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Genetic Improvement in Yield, Yield Attributes and Leaf Rust Resistance in Semi-dwarf Wheat Varieties Developed in India from Last 40 Years

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ABSTRACT

India witnessed Green Revolution with the introduction of semi-dwarf wheat varieties like Kalyan Sona and Sonalika from CIMMYT Mexico in 1963. However, from last seven years the total wheat production remained stagnated. Therefore, present investigation was undertaken to determine yield ceiling, improvement brought in yield, yield attributes and leaf rust resistance in newly released wheat varieties. The trials were laid down in Randomized Block Design (RBD) with four replications during two consecutive years 2005-06 and 2006-07. Data were recorded on 8 quantitative characters and were subjected to different statistical analysis. Mean performance of yield, yield attributes and leaf rust resistance of 13 promising newly released wheat varieties were compared with Kalyan Sona and Sonalika (Checks). The pooled yield data of two years indicate that PBW-343 and HD-2733 are the top yielding varieties. PBW-343 showed significant improvement in the mean yield performance over Kalyan Sona but non-significant improvement over Sonalika. PBW-343 and HD-2733 recorded maximum number of tillers/plant, spike length, grain/spike, harvest index and 1000 grain weight. However, their differences in mean values were non-significant over checks. Almost all latest wheat varieties (except HUW-318, Veeri, K-816, Kalyan Sona and Sonalika) have shown good degree of resistance to leaf rust races. It is concluded from present investigation that in wheat yield ceiling has reached once again. There has been no significant improvement brought in yield and yield attributes through breeding researches in India since 1969-2005. Resistance to leaf rust has been appreciated.

Key words: Wheat-*Triticum aestivum*, yield ceiling, yield, yield attributes leaf rust resistance

INTRODUCTION

India witnessed wheat revolution with the introduction of semi-dwarf Mexican wheat varieties in 1963. This was the time when country was facing acute shortage of food grains. Due to explosive population growth and successive drought for two consecutive years (1965-67), India import about 10.0 m.t. of food grains. It shattered the countries economy badly. However, with the introduction of semi-dwarf wheat varieties specially two selections- Kalyan Sona and Sonalika made out of CIMMYT breeding materials, production of wheat in India rose from 12.0 m.t. in 1965 to 76.3 m.t. in 1999-2000 (Nagarajan, 2005). This period is most famous an era of 'Green Revolution' in the Indian history. Both Kalyan Sona and Sonalika were ideal in plant type. They possesses short

plant stature, bold and amber grains, responsive to higher doses of fertilizer application (120N: 60P: 50K) and irrigation management (5-6) without lodging. Due to short maturity duration both fitted well in the "rice-wheat" cropping system which collectively brought "Wheat Revolution". In addition, these varieties were resistant to all the three wheat rust diseases viz; stem rust, leaf rust and stripe rust. As a result production of wheat tremendously increased per unit area and time (Choudary and Ali, 2008).

Unfortunately, from 2000-2007, the total wheat production remained stagnated around 76.0 m.t. (oscillating between 72.0-76.0 m.t.) and productivity around 27.0 q ha^{-1}. The Indian farmer's development agencies, wheat breeder, Planner and Politicians feel that sudden rise in temperature in Feb-March when crop is in milk stage is the reason of stagnation in yield (Chatrath *et al*., 2007). But there is general opinion around world that "ceiling in yield" has reached once more as a result production is stagnated. Nagarajan (2005) said "the last five years have been witnessing a downward production swing from 76.37 to 65.1 m.t". This resulted import of about 5.5 m.t. of wheat grains during 2006-07. Reeves (1996) reported stagnating wheat yields could put many peoples at risk of hunger and poverty. But data are not available to justify their reasoning.

