heterosis is the reverse of inbreeding depression, indicating that the traits which have decreased by inbreeding can be recovered by means of crossing.

The present results suggested that random crossing in promising segregating families and pure line selection in advance generation will be more effective for fixing allelic as well as epistatic additive X additive interaction for improving grain yield and its components in future breeding programme.

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