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Introduction and Exchange of Improved Bread Wheat Germplasm in the Eastern Gangetic Plains of South Asia

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ABSTRACT

Wheat (*Triticum aestivum* L.) yield must be increased in the Eastern Gangetic Plains (EGP) of South Asia to improve the livelihoods of poor farmers. The International Maize and Wheat Improvement Center (CIMMYT) and its partners in South Asia initiated a regional yield trial, the Eastern Gangetic Plains Wheat Yield Trial (EGPYT) in 2000 to identify wheat cultivars with high and stable grain yield, superior agronomic traits and disease resistance. Advanced breeding lines from CIMMYT, Mexico and wheat programs in the region were assembled each year and tested at key sites in Bangladesh, India and Nepal. A total of 168 experimental genotypes and four checks were tested over eight years (2000–2007). The wheat genotypes showed arrays of genetic variation in grain yield, days to heading, plant height, 1000-kernel weight (TKW), and spot blotch severity in the eight years. Several experimental genotypes were superior to checks in yield, TKW, spot blotch resistance in individual country and across the region. We identified two sets of superior lines across the region that could be used as parents (Parent 1 = 'BL1804', 'BL1968', 'BL2324', 'G162/BL1316//NL297', 'NL750', 'NL835' and 'Shatabdi'; Parent 2 = 'BL2966', 'Milan/Shanghai#7', 'NL966', 'PBW373', 'BL3122', 'BL3124', 'BL3191' and 'SW89.5124*2/Fasan') to develop new improved lines with high grain yield and TKW, spot blotch resistance, early maturity and acceptable plant height. New cultivars have been developed through this effort, and many outstanding lines selected by wheat breeders in the region are being used as parents in the breeding programs of different centers. This regional effort has helped in the introduction and exchange of superior wheat genotypes, thus enriching the germplasm base in the region. The findings underline the importance of region-focused varietal testing approach in developing and disseminating high yielding wheat germplasm.

Keywords: *Cochliobolus sativus*, grain yield, leaf blight, spot blotch resistance, temperature, *Triticum aestivum*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important staple of farmers in the Eastern Gangetic Plains (EGP) of South Asia. This region includes the eastern Indo-Gangetic Plains, the southern lowlands of Nepal and the plains of Bangladesh. Approximately 10 million hectares of wheat are grown in the EGP, predominantly as part of a rice-wheat production system. This region is characterized as a nontraditional warm wheat growing region. Such a region corresponds largely to CIMMYT wheat mega-environment 1 (van Ginkel and Rajaram 1993) with late planting or high temperatures but a significant part of this region also belongs to mega-environment 5A, which is characterized by high average temperatures during the winter months and a high relative humidity. Annual wheat production in the region is critically dependent on three factors: temperature during the grain filling period, input application, and the incidence of spot blotch (Ortiz-Ferrara *et al*. 2007). It is understood that a good level of leaf rust (*Puccinia triticina*) resistance is paramount in commercial cultivars. A short winter followed by a warm spring allows timely-planted (Nov. 20-Dec. 10) wheat to mature in 110 to 120 days. However, wheat is often seeded late after late-maturing rice crops are harvest and farmers must wait for wet soils to dry before sowing wheat (Hobbs and Giri 1997; Pandey *et al*. 2005). Analysis of a long-term trial has shown that aggregate system yields in rice-wheat cropping systems of the region are declining (Tirol-Padre and Ladha 2006).

A wheat crop in the EGP encounters several biotic and abiotic constraints. Since the leading commercial cultivars are resistant to leaf rust, the most important disease is spot blotch, caused by *Cochliobolus sativus* (Ito & Kurib.) Drechsler ex Dastur (anamorph *Bipolaris sorokiniana*) (Saari 1998; Dubin and Duveiller 2000; Sharma *et al*. 2004a). Recent studies have also emphasized the continuous importance of resistance to spot blotch in India (Joshi *et al*. 2004), Nepal (Sharma and Duveiller 2006) and Bangladesh (Siddique *et al*. 2006). High spring temperatures increase spot blotch severity and reduce yields of late-seeded wheat in the region (Nema and Joshi 1973; Chaurasia *et al*. 1999; de Lespinay 2004; Sharma and Duveiller 2004; Duveiller *et al*. 2005), a frequent circumstance since late-maturing rice cultivars used in rice-wheat cropping systems delay the sowing of wheat (Hobbs and Giri 1997). Yields of late-seeded wheat are also reduced as much as 40% as a result of high temperatures alone, when these occur at the grain-filling stage (Sharma 1993; de Lespinay 2004; Duveiller *et al*. 2005). High temperatures decrease grain yield directly by reducing TKW and indirectly through increase in spot blotch severity (Sharma *et al*. 2007). This is significant considering that a wheat variety must possess high

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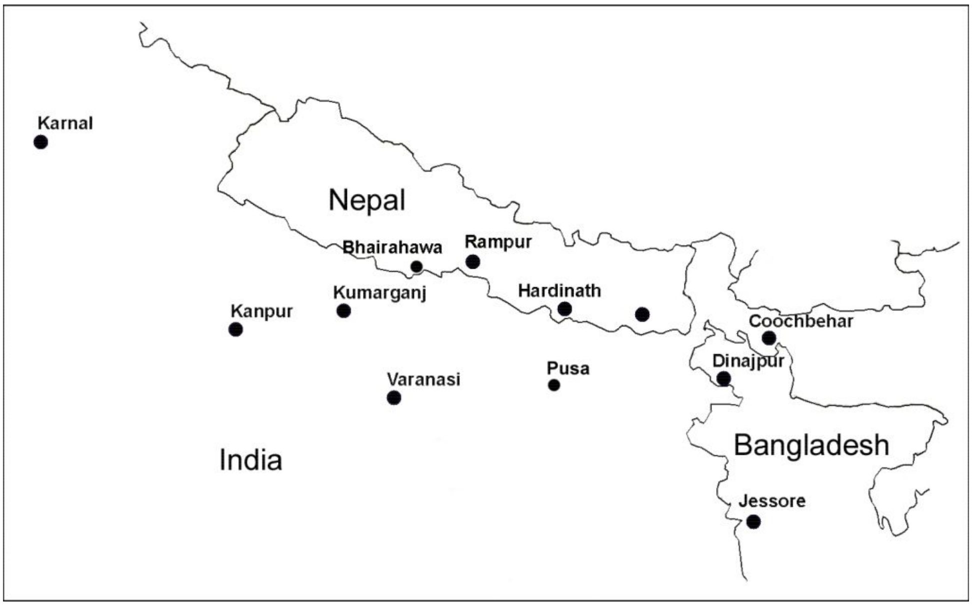

Fig. 1 A partial map of South Asia showing sites where the Eastern Gangetic Plains Wheat Trials were tested.

TKW, early maturity and spot blotch resistance in addition to high grain yield to be successful in the EGP region (Sharma and Duveiller 2003).

Wheat production statistics in the region in the past 10 years suggest yield is either stagnant or slightly decreasing over the years with exception in Nepal (FAO 2006). Further evidence supporting this observation is that due to lower production, India imported three million tons of wheat in 2006 (Reuter May 10, 2006) which contrasts with the optimism that followed the green revolution and raises concerns among agricultural policy makers regarding long term prospects of self-sufficient staple food production. Stagnant wheat yields in recent years could be partly due to heat stress characterized by an increase in average temperature during winter months in the recent years (Rane *et al*. 2000; Nagarajan 2005; Ortiz *et al*. 2008). Since high temperatures also aggravate spot blotch (Nema and Joshi 1973; de Lespinay 2004; Sharma and Duveiller 2004; Duveiller *et al*. 2005) wheat yield reductions in the EGP region could be due to increase in foliar blight epidemic severity over the recent years, which could curtail the benefits from progress recently achieved by local breeders toward incorporating resistance in locally adapted high yielding varieties. The above background information underlines the need of high yielding wheat cultivars with early maturity and spot blotch resistance for the EGP region.