Among wheat rusts, brown rust is most wide spread, black rust is restricted to Peninsular India, yellow rust to Northern and North-Western regions of India (Anonymous, 2007). Each has a number of physiological races such as 32 of stem rust; 24 of leaf rust and 20 of stripe rust. Therefore, it is very difficult for any variety to stay for longer (5-6 years) in the cultivation Kilpatrick (1975). The foundation varieties Kalyan Sona and Sonalika also broke down their resistance within five years to the leaf (brown) rust. These were quickly replaced by new semi-dwarf wheat varieties. Hence, present investigation was undertaken to generate data to derive concrete and conclusive evidences to prove:

- The level of increase in the yield obtained through breeding researches since 1969-2005 in India over Kalyan Sona and Sonalika
- To determine the ceiling in the yield of semi-dwarf wheat varieties evolved since 1969-2005 in India if so, the reasons of stagnation in yield and suggesting new breeding approaches to break the "yield barriers" if any, based on the findings of this present study
- The level of resistance incorporated to brown rust (*P. recondita)* by breeding researches over Kalyan Sona and Sonalika (Check) since 1969-2005 in India

MATERIALS AND METHODS

The materials used for present investigation comprised of 15 most popular semi-dwarf wheat varieties evolved since 1969-2005 including two checks (Kalyan Sona and Sonalika). The trials were laid down in Randomized Block Design (RBD) with four replications during two consecutive rabi season 2005-06 and 2006-07 at Experimental Research Farm, Department of Genetics and Plant Breeding Sam Higginbottom Institute of Agriculture, Sciences and Technology (formerly Allahabad Agriculture Institute) Deemed to be University, Allahabad. Each plot consisted of 4 rows, 1×5 m plot size with row and plant to plant distance of 25 and 5 cm, respectively. The recommended cultural practices were followed during the crop growth period. For data collection of different parameters, five randomly and competitive plants of each variety from each replication were selected. The data were recorded for number of tillers per plant, spike length (cm), number of grains

per spike, plant height (cm), harvest Index (%), 1000 grain weight (gram) and yield kg plot^{-1}. The harvest index was calculated by the following formula:

$$\text{Harvest index} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

The data recorded for the above mentioned parameters were averaged and analyzed statistically, subsequently mean performance of yield and yield contributing traits of each variety was compared with mean performance of yield and yield contributing traits of the first series of semi-dwarf wheat varieties Kalyan Sona and Sonalika (used as checks) introduced in India from CIMMYT, Mexico in the year 1963.

Yield difference (kg) over check was determined according to the following formula:

$$\text{Mean value of variety-Mean value of check}$$

Yield percentage increase/decrease over check was determined according to the following formula:

$$\text{Yield}(\%) = \frac{\text{Mean value of variety-Mean value of check}}{\text{Mean value of check}} \times 100$$

On the basis of CD (0.5%) values, significant and non significant performance of 13 semi-dwarf wheat varieties over two checks (Kalyan Sona and Sonalika) for yield and yield contributing traits was determined by using the following formula:

$$\text{CD value+Mean value of check} = \text{Observed value}$$

Observed value was compared with mean value of variety, if observed value is below than mean value of variety then mean performance of variety for yield and yield contributing traits are considered to be significant over check and if observed value exceeds above the mean value of variety then mean performance of variety for yield and yield contributing traits are considered to be non significant over check.

The infection of rust was checked on each plot and on the basis of intensity of infection (percentage of leaf area infected) plants were grouped into Highly resistant (HR-0% infection), Resistant (Traces, 1-10%), Moderate Resistant (MR, 11-20%), Moderate Susceptible (MS, 21-30%), Susceptibility (S, 31-50%), Highly Susceptible (HS, 51% to above). Rust infection was measured by using scale developed by U.S. Department of Agriculture Rust Scale (Herbert *et al*., 1955).

