Co-Adapted Yield Components in Elite Genepool of Bread Wheat Developed in North-Western and North-Eastern Plains of India

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Wheat breeding programme for the Indo-Gangetic plains is proactive. Wheat breeders of the North-western and North-eastern plains contribute in this programme to release varieties in either of the zones. The study is focussed to pin point advantages or disadvantages tagged to the breeding material developed in either zone. The North-western zone wheat breeding programme is good in adding grain number per unit area with assured grain weight. The material developed in this zone has better adaptation and tolerance against temperature spurt during grain filling period. On the other hand, the materials developed in the North-eastern region have more height instead of grains/M2 and fast ripening. The traits showing uniformity in expression across the zones have been discussed in both types of materials. The finding will prove useful in planning selection procedure for the development of bread wheat genotypes for the entire Indo-Gangetic plains stretching from Punjab to West Bengal.

Key Words: Co-adapted Traits, Elite Genepool, Growth Rate, North Eastern Plains Zone, North Western Plains Zone, *Triticum aestivum*, Yield Components

Introduction

In the Indo-Gangetic plains, over 15 million ha area is under timely sown irrigated condition. To facilitate the varietal development efforts, the All India Co-ordinated Wheat and Barley Improvement Project (AICWBIP) has divided the whole Indo-Gangetic region into two, agro-ecological zones, namely, North-western Plains Zone (NWPZ) and North-eastern Plains Zone (NEPZ). The NWPZ comprises states of Punjab, Haryana, Delhi, parts of Rajasthan (Alwar, Bharatpur and Sriganganagar), Paonta valley and Una district of Himachal Pradesh, while the states of Bihar, Jharkand, eastern part of Uttar Pradesh, West Bengal, Orissa and Assam constitute NEPZ. Active wheat improvement centres located in both the zones enrol new bread wheat entries for wide scale initial evaluation at the national level. These trials have test materials which are pre-tested for yield by the concerned centre and important diseases by the AICWBIP. The yield evaluation is carried out only to realise the yield potential under varying environments so that best line can be identified as a released variety for specific zone. The material put to test in the national trials is developed by a thorough understanding of the core germplasm as well as strategizing about ways to incorporate new traits into the core gene pool and therefore, according to Rasmusson (1996) it can be termed as 'elite gene pool'. The trial structure under the AICWBIP provides opportunity to compose performance of the elite gene pool coming from two distinct agro-ecological regions under two different environments. This system has helped in release of two wheat varieties *i.e.* HD 2733 and PBW 443 for the NEPZ. The wheat breeders located in NWPZ have bred these two varieties. Besides, another variety developed and notified for the NWPZ *i.e.* PBW 343 has also been recommended for cultivation in the NWPZ. The present study is an investigation in realise whether the elite gene pool developed in either zone through breeding has certain trait specific advantages. Apparently, there are just a few differences between two zones in the breeding methodology, use of parent lines and selection criteria for yield and component traits. It may be possible through this analysis to spot out advantages that get attached to breeding wheat in a specific region/zone.

Materials and Methods

The initial material coming for yield evaluation under timely sown condition in NIVT 1A and NIVT IB were considered for the five years period *i.e.* 1996-97 to 2000-2001. These normal sown trails are conducted in both the zones under irrigated conditions in 7x7 lattice design. Both these trials are individually conducted at nine locations in the NWPZ and 5 or 6 locations in the NEPZ, every crop season. In both kind of trials, the wheat material bred by NWPZ centres *i.e.* New Delhi, Hisar, Ludhiana, Pantnagar, Durgapura and Karnal, was separated from the NEPZ materials bred at places like Kanpur, Faizabad, Pusa, Varanasi, Sabour, Ranchi etc. In five years period of this study, 265 genotypes developed in NWPZ and 177 developed in NEPZ were evaluated in both the trails. Five years multilocation testing of such a large materials can give a fairly good indication of overall performance of an elite genepool for a particular trait in the targeted environment. Average performance of each category of materials was subjected to statistical analysis. The characteristics taken into account were phenological traits (vegetative, grain filling and total duration), grain yield and yield components like plant height, grains/m^2 and kernel weight. To analyse the yield contributing traits more critically, physiological efficiency of different materials was derived to measure the growth rate. This per day growth during grain filling period was expressed as grain fill rate *i.e.* per day grain growth and yield fill rate *i.e.* per day yield filling, were utilized as tools in examining the physiological efficiency.

Results and Discussion

Performance of wheat germplasm developed in two different environment was examined individually under two agro-ecologically different zones. Besides identifying genetic difference between these the two groups of wheat material, such an evaluation also permitted to identify traits that are easily influenced by environment. Phenology and yield attributes of these wheat materials were, therefore, examined as per genetic and environmental influences.

