New Plant Type for High Yield Potential in Wheat-designed

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To achieve a quantum jump in wheat productivity in India, there is a need to design a new plant type, combining negatively correlated yield components in a single genotype of very high yield potential. In this endeavour, new plant type combining two negatively correlated traits (high tillers with high grain weight and high grain weight with high grain number/ear) have been successfully combined resulting in significantly high yields. The second phase advance generation materials are in pipeline, which have optimum combination of all three yield components and also carry alien genes *(Lr24/Sr24)* for leaf and stem rusts resistance, would have further increased in yield potential.

Key Words: Plant Type, Rust Resistance, Wheat, Yield Components

Wheat production in India has increased due to development of varieties possessing high productivity for various agro-ecological zones of the country. The national average of wheat yield had increased from about one t/ha in early 1960s to nearly 27 t/ha in late 1990s. It is projected that by the year 2020, India will need 109 m t of wheat for internal consumption. To achieve this target, average yield must be increased from 2.7 t/ha to 4.0 t/ha. This increase in productivity is difficult to achieve through conventional wheat improvement approach of inter-varietal crosses. The other approach of tapping the variability existing in wild relatives of wheat, is also not yet perfected.

Since the last two decades, CIMMYT breeders are working on designing wheat architecture, named 'buitre type' with thicker stems, fewer tillers, larger heads and a higher number of grains without a commensurate decline in grains weight (Rajaram and Ginkel, 1996). Presently these positive traits are counter-balanced by an unknown physiological imbalance or disorder that results in a low number of tillers, largely sterile heads, mostly shrivelled grains and high susceptibility to leaf and stripe rusts (Pingali and Rajaram, 1999).

To further increase the yield potential, the uncommon approaches for exploiting the variability existing in local and diverse germplasm are to be used. Indian Agricultural Research Institute, New Delhi, initiated strategic research in 1994-95 by way of exploiting some local types characterized with very long spikes but shrivelled grains. These local types have shy tillering and are highly susceptible to rusts. The objective of utilizing these types was to develop wheat genotypes combining high grain weight with increased number of grains, optimum tillering and resistance to rusts. With the adoption of this strategy, several lines with new plant type were designed, resulting in very high yield and resistance to leaf and stem rusts.

Materials and Methods

The materials involved as parental lines, in the development of high yielding genotypes were local germplasm (SFW) and two released varieties (Vaishali and Vidisha) deriving leaf and stem rust resistance genes (*Lr24/Sr24*) from *Agropyron elongatum.*

The local germplasm was characterized by very long ear-head with unfilled middle spikelets, long and shrivelled grains, few tillers/plant and high susceptibility to rusts. This germpalsm line was included as one of the parents in crossing programme with a view to fill all the spikelets with bolder grains and combine other desirable traits from the second parent.

The other parents Vaishali and Vidisha, which were crossed with the local type, are released cultivars for timely sown irrigated conditions and late sown irrigated conditions in North Eastern Plain Zone and Central Zone, respectively. These parents were chosen with the objective to combine genes for resistance to stem and leaf rust and also to look for optimum combination of tillering habit, grain weight and grain number in single genotype. Along with this material four varieties namely PBW 343, HD 2687, HD 2329 and UP 2338 were included as check in the present investigation.

The new efficient plant type combining desirable yield components along with resistance to stem and leaf rusts were developed through modified pedigree method of selection from F_2 to F_5 filial generations. Two crosses of SFW (local type) with Vaishali and Vidisha were attempted and the F_1's were bulked. A very large F_2