RESULT AND DISCUSSION

The data of mean yield performance of the 15 semi-dwarf wheat varieties including two checks (Kalyan Sona and Sonalika) have been summarized in Table 1. The Pooled yield data of two years indicates that PBW-343 which is a selection from 'Attila' is the top yielding (2.25 kg/plot) variety among all the semi-dwarf wheat varieties including two checks under trial. It shows significant mean yield performance over Kalyan Sona (2.12 kg plot^{-1}) but non-significant improvement over Sonalika (2.14 kg plot^{-1}) and percentage increase in yield is hardly 6.13% over Kalyan Sona and

Table 1: Comparative pooled mean yield performance of 15 semi dwarf wheat varieties including two checks (Kalyan Sona and Sonalika)

Name of variety	Year of release	Mean yield kg/plot (Plot size 1×5 m= 5 m^2)	Yield differences (kg) over checks		Percentage increase/decrease over check	
			Kalyan sona (Pooled)	Sonalika (Pooled)	Kalyan sona (Pooled)	Sonalika (Pooled)
PBW-343	1996	2.25*	+0.13	+0.11	6.13	5.14
PBW-373	1996	2.00	-0.12	-0.14	-5.66	-6.54
HD-2733	2001	2.21	+0.09	+0.07	4.24	3.27
HD-2824	2003	1.86	-0.26	-0.28	-12.26	-13.08
HD-2009	1975	1.95	-0.17	-0.19	-8.01	-8.87
HUW-206 (Veeri)	1986	2.04	-0.08	-0.10	-3.77	-4.67
HUW-510	2002	2.10	-0.02	-0.04	-0.94	-1.86
HUW-318	1991	1.73	-0.39	-0.41	-18.39	-19.15
K-816	1974	1.90	-0.22	-0.24	-10.37	-11.21
K-9533	2002	2.06	-0.06	-0.08	-2.83	-3.73
RAJ-3777	2002	2.04	-0.08	-0.10	-3.77	-4.67
RAJ-4037	2003	2.09	-0.03	-0.05	-1.41	-2.33
UP-2594	1984	1.83	-0.29	-0.31	-13.67	-14.48
Kalyan Sona (Check)	1969	2.12				
Sonalika (Check)	1969	2.14				
SE (x) ±		0.065				

*Significant over Kalyan Sona

Table 2: Comparative pooled mean of yield component characters of 15 semi dwarf wheat varieties including two checks (Kalyan Sona and Sonalika)

Name of variety	No. of tillers/ plant	Spike length (cm)	No. of grains/ spike	Plant height (cm)	Harvest index (%)	1000 grain weight (g)
PBW-343	12.51*	11.49	57.53	94.12	40.32	42.66
PBW-373	8.45	10.21	54.31	91.47	32.42	37.23
HD-2733	12.09	11.29	57.28	84.14	37.30	42.37
HD-2824	8.57	9.15	53.18	80.72	31.51	36.02
HD-2009	8.70	9.12	53.09	79.99	31.82	37.42
Veeri	10.73	10.31	54.46	93.61	34.17	39.72
HUW-510	11.03	10.55	55.32	85.45	36.55	42.17
HUW-318	8.16	9.21	53.28	89.88	32.43	35.49
K-816	9.73	9.19	53.21	78.50	32.88	39.30
K-9533	10.32	10.67	55.52	98.57	35.07	40.23
RAJ-3777	9.80	10.38	55.18	93.35	34.69	40.78
RAJ-4037	10.55	10.49	55.27	85.35	35.63	42.08
UP-2594	9.75	9.16	53.17	94.02	31.77	35.25
Kalyan Sona (Check)	10.25	10.69	55.54	92.03	36.73	41.87
Sonalika (Check)	11.55	11.18	57.15	96.39	37.94	42.09
SE(x)±	0.98	0.99	2.44	3.53	1.83	1.93
CD (5%)	1.98	2.00	4.92	7.14	3.70	3.90

