# GENETIC PARAMETERS AND SELECTION STRATEGIES FOR BREEDING CLIMATE SMART WHEAT

## ABSTRACT

The nature and magnitude of genetic parameters like components of genetic variance (additive, dominance and epistatic), coefficient of variation, heritability and genetic advance may vary from character to character for the same population, from population to population for the same character and from environment to environment for the same population and same character. An abiotic stress may be the major cause of such variations. The magnitude of such variation may be relatively much more if there is simultaneous occurrence of two or more abiotic stresses such as drought, salt and heat stress coupled with the high seasonal and interannual variability of the environment. High temperature affects wheat crop yield by affecting in different ways including poor germination, reduced photosynthesis, increased leaf senescence, decreased pollen viability which leads to production of reduced number of effective tillers, number of spikelets per spike, less grains per ear and led to smaller grain size and consequently reduction in overall productivity.

Keywords: Heat stress, genetic parameters, Selection strategies-triple test cross, Climate smart, wheat

## Introduction

Wheat grown under higher temperature and $CO_2$ conditions (700 ppm CO2 and 30°C temperature rise) had significantly lower straw and grain yield, particularly due to severe reduction in direct or indirect traits like number of spikes per plant, although supplied with ample fertilization [1]. Similarly, Singh et *al.* [2] emphasized that continual heat stress is a problem in about 7.0 mha area, while terminal heat stress is a problem in about 40% of the irrigated wheat growing areas throughout the globe. Many workers have found in their studies conducted in different years that additive genetic component and unfixable epistasis respond more to change in environment than the dominance component and fixable epistasis indicating that heterozygotes exhibit higher stability than the corresponding homozygotes i.e. superiority of hybrids. Since the development of hybrid wheat varieties has not so far being successful at commercial scale, the best way to increase the magnitude of dominance variation in wheat is to increase magnitude of homozygous genomic heterosis (intergenomic heterozygosity) by utilizing alien gene transfer (i.e. 1B/1R and 7D/7Ae. etc.).The stress affects the means adversely, causes reduction in both genotypic and phenotypic variances, but increases heritability in many cases. Degree of dominance does not vary very much between the environment. Probably this is the main reasons why yields of cereals is stressed in dry land areas have increased only modestly as compared to irrigated areas. The estimation of genetic parameter should be done under the environment where selection is to be practiced. This paper briefly reviews impact of environment on character expression, genetic parameters and selection strategies for developing elite germplasm lines and/or improved wheat varieties.

## TARGET ENVIRONMENT AND BREEDING STRATEGY

Since yield is the integrated product of genotypic expression in a given environment, the production potential of the target environment can affect the decision regarding breeding strategies. Therefore, one important question arises that whether the breeding for the target environment should rely on selection under favourable conditions and subsequent testing of selected material in target environment or on direct selection under target environment, or stated differently, whether the estimates of genetic parameters (Which determine the kind of selection procedure to be adopted to maximize improvement) should be obtained from the target environment or from the favourable environment?

Temperature exposures above 30 °C are associated with large wheat yield reductions and contribute substantially to overall negative warming impacts. Falconer [3] emphasized that the genotypes selected under favourable environment though showed their superiority over the genotypes selected under unfavourable environment when grown under good crop growing conditions, the situation was just reverse when they were grown under poor crop growing conditions, that is, the genotypes performed better in the environment under which they were selected. While discussing barley and wheat improvement for moisture-limiting area in West Asia and North Africa, If the yield production potential of the target environment is high (30 q/h and above); then selection should effectively be practised in favourable crop-growing conditions [4]. However, if the yield potential is low (below 30 q/h), it would be more efficient to select plants directly under target environment. The estimation of genetic parameters should therefore be done under the environment where selection is to be practiced.

The view of [4] seems to be justified because the lines selected under favourable conditions will generally be different from those selected under unfavourable conditions, that is, selection for high yield potential under good crop-growing conditions does not generally cause a carry-over effect in stress environments (Table 1). Similarly, direct selection under stress environments will reduce yield under favourable environments unless genetic variances in unfavourable environment considerably greater than those in favourable environments and genetic correlations are positive and close to unity.