population (approx. 2500 plants) of these two crosses was planted. The spreader rows were planted all around and in between, at regular intervals. The artificial epiphytotic of leaf rust was created by inoculating the spreader rows with the urediospores of most virulent race 77-5 with the help of hypodermal syringe. The selection in F_2 generation was exercised for plants combining maximum tillering, long and well filled ear heads and resistance to leaf rust. Selected F_2 plants were individually harvested and screened for well filled, bold and lustrous grains. F_3 families were raised from F_2 plants in 2.5 m x 2 rows plots. In selected F_3 families exhibiting resistance to rust and high tillering, long and well filled ear heads were picked up and threshed individually. In F_4 and F_5 generation ear row progenies were planted in epiphytotic conditions of leaf rust and long, well-filled ear heads were selected from the selected progeny rows having desired plant type and grain selection was exercised. The finally selected ear-heads from a progeny row were bulked and evaluated in Yield Trial comprising 6 rows of 5 m length with 3 replications evaluated in randomized block design during 1999-2000. One square meter plot from the middle of the plot of each entry in all replications were cut from the ground level when it was fully mature. The data on biological weight, grains yield, number of tillers were recorded from this one square meter plot area. Number of grains/ear-head were calculated from randomly selected 50 ear-heads from the harvested plot.

Data collected on various traits were analyzed for analysis of variance (ANOVA) and correlation among these traits. Correlation coefficient were calculated according to Miller *et al.,* (1958).

Results and Discussion

All the traits (grain yield/sq. m., number of tillers/ sq. m, 1000-grain weight and number of grains/ ear-head) except biological yield were highly significant which indicate very high variability in the material under study (Table 1).

Out of the nine newly developed lines, four lines yielded higher than all checks including the most popular variety PBW 343 in northern and western parts of the country (Table 2). Line DL 1266-2 has significantly out-yielded the best check variety PBW 343 and also both parental lines (SFW and Vaishali). This genotype is the ideal genotype with respect to optimum combination of tillers/plant (335), high grain weight (45.6 g) and number of grains/ear (46). This genotype also occupied first rank on the basis of mean yield/plot. According to new strategy of breeding genotypes combining optimum tillers/plant and higher two yield contributing traits (grain weight and number of grains), DL-1266-2 is the most suitable example.

Another genotype DL 1266-1 from the same cross also yielded higher than all the four checks and parental lines. However, it ranked 8th on the basis of grain yield/ plot. This genotype has the best combination of 1000 grain weight (51.5 g) and grains/year (50) but with low tillering habit. This type of genotype becomes the base material for further improvement in tillering habit combining with little low values of 1000 grain weight and grains/ear. DL 1266-6 is the third genotype of the same parentage, which is similar to DL 1266-2 in optimum combination of the entire yield contributing traits.

The fourth genotype DL 1280-1 from a cross between HD 2339 and Vaishali is also superior to all the check varieties. However, this genotype has a different combination of yield contributing traits. It has highest number of tillers/plant (611) and also very high 1000 grain weight (46.1 g) but less number of grains/ear (24). This genotype ranked second on the basis of grain yield/plot.

DL 1267-3 (SFW × Vidisha) yielded at par with the best check (PBW 343) has optimum combination of all the three yield contributing traits.

The local germplasm line (SFW) has low tillering (304) and low 1000-grain weight (33.3 g) and moderate

Table 1. Analysis of variance for yield and yield component

Source	D.F.	Mean sum of square				
		Biological yield	Grain yield	No. of tillers	1000-grain weight (g)	Grains/ear-head
Replication	2	12964.58	26787.62	4730.27	45.10	2.428
Treatments	15	35643.88	14111.24**	38830.13**	130.33*	198.51**
Error	30	28886.81	5053.33	2823.45	3.99	19.62