*Significant over Kalyan Sona

5.14% over Sonalika. Both checks are first group of semi-dwarf wheat varieties released in 1969 which played major role in pushing the production of wheat in India as a result India celebrated wheat revolution. HD-2733 a recently released wheat variety which is also a selection out of a cross involving 'Attila' as one of the parents is the next top yielding (2.21 kg plot^{-1}) variety but its mean

yield performance is insignificant over both the checks and percentage increase in yield is hardly 4.24% over Kalyan Sona and 3.27% over Sonalika, respectively. Thus, the gain in yield is very low/negligible through breeding researches since 1969-2005. In fact on an average, Kalyan Sona and Sonalika were found good yielder as compared to other recently Indian bread wheat varieties and scored 3rd and 4th position, respectively. It also indicates that Attila is a good parent. This proves that ceiling in the yield of wheat varieties have reached once more. Our results supported the assumptions of Shoran *et al.* (1998), Conway and Toenniessen (1999), Nagarajan (2005), Chatrath *et al.* (2007) and Sharma *et al.* (2007). Yield is not an independent character but a product of a number of constellation of yield contributing characters such as tillers per plant which contributes to raise plant population per unit area; spike length, grain per spike and 1000 grain weight which form the 'Sink' and the harvest index which are considered directly related to yield. The numbers of tillers per plant, grains per spike and grain weight are highly influenced by heredity and environment. On the analysis of yield attributes viz., tillers per plant, spike length, grains per spike and 1000 gain weight, it was observed (Table 2) that significantly superior performance of PBW-343 in yield is mainly due to significantly higher number of tillers/plant (12.51), spike length (11.49 cm) grain/spike (57.53) and 1000 grain weight (42.66 g) over checks. It was followed by HD-2733 which too possesses better tillering ability (12.09), spike length (11.29 cm) grain/spike (57.28) and 1000 grain weight (42.37 g) than the checks (Kalyan Sona and Sonalika) but differences in mean values were non-significant. Other semi-dwarf wheat varieties were inferior to checks. This indicates that no systematic efforts have been made to improve these basic yield attributes to enhance the yield by component breeding approach by pyramiding gene/gene complex conditioning above said traits. Definitely, yield has no genes (Grafius, 1964) because it is a dependent character. But all the yield attributes like tillers/plant, spike length, grain per spike and grain weight in cereal grains are polygenically controlled traits specially by additive genes (Yoshida, 1972). Traditional wheat varieties with high tillering ability (WR-1451), higher grain number per spike (NP-824, NP-825) and higher 1000 grain weight (C-306) are available in the germplasm collections of Wheat Research Directorate (Karnal) as well as at other cooperating wheat breeding centres of All India Coordinated Wheat Improvement Project (AICWIP). Hence there was no problem to utilize these native wheat germplasm to incorporate the genes for above said yield traits in the genetic background of Mexican semi-dwarf varieties (Kalyan Sona and Sonalika) through intensive hybridization programme. Plant height is important with respect to lodging resistance and plant canopy. On the basis of pooled data, K-9533 was the tallest (98.57 cm) among the 15 varieties included in trial. There was no lodging in any variety included K-9533.

Harvest Index is the ratio of economic yield to total biological yield. Harvest index is considered an effective parameter to measure the yield advancement in yield. The term harvest index was given by eminent plant breeder Donald (1962) reported that indirect selection through harvest index was 43% as efficient as direct selection for yield.

Keeping in mind above concept, harvest index was taken as one of the criteria to measure the improvement brought in the yield of newly evolved wheat varieties over old ones (checks). It was observed that highest yielding wheat variety PBW-343 has the highest harvest index too (40.32) which is higher than Kalyan Sona (36.73) and Sonalika (37.94) but differences in the mean values on the pooled basis were not significant. This was followed by HD-2733 (37.30), the second high yielding variety but here too differences in the mean values were not significant. Infact, both checks- Sonalika and Kalyan Sona scored 2nd and 4th position for harvest index. The variety