CIMMYT, in collaboration with national wheat research programs in Bangladesh, Nepal and India, initiated the Eastern Gangetic Plains Wheat Yield Trial (EGPYT). This yield trial targeted to the EGP region was initiated to: i) introduce and exchange high yielding wheat genotypes with early maturity, bold kernels, and disease resistance to enrich germplasm in the region; and ii) identify new genotypes superior to the leading commercial cultivars.

MATERIALS AND METHODS

In the 1997-1998 wheat cropping season we first sent out the Eastern Gangetic Plains Screening Nursery (EGPSN), as a preliminary trial to prepare the EGPYT, which was to begin in the 1999-2000 season. The EGPSN comprises breeding lines from different wheat programs in the EGP, lines targeted for the region from CIMMYT's wheat improvement program, and a selection of the region's leading commercial cultivars – 150 lines in all, with new breeding lines each subsequent year. Since then, EGPSN is tested at more than 10 sites across the region every year. Based on grain yield, 1000-kernel weight (TKW), maturity, disease resistance, lodging, and plant type, 30 to 35 EGPSN lines are selected for potential use in EGPYT, their seed increased and quality tests performed. After testing for quality, a final set of 21 lines are selected for the EGPYT. EGPYT 1 was distributed and grown in the 1999-2000 (2000) wheat growing season; EGPYT 1–8 were tested each year during 2000–2007. A total of 168 experimental genotypes and four checks were tested over eight years (**Table 1**).

Each year the EGPYT comprised 25 genotypes, including 21 new breeding lines and a widely grown improved cultivar each from Bangladesh ('Kanchan'), India ('PBW343'), and Nepal ('Bhrikuti') plus the long time popular cultivar, 'Sonalika'. 'Kanchan', 'Bhrikuti' and 'PBW343' have comparatively early, medium and late maturity, respectively (Joshi *et al*. 2002; Sharma *et al*. 2004a, 2004b). Sonalika is an early-maturing cultivar with high susceptibility to spot blotch (Duveiller and Sharma 2004). 'PBW343', 'Bhrikuti', and 'Kanchan' are considered resistant, moderately resistant, and susceptible to foliar blight (Bhushan *et al*. 2002; Sharma *et al*. 2004b; Siddique *et al*. 2006). Among the commercial cultivars in the Nepal lowlands, 'Bhrikuti' is one of the highest grain yielders with the lowest spot blotch severity (Sharma *et al*. 2004b). 'Kanchan' has been the most widely grown wheat cultivar in Bangladesh in the past 20 years and still occupies a larger area than other cultivars (Siddique *et al*. 2006). 'PBW343' is grown on over 7 million ha in India. The old cultivar 'Sonalika' is still grown in over 1 million ha in the eastern plains of India and Nepal (Ortiz-Ferrara *et al*. 2007).

The trial sites included two in Bangladesh, five to eight in India, and two to four in Nepal (**Fig. 1**). The trial was grown at 9, 10, 10, 11, 11, 9, 9 and 6 sites in the EGP region in 2000, 2001, 2002, 2003, 2004, 2005, 2006 and 2007, respectively. Seed packages were prepared by the Wheat Research Program in Bhairahawa, Nepal, and distributed to each collaborator. The field trial was planted in an alpha lattice design with two replicates. Individual plots (4.5 m^2) were seeded at the standard rate of 120 kg ha^{-1}. Each plot comprised 6 rows of 3 m each sown 0.25 m apart. Fertilizers application, irrigation and other management practices were standard for each site.

Days to heading was recorded when approximately 50% of plants in a plot had spikes fully emerged from the boot. Spot blotch severity was scored visually, usually three times for each plot, using the double-digit scale (00–99) developed as a modification of Saari and Prescott's scale (Saari and Prescott 1975; Eyal *et al*. 1987). The first digit (D_1) indicates vertical disease progress on the plant and the second digit (D_2) refers to severity measured as diseased leaf area. For each score, percentage disease severity was based on the following formula:

$$\text{Severity (\%)} = (D_1/9) \times (D_2/9) \times 100$$

The highest disease severity rating per plot was used in the analysis.

At maturity, plant height was measured for each plot from the ground level to the tip of the spikes. After maturity, plots were individually harvested and threshed. One thousand randomly-taken kernels from each plot were weighed to measure TKW. The collaborators were also asked to identify the entries they selected as promising for further use as new cultivars or improved germplasm

Table 1 Entry name/pedigree of the different sets of genotypes tested at various sites in the Eastern Gangetic Plains Wheat Yield Trials (EGPYT) in different years