Table 1: Mean yield performance (q/ha) of wheat varieties tested under two different environmental conditions over different locations during the 2008 and 2009 years.

| Variety | Restricted irrigated conditions | Rank | Rainfed conditions | Rank |
|---|---|---|---|---|
| WH1080 | 34.9 | 3 | 32.2 | 1 |
| HD3013 | 33.5 | 8 | 32.0 | 2 |
| PBW 613 | 32.4 | 11 | 31.7 | 3 |
| WAS 315 | 34.1 | 6 | 31.3 | 4 |
| WH 1081 | 35.6 | 1 | 30.8 | 5 |
| C306# | 26.4 | 13 | 28.7 | 12 |
| PBW175# | 35.1 | 2 | 29.9 | 8 |
| CD | 2.2 | - | 1.1 | - |

Another basis for direct selection for yield potential under target environment is provided by the fact that general adaptation to a wide range of environments representing different stresses may cost the genotype some yield sacrifice. It is therefore, better to evolve separate varieties with best fitness in separate small areas, that is, sacrificing some wide adaptability in favour of specific adaptation to cope with prevailing stresses that limit yield and stability of production. For marking a breeding programme more effective to evolve elite germplasm particularly for poor environments (production, potential below 30 q/h), varieties should be developed to meet the specific needs of a particular area.

## MEAN VALUE AND GENETIC PARAMETERS

A number of studies have been carried out to know the effect of change in environment on the magnitude of various genetic parameters. Estimate of mean, coefficient of variation, heritability and genetic advance for seven metric traits in parents, F1 and F2 generations of a 9 X 9 wheat diallel grown under irrigated (normal) and rainfed (stress) conditions. They found significantly higher mean values for all the characters in normal environment than in the stress environment except 1000-grain weight [5]. On contrary, both genotypic and phenotypic coefficients of variation were higher in stress environment for all the traits. (ref)

Similarly, the estimates of heritability were higher in stress environment than in normal environment in majority of the cases. However, the values of genetic advance showed some what different trend. Whereas, the genetic advance was higher in stress environment for days to heading and 1000-grain weight, just a reverse condition was found for plant height, tiller number, total biomass and grain yield per plant, that is, its values were higher in normal environment than in stress environment. These results clearly indicate one thing that the trait 1000-grain weight can be more easily improved in stress environment.

Dhanda and Sethi [6] studied genetics of yield and its related traits in nine generations (P1, P2, F1, F2, F2, F3, F3, B1, B2, B1s and B2s) under irrigated and rainfed conditions in wheat cross CPAN 1992 x Kharchia 65.

The mean performance of all the characters was considerably lower under rainfed conditions than under irrigated conditions. Although both the additive and dominance components were involved in the expression of all the traits under both the environments, yet the dominance component, in general, suffered more than the additive component under rainfed conditions. Additive component appeared to be main source of genetic variation under both environments. The estimates of heritability and genetic advance were higher under irrigated than under rainfed conditions which may be due to better expression of genotypes under normal conditions.

Singh et *al.* [7] determines photothermal response, by raising 50 genotypes of wheat under four photothermal environments created through alteration of sowing dates from October through December. By taking days to heading as the key diagnostic character for photothermal response, they classified the genotypes into five groups—photoperiod non-responsive and high temperature sensitive. photoperiod non-responsive and low temperature responsive, photothermo sensitive, partial photothermo-responsive, and photothermo insensitive and computed groupwise phenotypic and genotypic correlation coefficients. Grain yield showed positive correlation with grain weight, grain number and tillers per plant in all the photothermal environments and negative correlation with days to heading, maturity and flag leaf duration in E1 and E3 environments (sowing dates, 5th October and 5th December, respectively). In general, the magnitude and direction of correlation changed with a change in photothermal environment.

Singh and Rana [8] conducted experiments to estimate various kinds of gene effects in six generations (P1, P2, F1, F2, B1 and B2) of eight bread wheat crosses for grain yield and its major components under three edaphic environments (normal, alkali and saline soils). They found a great impact of environmental conditions on trait expression as there was a lack of consistency in the significance of gene effects under different environments. This and a subsequent study conducted by Singh et *al.* (1991) led the authors to conclude that the estimation of gene effects should be carried in wide range of environments [9]. A similar study conducted by Redhu et *al.* [10] to quantify various gene effects in three wheat crosses (Kharchia 65 × WH 157, Kharchia 65× WH 283 and HD 2009× WH 283) grown under normal vis-a-vis saline environment, indicated differential genetic mechanism in two environments for all the three crosses in respect of the adequacy of model, the nature, magnitude and the level of significance of gene effects for yield and its component traits, Also, the duplicate type of epistasis was more pronounced in normal than in the saline environment.