Environmental Effect

Before identifying the genetic differences between two categories of wheat material, it is interesting to first identify the impact of a particular environment which may have on overall expression of wheat crop. NWPZ is the most productive land for wheat cultivation in the country. Information generated by the AICW&BIP, and compute simulations on the attainable yield indicates the NWPZ has potential of 7.0 t/ha grain yield (Nagarajan, 1998). The results indicate that vegetative period (days to heading), total maturity period and plant height expressed in this zone always remain significantly higher than the adjoining NEPZ in both type of germplasm (Table 1). All these traits converge to phenology that acts as a crucial factor for higher biomass production in NWPZ. Role of phenological development and its manipulation for increasing wheat yield potential has been emphasised by many wheat workers (Reynolds *et al.,* 1996, Slafer *et al.,* 1996 and Richard 1996). There was no significant difference among two zones in grain yield and grain number unit area. The differences for grain fill period and per day growth in grain development and yield filling also cease to exist between these two zones. Even though the native material under NEPZ conditions showed an edge over NWPZ-material in kernel weight, the difference was statistically insignificant. It implies that the NEPZ- bred material could match the yield levels of the NWPZ-bred material mainly on account of better physiological efficiency during vegetative phase that helped to produce more biomass expressed through tall plant types with matching grain number per unit area.

Crop growth and yield are derived from photosynthesis and, therefore, depend on receipt and capture of solar radiation (Loomis and Amthor, 1996). It has been suggested that increasing radiation use efficiency may improve yield directly by increasing total productivity, as well as indirectly by generating higher potential kernel number and weight (Reynolds *et al.,* 1996). It seems that broadly, both types of wheat germplasm match each other in their ability to make use of radiation energy under different environments.

Even with significant difference in the maturity period, 70-71% period of the crop duration is spent on vegetative growth in both the materials in the NWPZ. In the corresponding NEPZ, only 65% period of the crop duration gets utilized up to heading, leaving proportionately higher grain filling phase in comparison to NWPZ. Even in the absence of statistical significance, the numerical advantage that the wheat crop has for grain number per unit area in NWPZ and grain size in the NEPZ can be attributed to this phenomenon of phenological significance that aids in sustaining grain yield in the Indo-gangetic region.

Genetic Differences

Overall performance of the elite genepool developed in NWPZ was compared with elite genepool of the NEPZ under both the environments. The common difference noticed among the germplasm of two different origin lied in grain filling period and plant height (Table 2). The NWPZ-bred material generally had an added advantage of longer grain fill period when compared to NEPZ-material in both the environments whereas the NEPZ-bred material has specially in excelling for height under all environmental conditions. Though significant, the grain fill period difference in the NEPZ was not all wide to show any bearing on the kernel weight. However, this difference in grain fill period

Table 1. Environment effect on elite genepools from different regions (From 1996-97 to 2000-01)

Characteristics	NWPZ-bred elite genepool		NEPZ-bred elite genepool	
	NWPZ	NEPZ	NWPZ	NEPZ
Grain yield (q/ha)	47.5	44.7	44.6	43.7
Days to heading	98.5**	78.7	99.3**	78.9
Grain fill period (days)	42.3	43.1	40.7	42.1
Total duration (days)	141**	122	140**	121
Plant height (c)	95.4**	87.4	99.8**	91.5
Grains/m2 ('000)	12.7	11.8	12.2	11.5
Kernal weight (mg)	37.4	38.0	36.6	38.0
Grain fill rate (mg)	0.89	0.89	0.90	0.91
Yield fill rate (kg/ha)	113	105	110	104

* significant at P = 0.05
** significant at P = 0.01

Table 2. Genetic differences in elite genepools from different regions (Period 1996-97 to 2000-01)

Characteristics	North-western Plains Zone		North-western Plains Zone	
	NWPZ-bred elite genepool	NEPZ-bred elite genepool	NWPZ-bred elite genepool	NEPZ-bred elite genepool
Grain yield (q/ha)	47.5**	44.6	44.7	43.7
Days to heading	98.5	99.3	78.8	78.9
Grain fill period (days)	42.3*	40.7	43.1	42.1
Total duration (days)	141	140	122*	121
Plant height (c)	95.4**	99.8	87.4**	91.5
Grains/m2 ('000)	12.7*	12.2	11.8	11.5
Kernal weight (mg)	37.4	36.6	38.0	38.0
Grain fill rate (mg)	0.89	0.90	0.89	0.91*
Yield fill rate (kg/ha)	113	115	105	104

* significant at P = 0.05
** Significant at P = 0.01

became wider in the NWPZ and it also registered some impact on the grain size *i.e.* kernel weight. Quick maturity and small grain size in the NEPZ bred material under NWPZ condition indicates that this material tends to show lack of heat tolerance. Similarly, when the material that has genetic superiority for tallness *i.e.* NEPZ elite genepool, is exposed to an environment that is highly favourable for producing taller plants *i.e.* NWPZ, the compound effect resulting in excessive height proves detrimental as it caused yield lose due to lodging.