Number	Name/cross	Days to heading	Plant height (cm)	Grain yield (kg/ha)	1000-kernel weight (g)	Spot blotch severity (%)
EGPYT- 1 (2000)†						
1-1	BL1724=Para 2//Jup/Bjy/3/Vee#5/Jun/4/Nac	79	94 *NS*¶	3691 d§	39.4	27 bcd€
1-2	BL1804=Attila//Jup/Bjy/3/Attila	71 *ns*‡	97 *NS*	4365 abcd	45.6 abcd¥	36 cd
1-3	BL1835=Siddhartha/Ning8319//NL297	71 *ns*	99 *NS*	3866 d	47.2 abcd	36 cd
1-4	BL1666=NL297*2/LR25	75	100 *NS*	3858 d	46.9 abcd	28 cd
1-5	BL1905=ZSH12/HLB19//NL297	75	98 *NS*	3853 d	46.4 abcd	26 bcd
1-6	BL1910=ZSH23/HLB15//NL297	77	102 *NS*	3959 cd	48.4 abcd	36 cd
1-7	BL1911=ZSH13/HLB15//NL297	77	101 *NS*	3769 d	49.1 abcd	22 bcd
1-8	BL1912=ZSH13/HLB15//NL297	74	98 *NS*	4044 acd	42.8 b	39 cd
1-9	BL1915=ZSH23/HLB48//NL297	77	101 *NS*	3518	43.4 b	23 bcd
1-10	BL1917=Ymi#6/Vinayak//BL1022	70 *ns*	104 *NS*	3321	42.4 b	49 d
1-11	BL1945=Amsel//G.C.W-1/Vee#5	75	102 *NS*	3643 d	39.0	44 d
1-12	BL1968=NL297*2/Danial 88//HLB18	76	99 *NS*	4208 abcd	45.3 abcd	33 cd
1-13	BL1970=NL297*2/Danial 88//HLB18	80	103 *NS*	3893 d	45.4 abcd	26 bcd
1-14	BL1971=NL297*2/Danial 88//HLB18	83	105 *NS*	3858 d	44.6 ab	30 cd
1-15	BL1979=Siddharth//NL297/Ning7840/3/HUW234/NL297	72 *ns*	103 *NS*	3976 cd	42.8 b	29 cd
1-16	BL1981=G162/BL1066//NL297	72 *ns*	98 *NS*	4046 acd	46.7 abcd	33 cd
1-17	NL750=Chirya.3	81	97 *NS*	4274 abcd	41.7 b	20 bcd
1-18	NL835=Fch3/Trt//Vee#9	73 *ns*	96 *NS*	4214 abcd	43.6 ab	36 cd
1-19	Chirya.3	79	96 *NS*	3767 d	38.5	17 bcd
1-20	Chirya.7	80	95 *NS*	3827 d	42.8 b	26 bcd
1-21	SW89.5422	84	91 *NS*	3753 d	40.8 b	19 bcd
1-22	PBW343 (improved check from India)	85	93	3807	42.3	17
1-23	Bhrikuti (improved check from Nepal)	76	93	3986	39.1	33
1-24	Sonalika (long-term check)	71	107	3345	43.5	72
1-25	Kanchan (improved check from Bangladesh)	74	100	3705	43.4	47
EGPYT- 2 (2001)†						
2-1	NL 297 * 3/Nangjing7840	77 *ns*	97 *NS*	3660 d	47.0 abcd	22 bcd
2-2	NL297*2//Danial 88/HLB 25	76 *ns*‡	105 *NS*	3737 d	48.2 abcd	40
2-3	NL251/Ning8319//BL1022	80	110	3954 bd	38.4 b	24 cd
2-4	Sonalika/NL 609//NL 297	77 *ns*	103 *NS*	3919 d	43.6 abcd	28 d
2-5	ZSH12/HLB 19//2* NL297	78 *ns*	101 *NS*	3615 d	47.3 abcd	32 d
2-6	ZSH12/HLB 19//2* NL297	76 *ns*	98 *NS*	3669 d	47.7 abcd	32 d
2-7	G162/BL1316//NL297	77 *ns*	103 *NS*	4155 abcd	50.1 abcd	22 bcd
2-8	NL588/HD2307	75 *ns*	94 *NS*	3953 d	38.7 b	34 d
2-9	NL588/HD2307	74 *ns*	95 *NS*	4135 abcd	38.9 b	34 d
2-10	NL297*4/LR15	75 *ns*	97 *NS*	3370	40.8 ab	28 d
2-11	NL297*4/LR15	77 *ns*	100 *NS*	3791 d	40.8 abc	22 bcd
2-12	NL297*4/NL505	74 *ns*	97 *NS*	3404	43.8 abcd	35 d
2-13	NNR1 (Nnr 60+Rht 1)/Thb/3/Vee#5//Dove/Buc/4/NL 297	73 *ns*	99 *NS*	3914 d	46.8 abcd	35 d
2-14	NL560//Ka/Nac/6/Cmh80A.253/4/M2A/Cml//Ald/3/Ald4/5/Cno	79	99 *NS*	3868 d	38.2 b	32 d
2-15	Vee # 5/Sara//Kauz/3/Pvn/4/NL297	80	106 *NS*	3753 d	41.0 abc	29 d
2-16	CS/Th.cu//Glen3/Ald/Pvn/4/Ningmai 4/Oln//Ald/Yangmai	81	98 *NS*	4129 abd	41.1 abc	22 bcd
2-17	Kan/6/Coq/F 61.7011//Cnr/3/Oln/4/Phos/Mrng/Aldan/5/Cno	77 *ns*	102 *NS*	3826 d	38.4 b	31 d
2-18	VG 91423/Vee#3	76 *ns*	101 *NS*	3828 d	42.2 abcd	32 d
2-19	Pita/Gaa	81	96 *NS*	3818 d	38.1 b	27 d
2-20	FCH3/SN1//Nkt	80	97 *NS*	3979 abd	39.6 ab	29 d
2-21	PBW373 =ND/VG 9144//Kal/BB/3/Yaco/4/Vee#5	83	96 *NS*	3839 d	39.4 ab	17 abcd
2-22	PBW343 (improved check from India)	87	94	3726	38.1 i	24
2-23	Bhrikuti (improved check from Nepal)	80	90	3701	36.3 j	31
2-24	Sonalika (long-term check)	75	102	3323	41.0 f	45
2-25	Kanchan (improved check from Bangladesh)	77	101	3882	39.7 g	34
EGPYT- 3 (2002)†						
3-1	BL1882=NL297/Ocepar7//BL1022	74	98 *NS*	4316 a	41.4 abcd	30 cd
3-2	BL2108=ZSH23/HLB48//NL297	79	101 *NS*	4161 d	42.9 abcd	25 cd
3-3	BL2121=NNR1/Thb/3/Vee#5//Dove/Buc/4/NL297	71 *ns*	97 *NS*	4482 acd	45.1 abcd	36 cd
3-4	BL2180=NL588/HD2307//NL 623	73	98 *NS*	4422 acd	42.2 abcd	39 d
3-5	BL2189=Snb/4/Nac/A.acut//3*Pvn/3/Mirlo/Buc/5/Vee#7/6/NL297	73	91 *NS*	4399 ad	43.1 abcd	31 cd
3-6	BL2194=Snb/4/Nac/A.acut//3*Pvn/3/Mirlo/Buc/5/Vee#7/6/NL297	72 *ns*	95 *NS*	4090 d	43.1 abcd	29 cd
3-7	BL2195=Klat/Soren//Psn/3/Bow/4/Vee#5.10/5/Cno67/Mfd//Mon/3/Seri/6/NL297	72 *ns*	93 *NS*	4196 d	43.8 abcd	29 cd
3-8	BL2221=NL 588/NL297	72 *ns*	95 *NS*	4424 acd	41.1 abd	29 cd
3-9	BL2319=NL297*4/LR15	73	99 *NS*	4030 d	38.3	25 cd
3-10	BL2321=NL588/HD2307//NL 623	75	98 *NS*	4198 d	39.0	37 d
3-11	BL2322=NC588/HD2307//NL623	73	96 *NS*	4125 d	37.7	43 d
3-12	BL2324=Klat/Soren//Psn/3/Bow/4/Vee#5.10/5/Cno67/Mfd// Mon/3/Seri/6/NL297	75	95 *NS*	4554 abcd	42.6 abcd	27 cd
3-13	BL2325=Klat/Soren//Psn/3/Bow/4/Vee#5.10/5/Cno67/Mfd// Mon/3/Seri/6/NL297	82	96 *NS*	3973 d	38.9	21 bcd
3-14	NL945=Milan/Shanghai#7	80	105 *NS*	4383 ad	36.0	15 abcd
3-15	NL946=Chirya.3	81	91 *NS*	4149 d	36.0	18 bcd
3-16	NL947=Firetail	72 *ns*	92 *NS*	4480 acd	40.0 b	34 cd
3-17	NL948=Bacanora88/3/Nai60/HN7//SX	74	88 *NS*	3898 d	36.9	37 d
3-18	NL949=Bow/Buc//Bul	76	90 *NS*	4043 d	36.1	28 cd

Table 1 (Cont.)