However, the saline soils are typically patchy in their salinity, the yields of crops growing on them are similarly patchy. But, since most of the yield from such fields comes from least saline areas, the best strategy for maximising overall yield is to select for high yield on non-saline soils.

Mohsin et *al.* [11] also evaluated genetic variability for quantitative traits and found characters like biomass, number of spikes, spike length, grain for spike, 1000-grain weight and harvest index of utmost importance that may be used as suitable selection criteria in wheat breeding

## TRIPLE TEST CROSS APPROACH-SOME RESULTS

In a set of 90 triple test cross progeny families produced by crossing 30 homozygous and genetically diverse varieties of wheat with three testers and grown in two years, Singh (1980) reported that the fixable and unfixable components of epistasis were equally sensitive to the environmental change. However, the response of dominance component to year difference was negligible as compared to that of additive genetic component which was highly sensitive to micro-as well as to macro-environmental differences [12].

## TRIPLE TEST CROSS APPROACH-SOME RESULTS

Phougat and Panwar. [13,14] reported forty eight triple test cross families and 16 varieties of bread wheat were raised into environments (timely and late sown) to detect and measure the interactions between the environments and additive, dominance and epistatic effects of the genes for seven metric traits including grain yield and its component traits. In both environments, epistasis was important for grain yield and its component traits. The additive gene effects were more sensitive to environmental changes than dominance gene effect suggesting superiority of hybrids in terms of stability.

Additive × additive epistasis (i) was relatively less sensitive to environmental change than additive × dominance and dominance × dominance (j and l) components of epistasis. Testers were also found to be adequate for all the traits. Though both the additive (D) and dominance (H) components were significant for all the traits in both the environments (except dominance component for 1000-grain weight (g) in both the environments) the D component was relatively more important in all the cases.

Exactly similar results were obtained regarding the sensitivity of additive, dominance and epistatic components to environmental differences in another set of 45 wheat triple test cross families raised in two environments (normal and late sowings). Higher sensitivity of additive component to environmental differences was also noted by Singh (1990) in 324 triple test cross families produced from three wheat, crosses (HD 2009 × WH 147, NP 876 × HD 2160 and Sonalika × WL 711) [15].

In sixty TTC families, produced by crossing 20 pure breeding varieties/strains of wheat with three testers to detect epistasis and test and estimate D and H components of genetic variation for six metric traits at two locations. Epistasis was significant for plant height, 1000-grain weight and grain yield. The component D was more important than H for almost all the character studied [16]. In 1996, they used the data of these families to study interaction of additive, dominance and epistatic effects with environment. Additive gene effects were more sensitive to environmental differences than the dominance gene effects indicating higher stability of heterozygous genotypes than the homozygous varieties. However, non-fixable epistasis was more sensitive than fixable epitasis.

Similarly the results of several other such studies carried out in wheat also indicate that the additive gene effects are sensitive to environmental change than the dominance gene effects [17,18].

## CONCLUSIONS

On the basis of the results discussed above regarding the sensitivity of variance components to environmental differences in wheat a few generalizations can easily be made: (1) Additive genetic component and unfixable epistasis respond more to the change in environment than the dominance component and fixable epistasis; (2) heterozygotes exhibit higher stability than the corresponding homozygotes; indicating superiority of hybrids. Since the development of hybrid wheat varieties has not so far been successful at commercial scale, the best way to increase the magnitude of dominance variation in this cereal is to increase magnitude of homozygous genomic heterosis (intergenomic heterozygosity) and (3) though the degree of dominance may vary from character to character and from material to material for the same character, it does not vary very much between the environments.

Job of plant breeder is very difficult in choosing selection criteria under biotic and abiotic stress environments for combining high yield with resistance to adverse biotic and abiotic factors leading to poor yield. The information about the relative magnitudes of genetic parameters over a range of environments may help in making the plant breeding programme scientifically more sound. However, while dealing with a breeding for dry areas, one must try to screen his material at the earliest segregating stage in the target environment to avoid the risk of losing highly drought resistant genotypes by selecting for one or more cycles in a favourable environment.

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