** Significant at 1%

Table 2. Mean values of yield and yield components

Varieties	Biological Yield/m²	Grain yield/m²	No. of tillers/m²	1000-grains wt.(g)	Grains/ ear	Plot yield (kg)
DL 1266-2	2166.00	707.83 (1)	335.33	45.60	46.44	4.320
DL 1266-1	1883.33	695.97 (2)	274.00	51.47	49.84	3.829
DL 1280-1	2113.33	667.77 (3)	611.00	46.13	23.79	4.134
DL 1266-6	1953.33	649.87 (4)	340.67	40.27	47.75	3.603
Vidisha (P)	2006.67	643.03 (5)	541.33	36.00	33.58	3.969
PBW 343 (C)	1956.67	625.47 (6)	514.67	33.47	36.40	4.125
DL 1267-3	1803.33	625.23 (7)	375.67	39.73	41.94	3.765
DL 1267-2	1956.67	625.17 (8)	376.67	39.73	41.97	3.778
HD 2329 (C)	1820.00	620.93 (9)	482.00	34.93	37.42	3.861
DL 1270-4	1950.00	610.80 (10)	487.33	38.00	33.19	3.830
DL 1266-3	1940.00	609.20 (11)	279.00	44.93	48.70	3.995
Vaishali (P)	1916.67	604.20 (12)	532.00	37.20	30.80	3.777
DL 1266-5	1806.67	601.73 (13)	222.00	48.67	56.03	3.781
HD 2687 (C)	2036.67	584.73 (14)	467.00	29.60	41.58	3.497
UP 2338 (C)	1930.00	553.87 (15)	446.33	29.47	42.51	3.627
SFW (P)	1723.33	402.27 (16)	303.67	33.33	40.40	2.702
CV (%)	8.76	11.57	12.90	5.08	10.86	–
SE	42.49	17.77	13.29	0.49	1.11	–
CD at 5%	283.4	118.5	88.60	3.33	7.38	–
CD at 1%	381.6	159.30	4.48	9.94	–	

P and C indicate parents and checks, respectively
Values within parentheses indicate ranks

grains/ear (40) but the number of spikelets/spike were very high which were poorly filled. It has been observed that the grains were very long but shrivelled resulting in low grain weight. The two parents Vaishali and Vidisha have higher tillers/plant and low grain weight and grain number/ear.

With the adoption of new strategy to have optimum combination of yield components DL 1266-2, DL 1266-1, DL 1266-6 (with common parentage) have been developed with new plant type where in the physiological efficiency of partitioning of the dry matter to economic yield has increased. This increase in physiological efficiency is due to increased availability of photosynthate for proper filling of sink leading to very high grain weight and proper filling of all the grains in all the spikelets resulting in higher number of grain/ear. In fact in SFW, the numbers of spikelets/spike are very high but grain formation is low because very poorly filled grains are highly shrivelled and unaccountable. The grains/ear in line DL 1280-1, which do not have SFW as one of the parent, is very low (24), further suggesting the role of SFW in contributing high grain number in newly developed genotypes. It is generally observed by several workers (Gandhi *et al.*, 1964; Bhatt, 1973; Chaudhary *et al.*, 1977; Sinha and Sharma, 1979; Balyan and Singh, 1987; Pawar *et al.*, 1990) that two yield contributing traits, grain weight and grain number/spike are negatively correlated. It is also known that the increase in tiller number/plant leads to decrease in seed weight and number of seeds/ear as is also evident from Table 3. However, the newly constituted plant type in the form of DL 1266-1, DL 1266-2, and DL 1266-6, have shown increase both in grain weight and grain number/ear. The significant positive correlation between grain weight and grains/ear is evident from this study (Table 3). It was also successfully possible to combine high tiller number and high grain weight in a genotype DL 1280-1, which are otherwise negatively correlated components of yield.

Table 3. Correction coefficient among yield and yield components

Character	Biological yield	Grain yield	No. of tillers	1000 grain wt.	Grains/ear
Biological yield	–	0.727**	0.402**	0.120	-0.129
Grain yield		–	0.212	0479**	0.086
No. of tillers			–	0.418**	0.874**
100-grain wt.				–	0.327*

* Significant at 5%; ** significant at 1%

The concerted efforts are on in the directions of amalgamating two positive combination of yield components present in DL 1266 group and DL 1280-1, along with optimising selection criteria leading to maximizing the productivity. This advance material in pipeline has passed through preliminary yield trials and are under testing in replicated multi-location trials.

The *Agropyron elongatum* derived leaf rust resistance gene *Lr24* is effective till today in Indian sub-continent. This leaf rust resistance gene is linked with stem rust resistance gene *Sr24* which is effective to an array of virulent and prevalent races in the country. All the newly developed genotypes in the study carry this combination of leaf and stem rust resistance genes, introgressed through two released wheats Vaishali and Vidisha, the carrier of these genes *i.e. Lr24/Sr24*. All these genotypes were found highly resistant to leaf and stem rusts when tested as seeding in the glasshouse and as adult plants at hot spots.

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