Number	Name/cross	Days to heading	Plant height (cm)	Grain yield (kg/ha)	1000-kernel weight (g)	Spot blotch severity (%)
3-19	NL950=Seri 82//Vee'S'/Snb'S'	82	90 *NS*	4115 d	37.7	20 bcd
3-20	NL951=Srma/Mon//Attila	81	89 *NS*	4385 ad	39.3 b	23 bcd
3-21	NL952=Pvn/Yaco/3/Kauz*2/Trap//Kauz	80	87 *NS*	4099 d	36.7	23 bcd
3-22	PBW343 (improved check from India)	83	91	3968	38.9	21
3-23	Bhrikuti (improved check from Nepal)	75	87	4185	37.5	29
3-24	Sonalika (long-term check)	70	96	3280	38.4	62
3-25	Kanchan (improved check from Bangladesh)	73	99	4108	39.6	42
EGPYT- 4 (2003)†						
4-1	BL2352=NL251/ZSH22	86	101 *NS*	2950 d	35.8	43 d
4-2	BL2411=Amsel/3/HE1 /3*Cno 79//2*Seri/4/Parus	78	91 *NS*	3585 cd	36.0	43 d
4-3	BL2429=CMH 84.3631/Munia//Milan/Kauz	79	94 *NS*	3394 cd	36.5	38 cd
4-4	BL2457=Kauz//Kauz/Star/3/Prinia/4/Milan/Kauz	80	89 *NS*	3447 cd	36.9	42 d
4-5	BL2481=Ning8201/Kauz//Prinia	79	91 *NS*	3445 cd	36.7	39 cd
4-6	BL2483=Chirya.3/Pastor	79	92 *NS*	3615 cd	36.6	40 cd
4-7	BL2487=Chirya.3//Opata/Kill	80	92 *NS*	3389 cd	37.1	37 cd
4-8	BL2531=CS/Th.cu//Glen/3/Gen/4/Myna/Vul/5/Fang60/6/Chirya.6/7/Sha-7//Prl/Vee#6	75 *ns*	105 *NS*	3517 cd	39.6 b	50 d
4-9	BL2541=Yar/Ae.sq.(524)//Cbrd/4/SHA-7//Prl/Vee #6/3/Fasan	83	96 *NS*	2935 d	39.6 bd	37 cd
4-10	NL960=RW3482	80	86 *NS*	2650	37.7	48 d
4-11	NL961=Kauz*2//K134(60)/Vee	81	96 *NS*	3564 cd	38.7	38 cd
4-12	NL962=Tracha-2//Cmh76-252/Pvn'S'	79	87 *NS*	3147 d	38.9 b	49 d
4-13	NL963=Gomam/GRU90-205266	76 *ns*	90 *NS*	3332 d	36.7	51 d
4-14	NL964=Weaver//Vee/Pjn/3/Milan	79	89 *NS*	3592 cd	35.8	43 d
4-15	NL965=Weaver//Vee/Pjn/3/Milan	80	92 *NS*	3106 d	41.0 bcd	42 d
4-16	NL966=Filin/Trena/5/Cndo/R143//Ente/Mexi-2/3/Ae. sq. (Taus)/ 4/Weaver	81	101 *NS*	3407 cd	44.0 abcd	29 abcd
4-17	NL967=W462/Vee/Koel/3/Peg//Mrl/Buc	80	94 *NS*	3267 d	39.2 b	35 bcd
4-18	NL968=W462/Vee/Koel/3/Peg//Mrl/Buc	80	94 *NS*	3025 d	37.4	36 bcd
4-19	NL969=Ckr/HD2172/8/IAS58/6/Kal//BB/5/ALD/4/Oln/Trm//7C/ Ald/7/Maya/Pvr	78	107 *NS*	3574 cd	37.7	42 d
4-20	NL970=Gaa/Kea//Gaa	81	99 *NS*	3418 cd	39.6 b	39 cd
4-21	NL971=Mrng/Buc//Blo/Pvn/3/Pnb81	80	101 *NS*	3734 cd	42.3 abcd	38 cd
4-22	PBW343 (improved check from India)	85	92	3522	39.3	34
4-23	Bhrikuti (improved check from Nepal)	79	92	3711	36.8	44
4-24	Sonalika (long-term check)	75	102	2708	37.6	65
4-25	Kanchan (improved check from Bangladesh)	77	97	3133	38.9	48
EGPYT- 5 (2004)†						
5-1	Cmh81.38//Cmh76.1084/2*Cmh72A429/3/Cmh82.17/4/Chen1	74	89 *NS*	3550 d	32.2	44 d
5-2	GS348/NL746//NL748	75	98 *NS*	3690 cd	39.0 abcd	41 cd
5-3	Nac/Vee'S'//Attila	73 *ns*	96 *NS*	3399 d	36.0 b	39 cd
5-4	BL1530/BL1095//NL297/Chirya.7	69 *ns*	105 *NS*	3291 d	40.2 abcd	52 d
5-5	CS/Th.cu//3*Pvn/3/Mirlo/Buc/4/Milan/5/Attila/3/Hui/ Carc//Chen/Chto/4/Attila	74	89 *NS*	3486 d	32.9	42 d
5-6	90B57/4/R37/GHL121//Kal/BB/3/Jup/Mus/5/SW90.1057	78	96 *NS*	3265 d	32.7	42 cd
5-7	Munia/Chto/3/Pfau/Bow//Vee#9/4/Chen/Ae. sq. (TAUS)//Bcn	80	92 *NS*	3261 d	34.5	33 cd
5-8	Rayon F89	79	92 *NS*	3558 d	35.0	31 cd
5-9	Almkyn	75	96 *NS*	3123	35.3	57 d
5-10	Kauz/Star//SW89.5193/3/Milan	79	90 *NS*	3023	34.3	38 cd
5-11	Hpo/Tan//Vee/3/2*Pgo/4/Croc-1/Ae. sq. (213)//Pgo	78	96 *NS*	2943	39.3 abcd	39 cd
5-12	Hpo/Tan//Vee/3/2*Pgo/4/Croc-1/Ae. sq.(213)//Pgo	77	88 *NS*	3241 d	35.1	41 cd
5-13	Hpo/Tan//Vee/3/2*Pgo/4/Croc-1/Ae. sq. (213)//Pgo	77	93 *NS*	3362 d	36.7 abd	46 d
5-14	HE1/3*Cno79//2*Seri/3/Croc-1/Ae. sq. (213)//Pgo	75	90 *NS*	3098	31.5	45 d
5-15	HUW542	83	96 *NS*	3187 d	33.3	34 cd
5-16	GW326	68	91 *NS*	3352 d	36.2 b	51 d
5-17	Shatabdi (Mrng/Bvc//Blo/Pvn/3/Pnb81)	77	103 *NS*	4069 abcd	39.4 abcd	29 cd
5-18	Barkat/Kvz	74	90 *NS*	3482 d	37.3 abd	40 cd
5-19	IAS58/3/Kal/BB//Ald/4/Oln/Trn//7C/Ald/5/Peacock	74	97 *NS*	3428 d	35.3	41 cd
5-20	Fang 60//RL6043/4*Nac	71 *ns*	97 *NS*	3571 d	39.3 abcd	47 d
5-21	Rawal87//Buc/Bjy	75	103 *NS*	3450 d	38.8 abcd	37 cd
5-22	PBW343 (improved check from India)	82	96	3721	35.1	35
5-23	Bhrikuti (improved check from Nepal)	74	90	3780	34.2	37
5-24	Sonalika (long-term check)	71	101	3007	35.0	69
5-25	Kanchan (improved check from Bangladesh)	72	99	3428	37.4	50
EGPYT- 6 (2005)†						
6-1	NL588/HD2307	67 *ns*	92 *NS*	3020 d	38.3 abd	47 bcd
6-2	Prl/NL297	67 ns	90 *NS*	2865	37.7 ab	54 d
6-3	Fang 60/NL352//NL724	68 ns	93 *NS*	2605	38.8 abd	51 d
6-4	DL784-3/Vee#7//Prl/UP262/3/Chirya.7	75	95 *NS*	3212 acd	34.9	38 bcd
6-5	NL712/NL297//BL1473	72	97 *NS*	2890	37.8 ab	45 bcd
6-6	BL1530/BL1095//NL297/Chirya.7	69 ns	90 *NS*	2414	36.8	50 d
6-7	BL1530/BL1095//NL297/Chirya.7	68 ns	98 *NS*	2843	38.8 abd	45 cd
6-8	NL297/BL1530//NL778	72	90 *NS*	3141 acd	33.5	53 d
6-9	GS348/NL746//NL748	71	91 *NS*	3204 acd	40.6 abd	42 bcd
6-10	GS348/NL746//NL748	75	94 *NS*	2671	39.4 abd	44 bcd
6-11	SW89.5124*2/Fasan	70 ns	84 *NS*	3030 d	36.2	45 bcd

Table 1 (Cont.)