Genetic Similarities

Both types of materials were examined for genetic similarities and it was noted that days to heading, grain size and also the seed fill rate were some of the traits which showed no significant differences under different environments (Table 2). It revealed that photo-thermal response remained similar in either of the zones and as such environment was no factor in bringing to surface any difference in biomass production among the germplasm. Both types of materials has similar potential in development of the grain, the numerical disadvantage that existed in the NEPZ-bred material under NWPZ conditions was mainly due to few environmental restrictions imposed on the grain ripening period. Translocation of the assimilates for yield accumulation was also carried out at similar rate that again supports the idea that no genetic differences existed among the materials in physiological efficiency as far as grain yield in concerned.

G × E Interaction

Exploitation of G × E to make better use of the favourable environmental conditions is also an advantages that a breeder would always like to have in the developed material. Such an interaction for grain yield was not visible among the two categories of wheat germplasm under North-eastern conditions (Table 2). Overall yield in both the materials remained around 44 q/ha. It was mainly because both the materials looked alike as far as the key yield components like grain number/unit area and kernels weight were concerned. However, with change of environment, both the materials started registering differences for these important traits. Besides, grain yield and grains/m^2, another trait that registered G × E interaction was the grain fill rate. There was no difference in the grain fill rate among two types of germplasm in NWPZ. However, the same set of materials showed significant differences for this trait in the NEPZ. Such an interaction in NEPZ helped the native material to match with the corresponding materials in kernel weight inspite of faster grain fill period. Grain weight in wheat is the product of rate and duration of grain filling (Nass and Reiser, 1975). Przulj and Mladenov (1997) found no strong relation between grain fill duration and grain fill rate which enables the combining of these two traits in the process of cultivar development. They have suggested that in regions with shorter growing season, the yield can be more easily raised by increasing grain fill rate while in the temperate regions different values of these parameters can be combined.

Interaction could also be noted for maturity period, as significant differences among two materials of different origin could only be noticed in the NEPZ. Even though, the difference was too small to have an impact on yield, it does have relevance under NEPZ conditions where late maturity of the NWPZ material is normally argued.

Material for NWPZ

Under NWPZ conditions, overall performance of the locally derived elite genepool was better than NEPZ-bred material. An additional 2.8 q/ha yield was added to the native materials due to its distinct superiority in grain number/m^2 (Table 2). The grain fill period in the native material was also longer than the NEPZ-bred material which may have contributed to better grain size. The real advantage that the NWPZ-bred material has in the native zone, therefore, comes basically from three factors *i.e.* more number of grains/m^2, longer grain filling duration in aid to better grain filling, and proper plant height. It appears that the NWPZ-bred material has a better combination of traits that helps in adaptation and realising high yield potential under diverse environments. As evident from the historical evidence, it is the grain number that has been consistently associated with increase in wheat yields (Slafer *et al.* 1994 and 1996; Villariel *et al.,* 1994, 1995). The elite genepool derived in this region comes largely from winter × spring genepool recombination. Besides the 1B/1R translocation, other agronomic characters, a higher number of grains through either higher number of heads/m^2 or through bigger heads contribute to high yield in winter × spring wheat derived genepool (Rajaram and van Ginkel, 1996).

The NEPZ-bred material could not exploit the favourable environment of NWPZ to a real yield advantage, mainly for two reasons. First being the faster vertical growth *i.e.* plant height (100 cm) that not only added extra height to an disadvantage through lodging but it also helped in restricting the horizontal growth *i.e.* tillering, consequently resulting in limitation to the source and grain number/unit area. The second factor was short grain filling period that resulted ultimately in lower kernel weight. With matching rate in yield and grain fillings, it was clear that physiologically both the genepools were equally efficient in translocating assimilated to the heads during grain filling period. The reduction in grain filling period, therefore, can not be regarded as quick maturing, it is rather a forced maturity resulting on account of poor tolerance under sudden increased temperature. It is a kind of abiotic stress to which the NEPZ breeding materials is not exposed in the native zone during the process of development.