Table 3: Comparative data of Leaf Rust Infection on 15 semi-dwarf wheat varieties in the first and second year crop season (2005-06 and 2006-07)

Name of variety	Leaf Rust Infection in percentage (2005-06)	Leaf Rust Infection in percentage (2006-07)	Status
PBW-343	F	F	Highly resistant (HR)
PBW-373	F	F	Highly resistant (HR)
HD-2733	F	F	Highly resistant (HR)
HD-2824	F	F	Highly resistant (HR)
HD-2009	F	F	Highly resistant (HR)
VEERI	21-24%	21-25%	Moderate susceptibility (MS)
HUW-318	21-27%	21-24%	Moderate susceptibility (MS)
HUW-310	F	F	Highly resistant (HR)
K-816	21-24%	21-27%	Moderate susceptibility (MS)
K-9533	F	F	Highly resistant (HR)
Raj-4037	F	F	Highly resistant (HR)
Raj-3777	F	F	Highly resistant (HR)
UP-2594	F	F	Highly resistant (HR)
Kalyan Sona	21-25%	21-23%	Moderate susceptibility (MS)
Sonalika	11-17%	11-16%	Moderate resistant (MR)

F: Free from infection (Highly Resistance HR) 21-30%: Moderate Susceptibility MS), 1-10%: (Traces) Resistance (R) 31-50%: Susceptible (S), 11-20%: Moderate Resistance (MR) 51% to above: Highly Susceptible (HS)

HD-2824 scored lowest harvest index value (31.51), other varieties scored between 31.77 to 36.55 harvest index which are lower than checks.

This indicates that selection has been performed in breeding nursery based on 'yield' and not based on the most accepted scientific norm/parameters the "harvest index". Kertez (1985) reported that grain yield of cereal grain was doubled in Europe mainly due to increase in the harvest index and to lesser extent due to biological yield. The basic reason he cited that improved harvest index increases the physiological capacity to mobilize and translocate photosynthetic products to the organ of economic interest. But in wheat breeding programme this important character has been almost ignored.

Leaf rust is a very dreaded disease for wheat and cause about 10-15% loss in yield every year, Prasada (1960). Present investigation envisages that out of the three wheat rusts diseases, only leaf rust (*Puccinia recondita*) is a great problem in eastern U.P. Every year leaf rust infection starts by first week of March and continues upto full March and cause about 10-15% loss in yield (Kolmer, 1996). Table 3 indicates that among the 15 varieties tested, only HUW-318, Veeri and K-816 show moderate susceptibility (21-30%) to leaf rust. Among two checks, Kalyan Sona also showed moderate susceptibility (21-30%) whereas Sonalika showed moderate resistance (11-16%) to leaf rust. All other wheat varieties were free from even traces of infection during both the years It appears that all the newly semi-dwarf wheat varieties released after Kalyan Sona and Sonalika possess reasonably fair degree of resistance to the leaf rust race flora prevalent in eastern U.P. This indicates that major attention has been paid to incorporate leaf rust resistance in the wheat breeding programme and during selection in breeding nursery as well as from entry to the promotion of new lines/genotypes from initial evaluation trial to uniform regional trials under AICWIP, the entries/lines having yield at par with check but resistant to the leaf rust were considered for promotion as a policy matter.

CONCLUSION

On the basis of present investigation it is concluded that no significant improvement has been achieved in yield through breeding research during last 40 years in India. Yield differences between the latest wheat varieties over the first series of semi-dwarf wheat varieties Kalyan Sona and Sonalika has been very marginal. Yield is product of constellation of a group of yield contributing traits such as tillers/plant, grain/spike, grain weight etc and there have been insignificant improvement in these attributes. Thus, the information from present investigation provides evidence that yield ceiling in wheat varieties have reached once more. Ofcourse, major attention has been paid to incorporate the resistance to leaf rust. Almost all the latest wheat varieties have shown good degree of resistance to leaf rust disease.

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