Number	Name/cross	Days to heading	Plant height (cm)	Grain yield (kg/ha)	1000-kernel weight (g)	Spot blotch severity (%)
6-12	BL2564=Cndr/Priniya	75	91 *NS*	2820	37.4 ab	49 d
6-13	BL2146=NL297*4/VL421	69 ns	92 *NS*	2674	41.2 abcd	50 d
6-14	Kauz//Kauz/STAR/3/Bav 92/4/Pastor	72	83 *NS*	3092 acd	31.6	45 bcd
6-15	Sha3/Seri//Sha4/Lira/3/Chirya.1	73	93 *NS*	2779	33.5	42 bcd
6-16	VIV90/91.28/3/Chen/Ae.sq.(Taus)//Bcn	77	95 *NS*	2941 d	35.1	47 cd
6-17	Site/Mon//Milan/3/PBW343	78	92 *NS*	3006 d	33.1	40 bcd
6-18	W462//Vee/Koel/3/Peg//Mrl/Buc	74	87 *NS*	2849	34.3	41 bcd
6-19	BAW897(Nac/Vee)/3/Nac/Vee//Catbird	73	90 *NS*	3001 d	38.3 abd	51 d
6-20	Agi/5/Coq/F61.70//Cndr/3/Oln/4/Pgo	72	94 *NS*	2833	37.0 ab	48 cd
6-21	Fang60//RL6043/4*Nac	71	91 *NS*	3101 acd	38.0 ab	52 d
6-22	PBW343 (improved check from India)	80	88	2836	35.2	43
6-23	Bhrikuti (improved check from Nepal)	73	87	3019	35.1	51
6-24	Sonalika (long-term check)	68	98	2683	36.5	69
6-25	Kanchan (improved check from Bangladesh)	71	95	2824	39.2	54
EGPYT- 7 (2006)†						
7-1	BL2927=NL724/NL750//NL297	76	102 *NS*	3161 bcd	40.5 abcd	38 bcd
7-2	BL2966=NL778/NL756//NL792	73 ns	91 *NS*	2991 bcd	42..8 abcd	37 abcd
7-3	BL3016=NL795/UP262//NL731	75	99 *NS*	2625	41.5 abcd	43 cd
7-4	BL3017=Zsh20/Pvn76//NL 753	75	96 *NS*	2900 d	40.6 abcd	46 d
7-5	BL3025=Pr/Vee# 10//Trt/3/HD2307	73 ns	95 *NS*	3043 bcd	34.9 b	53 d
7-6	BL3063=NL748/NL837	72 ns	98 *NS*	3184 bcd	43.9 abcd	42 cd
7-7	BL3065=NL748/NL837	74 ns	94 *NS*	3237 bcd	41.7 abcd	45 cd
7-8	BL3066=NL683/NL836	75	94 *NS*	2938 cd	41.6 abcd	43 cd
7-9	BL2774=Prl/NL297	73 ns	86 *NS*	2765 d	40.4 abcd	52 d
7-10	HD2824=Pto-1/Cno 79/Prl/Gaa/3/HD1951	78	86 *NS*	2930 cd	35.1 b	44 cd
7-11	Shatabdi=Mrng/Bvc//Blo/Pvn/3/Pjb81	77	96 *NS*	3135 bcd	39.5 bcd	39 bcd
7-12	Nac/Vee//K9211	76	91 *NS*	2915 cd	36.9 bcd	38 bcd
7-13	Nac/Vee//Catbird	73 ns	85 *NS*	2840 d	39.1 bcd	43 cd
7-14	Garuda//Bucula/Akr	76	92 *NS*	2780 d	31.6	48 d
7-15	Nac/Vee//Catbird	74 ns	89 *NS*	2854 d	38.8 bcd	39 bcd
7-16	BAW378//BB/Tob//Cno67/3/Huac/4/Tiresel/3/BB/PL//SX/5/Ictal-123	75	91 *NS*	2896 d	38.9 bcd	42 cd
7-17	Ictal123/3/Rawal87//Vee/HD2285	74 ns	90 *NS*	2946 cd	37.8 bcd	46 cd
7-18	Ictal123/3/Rawal87//Vee/HD2285	81	88 *NS*	2956 cd	37.5 bcd	42 bcd
7-19	Vee/Myna//Protiva	71 ns	89 *NS*	2642 d	39.8 bcd	52 d
7-20	Fang60//RL6043/4*Nac	69 ns	90 *NS*	2636	38.6 bcd	56 d
7-21	BAW1004=Akr/Balaka//Fyn/Pvn	76	99 *NS*	3120 bcd	42.8 abcd	39 bcd
7-22	PBW 343 (improved check from India)	75	91	3168	39.2	41
7-23	Bhrikuti (improved check from Nepal)	75	86	2815	32.6	46
7-24	Sonalika (long-term check)	72	97	2472	35.4	63
7-25	Kanchan (improved check from Bangladesh)	74	92	2747	35.3	50
EGPYT- 8 (2007)†						
8-1	BL3078 = Opata85/Triveni//NL872	81	116	2571	41.6 b	39.7 cd
8-2	BL3122 = BL1093/NL792//BL1907	86	102 *NS*	3551 cd	47.4 abcd	26.8 abcd
8-3	BL3124=BL 1093/NL 792//BL 1907	86	101 *NS*	3247 d	43.6 bcd	27.7 abcd
8-4	BL3144=Prl/BL 1066//NL 753	79	108	3627 cd	45.6 abcd	35.4 bcd
8-5	BL3156=WK804/NL795//NL781	78	98 *NS*	3516 cd	46.9 abcd	40.5 cd
8-6	BL3172=Weaver/K 8962//NL 750/3/NL 297	75 ns	93 *NS*	3350 d	38.6	49.2 cd
8-7	BL3178=NL728/NL297//NL789/3/NL835	80	116	2499	45.8 abcd	41.9 cd
8-8	BL3191=BH1146*3/ALD//CHIRYA-3/3/BL1361	76 ns	101 *NS*	3177 d	43.4 bcd	32.9 abcd
8-9	BL3201=BL1761/BL1811	79	98 *NS*	3485 cd	41.8 b	38.4 cd
8-10	BL3218=BL1748/BL1699	84	103 *NS*	3931 cd	50.6 abcd	41.5 cd
8-11	BL3220=BL1748/BL1699	74 ns	105	3111 d	46.2 abcd	44.1 cd
8-12	BL3232=NL872/NL868	81	105	3485 cd	38.7	30.9 abcd
8-13	BL3234=NL872/NL868	81	102 *NS*	3190 d	43.1 bcd	38.7 cd
8-14	BL3259=Vinayak/HLB 25//Vinayak	73 ns	96 *NS*	3078 d	46.2 abcd	41.3 cd
8-15	BL3280=NL897/NL872	81	97 *NS*	3319 d	43.4 bcd	49.8 cd
8-16	BL3311=RR21/NL751	81	101 *NS*	3520 cd	45.6 abcd	45.5 cd
8-17	Ictal123/3/Rawal87//Vee/HD2285	74 ns	93 *NS*	3537 cd	43.3 bcd	39.6 cd
8-18	BAW65//Prl/Toni	76 ns	101 *NS*	3305 d	44.2 bcd	36.4 cd
8-19	BAW761//Rawal/BAW56	80	97 *NS*	3120 d	49.7 abcd	45.6 cd
8-20	SW89-5124*2/Fasan	78	88 *NS*	3727 cd	43.4 bcd	34.0 abcd
8-21	Nac/Vee//Catbird	79	92 *NS*	3590 cd	45.2 abcd	36.7 cd
8-22	PBW 343 (improved check from India)	77	94	3948	43.4	39.8
8-23	Bhrikuti (improved check from Nepal)	79	93	3753	38.6	40.9
8-24	Sonalika (long-term check)	75	100	2703	40.0	80.6
8-25	Kanchan (improved check from Bangladesh)	76	96	3155	40.4	60.1

†Wheat crop harvest year.