Material for NEPZ

Under NEPZ conditions, there was not much to choose between two types of materials as they matched each other in yield and yield components like grain number/m^2 and grain size. Morphologically, the NEPZ material appeared distinct only in height but this much height (92 cm) does not result in lodging, rather it adds to the total biomass under NEPZ conditions. Another difference lied in the phasic development where grain fill period of the native material was shorter than the NWPZ-bred material. Reduction in the grain fill period of the native material was not forced as the grain fill rate in this elite genepool was even better than the material developed in NWPZ. This faster filling of grains in the locally developed elite genepool was instrumental in sustaining grain yield. It became quite clear that under any environment, there are two in-built characteristics in the NEPZ-bred material (i) taller height and (ii) quick grain filling.

There were also indications that the NWPZ material attains maturity slightly later when compared to the native material. Even though the magnitude of such a difference was quite small with no bearing on the overall yield, it does have a great relevance under NEPZ conditions where late maturity of the NWPZ material is normally argued. In the past three years, three varieties for normal sown conditions have been released for NEPZ out of which, two varieties *i.e.* HD 2733 and PBW 443 have been developed in the NWPZ. It has been noted that in comparison to 118 days crop duration in case of native variety HUW 468, the NWPZ-bred varieties HD 2733 and PBW 443 took 123 and 121 days, respectively, to complete maturity under NEPZ conditions (AVT: NEPZ, 198-99 to 2000-10). PBW 343, another NWPZ-bred variety recommended for NEPZ conditions as well, matures six days later than HUW 468 (AVT: 2000-01). Slight delay in maturity can hinder prospects of a high yielding variety in the NEPZ as the production condition favours short duration wheat varieties in this region.

The breeders located in the NWPZ and NEPZ are conducting wheat improvement programme in the Indo-Gangetic plains in combination. The trails run by the AICW&BIP for timely-sown irrigated condition are also common for yield evaluation of the incoming materials. It is, therefore, necessary for the breeders of each zone to know the kind of general behaviour of their material are expected to give within and outside the zone. To exploit conditions best to the yield advantage, it is also necessary to know the traits that remain unaffected with changing of environment and the specific advantages different materials carry under different environments. There is always certain in-built advantage of the place where a particular material is developed or selected. Wheat material developed in harsh environment carry certain degree of tolerance against moisture stress and high temperature. So is the case when wheat breeding and selection is carried out in salt-affected soils, knowingly or unknowingly, the developed materials usually have added advantage of better adaptation under saline-alkaline conditions. Whether breeding in a particular region also influences yield traits, is the key issue addressed in this investigation. The NWPZ is not only the most favourable area for wheat production in India but it also leads in development of improved wheat varieties. Since 1970, one third of the total notified wheat varieties belong to this region and NEPZ is the next to follow. Per hectare yield of over 7 tonnes has been recorded in many entries including check PBW 343 the most popular wheat varieties bred in NWPZ are capable of competing native varieties of the adjoining NEPZ, too (Mohan and Jag Shoran, 1999). In a related study, the authors have earlier indicated that the NIVT-1A, a trial where majority of the incoming material hails from NWPZ, has shown better adaptation across these zones when compared with NIVT-1B, a trial mostly packed with NEPZ-bred materials (Mohan and Jag Shoran, 2000). This analysis has confirmed that such kind of wider adaptation and ability to exploit favourable conditions to yield advantage though higher number of grains/m^2 is an in-built advantage tagged to the elite wheat breeding developed in the North-western region. Although the elite genepool bred in the North-eastern region is able to maintain its yield under NWPZ conditions but it fails to draw advantage of this favourable climate on account of small grain size and extra height. Tolerance to sudden rise in temperature during grain filling period and ability to exploit cooler environmental conditions of NWPZ for producing extra tillers, are missed in the elite genepool of the eastern region. Partitioning of yield through height rather than tillers is also a co-adapted trait in the NEPZ-bred wheat materials under NWPZ conditions, derivatives of winter × spring programme might prove more useful in exploiting yield through increased grain number/unit area and tolerance against spurt during grain filling.

Present study clearly suggests that some important yield components in wheat co-adapt during the process of varietal development. It could be demonstrated that there lies advantage of better adaptation, high grain number/m^2 through better tillering and good grain size, better tolerance against abiotic stresses especially during grain filling period in the elite genepool developed under NWPZ conditions. Extra height and short grain filling period, two important attributes of the elite genepool developed under NEPZ conditions, have some utility only under NEPZ conditions where they effectively contribute in sustaining grain yield. It is perceived that winter × spring genepool combinations and shuttle-breeding approach can prove handy to the NEPZ breeders in developing competitive elite genepool for the adjoining areas.

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