‡ An entry with means followed by *ns* is not significantly (p=0.05) later for days to heading than the earliest maturing check Sonalika in a given year.

¶ An entry with means followed by *NS* is not significantly (p=0.05) taller than the standard height check Sonalika in a given year.

§ An entry with means followed by a, b, c, and d has significantly (p=0.05) higher grain yield than the checks PBW343, Bhrikuti, Kanchan, and Sonalika, respectively, in a given year.

¥ An entry with means followed by a, b, c, and d has significantly (p=0.05) higher 1000-kernel weight than the checks PBW343, Bhrikuti, Kanchan, and Sonalika, respectively, in a given year.

€ An entry with means followed by a, b, c, and d has significantly (p=0.05) lower spot blotch severity than the checks PBW343, Bhrikuti, Kanchan, and Sonalika, respectively, in a given year.

for use in a crossing program.

Each year–site combination was considered a unique and random environment, while genotypic effect was analyzed as fixed. The test of significance using F-ratios was conducted according to the procedure outlined by McIntosh (1983) for the analysis of combined experiments. The statistical analyses included an analysis of variance for each environment and a combined analysis across environments in a year using SAS (2003) software. Experimental genotypes that yielded significantly higher or had higher TKW or lower spot blotch severity than the check in each country were identified. Similarly, the experimental lines were identified that did not differ significantly from Sonalika for days to heading and plant height. PBW343 was used as a standard for spot blotch resistance because it is more resistant than other three checks. The highest yielding genotype in each year and the four checks were regressed over trial means in the eight years to compare their relative performance across different levels of productivity.

RESULTS

General observation

The eight wheat seasons, except 2002, were typical for the region with yield levels average for the region. In 2002, a longer than average cool season was experienced during wheat grain filling period that resulted in the highest average grain yield in the eight years. High spot blotch severity occurred in the experimental plots at several sites in each year as shown by high disease severity rating on the susceptible cultivar 'Sonalika', and no other wheat foliar disease of consequence was present. In particular, the level of leaf rust remained negligible throughout the growing season in all years.

Table 2 shows the number of entries and sites in different years where the EGPSN and EGPYT material were been distributed within the Eastern Gangetic Plains from 1998 to 2007. About 1,645 improved lines have been distributed in 244 environments (site-year combination) during that period. The trials had been distributed to more sites in each year than reported in this study. One or more collaborators did not return the trial data in some years.

Overall genotype performance

There was a significant effect of environment on grain yield, TKW, days to heading, plant height and spot blotch each year (ANOVA not shown). The 25 genotypes differed significantly ($P < 0.01$) for all traits each year. The genotype × environment interaction was significant ($P < 0.05$) for all traits, suggesting that relative genotypic values for these traits changed significantly over environments in each year. The 21 experimental genotypes and the four checks differed widely for days to heading, plant height, grain yield, TKW and spot blotch severity in each year (**Table 1**). The individual collaborators had identified several promising lines in each year (data not shown).

The genotypes in different years that produced significantly higher grain yield than the four checks across the sites were #1-2, #1-12, #1-17, #1-18, #2-7, #2-9, #3-12 and #5-17 (**Table 1**). There were 54 genotypes that showed significantly higher TKW than the four checks. The genotypes #1-7, #1-17, #1-19, #1-21, #2-21, #3-14, #4-16, #7-2 had significantly lower spot blotch severity than the most resistant check PBW343. Besides, there were several genotypes that showed spot blotch severity not significantly different from 'PBW343'.

When grain yield of the best experimental genotype in each environment was regressed over the trial mean, the slope of the regression line was 1.06 – significantly higher than slope (0.94) of the highest yielding check, 'Bhrikuti' (**Fig. 2**). Other checks also had significantly lower values for slope of the regression compared to that of the highest yielding genotypes.

Table 2 Genetic material distributed in the Eastern Gangetic Plains Wheat Screening Nursery (EGPSN) and the Eastern Gangetic Plains Wheat Yield Trial (EGPYT) from 1997 to 2006.

Nursery/Trial	No. of Trials/Year	No. of Entries
1st EGPSN (1997-98)	7	90
2nd EGPSN (1998-99)	10	155
3rd EGPSN (1999-00)	12	150
4th EGPSN (2000-01)	14	150
5th EGPSN (2001-02)	15	150
6th EGPSN (2002-03)	15	150
7th EGPSN (2003-04)	15	150
8th EGPSN (2004-05)	18	150
9th EGPSN (2005-06)	17	150
10th EGPSN (2006-07)	15	150
1st EGPYT (1999-00)	10	25
2nd EGPYT (2000-01)	10	25
3rd EGPYT (2001-02)	14	25
4th EGPYT (2002-03)	15	25
5th EGPYT (2003-04)	14	25
6th EGPYT (2004-05)	16	25
7th EGPYT (2005-06)	17	25
8th EGPYT (2006-07)	10	25
Total:	244	1,645

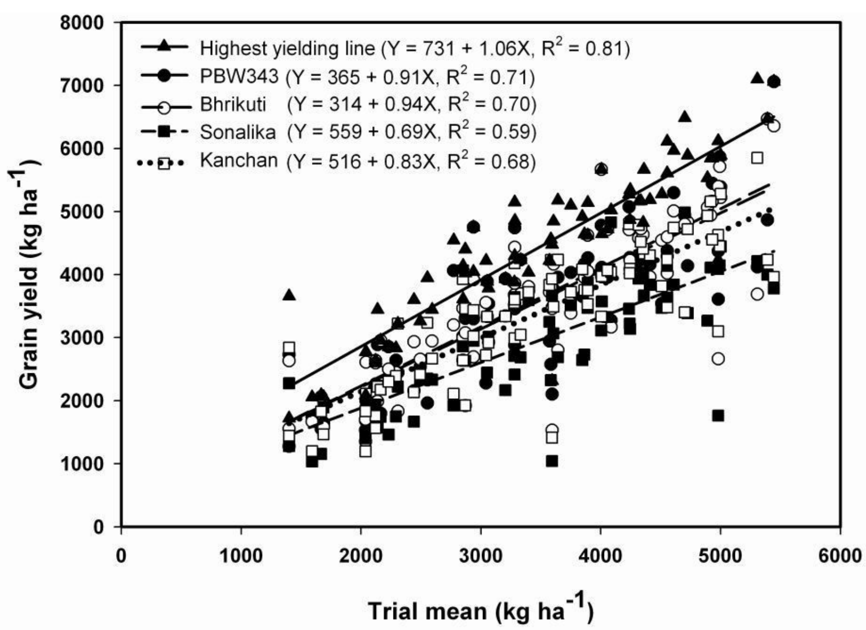

Fig. 2 Regression analysis of four checks and the best line for grain yield over mean yield in each of the 75 environments in the Eastern Gangetic Plains of South Asia.

Country-wise genotype performance

The number of genotypes showing significantly higher grain yield than the local check differed in each country (**Table 3**). In general, there was a greater number of lines showing grain yield superiority over local check 'Kanchan' in Bangladesh compared to 'PBW343' and 'Bhrikuti' in India and Nepal, respectively.

The number of experimental genotypes showing significantly higher TKW than the check differed in the three countries in each year (**Table 4**). There was at least one genotype in each year, except for 2002 in India that consistently showed significantly higher TKW than the check in each country. The genotypes that showed significantly higher TKW than the local check in each country in individual years included, #1-5 and #1-7 in 2000, #2-1, #2-2, #2-4, #2-5, #2-7 and #2-13 in 2001, #4-16 in 2003, #5-2, #5-4, #5-17, #5-20 and #5-21 in 2004, #6-9 and #6-13 in 2005, #7-6 and #7-21 in 2006, and #8-10 and #8-19 in 2007.

The number of experimental genotypes showing significantly lower spot blotch severity than the check differed in the three countries in each year (**Table 5**). In general, there was a greater number of lines showing lower disease severity than 'Kanchan' in Bangladesh compared to 'PBW343' and 'Bhrikuti' in India and Nepal, respectively. However, there were several genotypes (data not shown) that showed spot blotch severity comparable to 'PBW343' and 'Bhrikuti' in India and Nepal, respectively.

DISCUSSION

Based on variability for grain yield, TKW, maturity and disease resistance, many wheat genotypes tested in different years in the Eastern Gangetic Plains of Bangladesh, India, and Nepal are valuable for the region. Different sets of genotype out-yielded the local check in Bangladesh, India and Nepal that show their specific adaptation and genetic diversity now available in the region. This was also reflected in different set of lines selected by collaborators in different centers. In some years, certain genotypes showed higher yield than all four checks which reflects their wider adaptation and value for the entire region. The highest yielding lines in eight years were superior to check in both low and high productivity environments suggesting that wheat genotypes introduced into the region could be useful for a range of management conditions in the rice-wheat cropping

Table 3 Wheat genotypes with significantly (p=0.05) higher grain yield than local check in Bangladesh (Kanchan), India (PBW343), and Nepal (Bhrikuti).

Year	Bangladesh (local check Kanchan)	India (local check PBW343)	Nepal (local check Bhrikuti)
2000 (EGPYT-1)	Geno 1-17†	None	1-2
2001 (EGPYT-2)	Geno 2-3, 2-14	Geno 2-7, 2-9	Geno 2-8
2002 (EGPYT-3)	Geno 3-1, 3-2, 3-14, 3-15, 3-16	Geno 3-3, 3-4, 3-5, 3-8, 3-12, 3-14, 3-16, 3-20	None
2003 (EGPYT-4)	Geno 4-2, 4-6, 4-7, 4-8, 4-11, 4-14, 4-19, 4-20, 4-21	None	None
2004 (EGPYT-5)	Geno 5-17	None	Geno 5-17
2005 (EGPYT-6)	Geno 6-1, 6-2, 6-8, 6-9, 6-11, 6-14, 6-15, 6-17, 6-19, 6-20, 6-21	Geno 6-4, 6-14	Geno 6-1
2006 (EGPYT-7)	Geno 7-13, 7-14	None	None
2007 (EGPYT-8)	Gemo 8-20	Geno 8-10	None

†Refer to **Table 1** for the name of the genotype.

Table 4 Wheat genotypes with significantly (p=0.05) higher 1000-kernel weight than local check in Bangladesh (Kanchan), India (PBW343), and Nepal (Bhrikuti).

Year	Bangladesh (local check Kanchan)	India (local check PBW343)	Nepal (local check Bhrikuti)
2000 (EGPYT-1)	Geno 1-2†, 1-3, 1-4, 1-5, 1-6, 1-7, 1-12, 1-13, 1-16	Geno 1-5, 1-7	Geno 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 1-9, 1-10, 1-12, 1-13, 1-14, 1-15, 1-16, 1-18, 1-20
2001 (EGPYT-2)	Geno 2-1, 2-2, 2-4, 2-5, 2-6, 2-7, 2-13	Geno 2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, 2-9, 2-10, 2-11, 2-12, 2-13, 2-15, 2-16, 2-17, 2-18, 2-19, 2-20, 2-21	Geno 2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, 2-9, 2-10, 2-11, 2-12, 2-13, 2-14, 2-15, 2-16, 2-17, 2-18, 2-19, 2-20, 2-21
2002 (EGPYT-3)	Geno 3-1, 3-12, 3-13	None	Geno 3-1, 3-2, 3-3, 3-4, 3-5, 3-6, 3-7, 3-8, 3-9, 3-12, 3-13, 3-16, 3-20
2003 (EGPYT-4)	Geno 4-12, 4-15, 4-16	Geno 4-16, 4-21	Geno 4-16
2004 (EGPYT-5)	Geno 5-2, 5-4, 5-11, 5-17, 5-18, 5-20, 5-21	Geno 5-2, 5-4, 5-16, 5-17, 5-20, 5-21	Geno 5-2, 5-4, 5-10, 5-11, 5-12, 5-17, 5-18, 5-20, 5-21
2005 (EGPYT-6)	Geno 6-9, 6-13	Geno 6-1, 6-2, 6-9, 6-10, 6-12, 6-13, 6-16, 6-19, 6-21	Geno 6-3, 6-7, 6-9, 6-13
2006 (EGPYT-7)	Geno 7-1, 7-2, 7-3, 7-4, 7-6, 7-7, 7-8, 7-9, 7-11, 7-12, 7-13, 7-15, 7-16, 7-17, 7-18, 7-19, 7-20, 7-21	Geno 7-6, 7-21	Geno 7-1, 7-2, 7-3, 7-4, 7-5, 7-6, 7-7, 7-8, 7-9, 7-11, 7-12, 7-13, 7-15, 7-16, 7-17, 7-18, 7-19, 7-20, 7-21
2007 (EGPYT-8)	Geno 8-4, 8-7, 8-10, 8-11, 8-16, 8-19	Geno 8-2, 8-5, 8-10, 8-19	Geno 8-1, 8-2, 8-3, 8-5, 8-7, 8-8, 8-10, 8-11, 8-14, 8-17, 8-19, 8-20, 8-21

†Refer to **Table 1** for the name of the genotype.

Table 5 Wheat genotypes with significantly (p=0.05) lower spot blotch severity than local check in Bangladesh (Kanchan), India (PBW343), and Nepal (Bhrikuti).

Year	Bangladesh (local check Kanchan)	India (local check PBW343)	Nepal (local check Bhrikuti)
2000 (EGPYT-1)	Geno 1-1†, 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 1-9, 1-11, 1-12, 1-13, 1-14, 1-15, 1-17, 1-18, 1-19, 1-20, 1-21	Geno 1-7, 1-19	Geno 1-13, 1-19, 1-21
2001 (EGPYT-2)	Geno 2-3, 2-21	Geno 2-21	Geno 2-11, 2-16, 2-21
2002 (EGPYT-3)	Geno 3-6, 3-8, 3-9, 3-13, 3-14, 3-15, 3-16, 3-18, 3-19, 3-20, 3-21	Geno 3-14	Geno 3-14, 3-15, 3-19
2003 (EGPYT-4)	Geno 4-9, 4-15, 4-16, 4-17, 4-18	Geno 4-5, 4-6, 4-7, 4-16	Geno 4-3, 4-9, 4-11, 4-16, 4-17, 4-18
2004 (EGPYT-5)	Geno 5-7, 5-8, 5-17	Geno 5-8, 5-10, 5-15	Geno 5-7, 5-8, 5-11, 5-15, 5-17, 5-21
2005 (EGPYT-6)	Geno 6-1 to 6-21	Geno 6-4, 6-9, 6-15, 6-17	Geno 6-4, 6-18
2006 (EGPYT-7)	Geno 7-2, 7-5, 7-7, 7-8, 7-9, 7-10, 7-13, 7-15, 7-17, 7-21	Geno 7-12	Geno 7-1, 7-2, 7-11, 7-18
2007 (EGPYT-8)	Geno 8-2, 8-9, 8-12	Geno 8-2, 8-3, 8-4, 8-8, 8-12, 8-20	Geno 8-2, 8-3, 8-8, 8-12, 8-20

†Refer to **Table 1** for the name of the genotype.

Table 6 Superior genotypes suitable as parents for improving maturity, grain yield, 1000-kernel weight and spot blotch resistance through selective breeding.

Parent 1			Parent 2		
Entry number	**Name / cross**	**Superior trait†**	**Entry number**	**Name / cross**	**Superior trait**
1-2	BL1804	DH, PHT, GY, TKW	2-21	PBW373	PHT, SB
1-12	BL1968	PHT, GY, TKW	3-14	Milan/Shanghai#7	PHT, SB
1-17	NL750	PHT, GY	4-16	NL966	PHT, TKW, SB
1-18	NL835	DH, PHT, GY	7-2	BL2966	DH, PHT, TKW, SB
2-7	G162/BL1316//NL297	DH, PHT, GY, TKW	8-2	BL3122	PHT, TKW, SB
3-12	BL2324	PHT, GY, TKW	8-3	BL3124	PHT, TKW, SB
5-17	Shatabdi	PHT, GY, TKW	8-20	SW89.5124*2/Fasan	PHT, TKW, SB
8-10	BL3218	PHT, GY, TKW	8-8	BL3191	DH, PHT, TKW, SB

† DH = days to heading, GY = grain yield, PHT = plant height, SB = spot blotch resistance, TKW = 1000-kernel weight.

system. A few high yielding genotypes that could be valuable across the region are #1-2 ('BL1804'), #1-12 ('BL1968'), #1-17 ('Chirya.3'), #1-18 ('NL835'), #2-7 ('G162/BL1316//NL297'), #2-9 ('NL588/HD2307'), #3-12 ('BL2324'), and #5-17 ('Shatabdi').

Many genotypes showed higher TKW than the local check in each country as well as across the region suggesting their value in improving this trait in the region. Since the wheat growing season in the EGP region is short, TKW is considered an important trait in determining stability of grain yield and successful adoption of a cultivar by the farmers (Sharma and Duveiller 2003). Since a large number of experimental genotypes showed higher TKW than the local check, it also underlines the importance given by the wheat breeders in the region in improving this trait. Kernel weight of a wheat genotype is considered important both for adaptation to high temperature and drought (Reynolds *et al*. 2005), and could be an indirect selection criterion to improve heat tolerance (Sharma *et al*. 2008) and spot blotch resistance (Sharma and Duveiller 2003).

Even though not many experimental genotypes showed significantly lower spot blotch severity than the most resistant check 'PBW343' in India, there was at least one in each year. However, there were several genotypes in each year that compared well with 'PBW343' for spot blotch resistance in India. Such genotypes could also be valuable if they possess earlier maturity and higher grain yield and/or TKW than 'PBW343'. There were many genotypes that could be valuable for improving spot blotch resistance of wheat cultivars in Nepal and Bangladesh. The highly resistant genotypes that could be valuable across the region are #2-21 ('ND/VG 9144//Kal/BB/3/Yaco/4/Vee#5'), #3-14 ('Milan/Shanghai#7'), #4-16 ('NL966') and #7-2 ('BL2966'). In a separate recent study, Sharma and Duveiller (2007) reported that 'Milan/Shanghai#7' (genotype #3-14) was the most stable for spot blotch resistance among a number of resistant lines tested across 35 environments in the EGP region. In general, the lowest disease severity in this study was between 17 and 22% in the eight years, which can be further improved. This finding underlines the need to introduce more resistant lines in the region, and supports the conclusion by Sharma and Duveiller (2007). It is particularly important considering that newly developed wheat genotypes in the region continue to show substantial spot blotch-induced reductions in grain yield (Sharma and Duveiller 2006, 2007).

Some experimental lines had maturities similar to that of 'Sonalika', the earliest-heading and maturing wheat cultivar in the region in each year. Plant heights of several experimental lines compared reasonably well with those of the checks each year. These results show that agronomically improved wheat lines have been introduced in the EGP through EGPYT. The experimental lines were much superior to the older checks 'Kanchan' and 'Sonalika', cultivars still grown by resource-poor farmers in remote areas of Bangladesh and Nepal (Ortiz-Ferrara *et al*. 2007). This demonstrates that the EGPYT can expand farmers' choices of improved wheat germplasm, if seed of the improved varieties becomes available.

An evidence of continuous improvement in grain yield of the experimental genotype was reflected through the higher value of the slope of the regression line of the highest yielding genotypes compared to the checks. Identification of new high yielding genotypes in each year adds to the diversity of improved wheat germplasm in the region. This was further substantiated by selection of promising lines from EGPYT by individual breeders for use in specific environments.

There were several genotypes, superior for various traits that could be valuable in individual country. Moreover, there a few genotypes that were superior for complementary traits; hence could be suitable as parents for developing wheat cultivars with high grain yield and TKW, early maturity, suitable plant height and spot blotch resistance. Such complementary genotypes are listed in **Table 6**.

Wheat yields in the EGP have been stagnant in recent years (FAO 2006) and at least one country – India – is beginning to import wheat grain (Reuters 2006). Besides, the present high price of food grains (including wheat) in South Asia and elsewhere has prompted the Government in the region to reduce wheat export, or export at a higher price. This has resulted in food grain scarcity in South Asia. Hence, the resource-poor farmers in the EGP urgently need wheat cultivars with enhanced grain yields, high TKW, early maturity, medium-tall height, and spot blotch resistance. The testing of EGPSN and EGPYT has complemented regional efforts to breed for increased wheat yields by promoting synergies to exchange and introduce superior wheat germplasm into non-traditional wheat growing areas. This trial has also complemented another regional effort through participatory varietal selection (Ortiz-Ferrara *et al*. 2007). As a result, the farmers in Bangladesh have adopted 'BAW-1006' (BL1666=NL297*2/HLB25, EGPYT-1), 'BAW-1008' (BL2029=G162/BL1316//NL297, EGPYT-2) and 'Shatabdi' (Mrng/Buc//Blo/Pvn/3/Pjb81, EGPYT-5). 'BAW-1008' was released as Prodip in Bangladesh in 2005. Similarly, two lines, 'BL1804' (Attila//Jup/Bjy/3/Attila, EGPYT-1) and 'NL971' (Mrng/Buc//Blo/Pvn/3/Pjb81, EGPYT-4) have been widely used in crossing program and are being promoted in Nepal. 'BL1804' and 'NL971' were developed by CIMMYT, Mexico and selected in Nepal before including in the regional trial. Similarly, 'BAW-1006' and 'BAW-1008' were developed in Nepal and tested in the regional trial. This demonstrates how the regional trial has helped in exchange of valuable germplasm in the region. In addition, the exceptional lines identified though these trials are also being linked with participatory approach of germplasm dissemination in the EGP especially for benefiting small and marginal farmers (Witcombe *et al*. 2001; Ortiz-Ferrara *et al*. 2007).

CONCLUSION

Wheat genotypes included in the EGPYT showed significant variation for grain yield, TKW, days to heading, plant height, and spot blotch resistance in each year. One or more experimental lines outyielded the checks each year, indicating that superior germplasm is being introduced through this collaborative work. Germplasm with high spot blotch resistance could be valuable for other regions of the world faced with this disease.

New cultivars have been synthesized through this effort and many outstanding lines have been selected by wheat breeders in the region and are being used as parents in the breeding programs of different centers. This region-targeted approach of germplasm testing and dissemination could be useful for other regions and/or in other crops particularly under increasing resource constraints currently being faced by the international research centers. Such efforts could lead efficient dissemination of valuable germplasm and resource saving.

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