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Performance of marker-assisted backcross bread-wheat (*Triticum aestivum*) variety *Unnat* PBW 343 under diverse environments

HARI RAM[1]*, NEHA GUPTA[1], GURBRINDER SINGH[1], HARWINDER KAUR[1], JASPAL KAUR[1] and PUJA SRIVASTVA[1]

Punjab Agricultural University, Ludhiana, Punjab 141 004, India

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ABSTRACT

The field studies were carried out to evaluate the performance of newly developed wheat (*Triticum aestivum* L.) variety *Unnat* PBW 343 through marker-assisted backcross breeding under different sowing environments. The experiment was conducted at the Punjab Agricultural University, Ludhiana during *rabi* 2014–15 to 2016–17 in split-plot design replicated thrice with two main plot treatments [timely sown conditions–1st week of November and late sown conditions–1st week of December] and five wheat genotypes (*Unnat* PBW 343, PBW 343, HD 2967, PBW 621 and WH 1105) including one developed through marker-assisted backcross breeding. Based on the pooled analysis, timely sown crop recorded significantly higher grain yield (23.8%) than late sown crop. Lowest yellow rust score was recorded in *Unnat* PBW 343 over all the check varieties. Among wheat varieties, mean grain yield of *Unnat* PBW 343 was the highest and statistically at par with PBW 621 and WH 1105 in different years and showed significant improvement over check varieties PBW 343 and HD 2967. So, *Unnat* PBW 343 found to be resistant to yellow rust and can be sown under timely sown conditions in northwestern Indian conditions.

Keywords: Agro-meteorological indices, Sowing dates, *Unnat* PBW 343**,** Wheat yield, Yellow rust

Wheat (*Triticum aestivum* L.) is staple food crop worldwide, but its production is constantly hampered by various abiotic (terminal heat and water stress) and biotic (weeds, insects and yellow rust) constraints that results in yield loss of more than 50% globally (Sharma *et al.* 2016, Kumar *et al.* 2018). Genetic modification by breeding for rust resistance is the primary solution to prevent rust infection in high yielding susceptible cultivars. More than 50 loci for stripe rust have been identified resistance (R) genes in wild germplasm of wheat. The development of rust resistant cultivars through transfer of alleles at one or more loci from donor parent through backcross breeding usually takes 6-7 years. However, in parallel, continuous evolution of rust pathogen results in emergence of new virulent pathotypes of stripe rust. Due to which rust resistance imparted by many of the R genes either have been broken down or lost within 2-3 years of its release. Thus, current breeding strategy works on pyramiding of these R genes in which disease resistance against three rusts (stripe, stem and leaf) is accomplished by introduction of different R alleles in a recipient parent. Marker-assisted backcross breeding (MABB) is frequently used for identification of suitable gene combination in a segregating population with less time. Success stories using MABB technology in practical are available in wheat (Bonnett *et al.* 2005, Kuchel *et al.* 2007) and also open new avenues in wheat molecular resistance breeding. Wheat variety *Unnat* PBW 343, has been developed by Punjab Agricultural University's scientists using MABB. It is a complex cross derivative, in which introgressions from *Thatcher, Aegilops ventricosa* (carrying *Lr37/Yr17/Sr38*) and *Aegilops umbellulata* (*Lr57/Yr50*) are subjected in recipient hexaploid parent PBW 343. As *Aegilops* sp.are diploid, so WH 890 durum wheat is used as bridging species along with Chinese spring (with *Ph1* supressor, i.e.CS (S)) to generate chromosomal translocations. The present study is undertaken to depict agronomic performance of *Unnat* PBW 343, also named as PBW 723, in relation to various check varieties under different sowing environments.

MATERIALS AND METHODS

The field studies were carried out at the experimental farm of the Punjab Aagricultural University, Ludhiana (30^0 54' N and 75^0 48' E; 247 amsl) during *rabi* 2014–15 to 2016–17. Soil characteristics of experimental site were loamy sand, low organic matter (3.3 g C/kg) and slightly alkaline (*p*H 7.5). Crop experiment was laid out in split-plot design with three replications. Main plot treatments were normal timely sown (1st week of November) and late

Present address: [1] Punjab Agricultural University, Ludhiana, Punjab. *Corresponding author e-mail: hr_saharan @yahoo.com.

sown conditions (1st week of December). The advanced five wheat genotypes for comparison of *Unnat* PBW 343 with high yielding checks (HDF 2967, PBW 621 and WH 1105) acted as sub-plot treatment. Pedigree details of these wheat genotypes were;. *Unnat* PBW 343 - PBW 343/TC+Lr 37//3*PBW 343/4/WH 890-Ae. umb.3732amph./CS(S)// WL711NN /3/3* PBW 343, PBW 343-NORD-DESPREZ/ VG-1944//Kalyansona//Bluebird/3/YACO (SIB)/4/ Veery-5, HD 2967-ALD/COC//URES/HD 2160M/HD 2278 PBW 621-KAUZ/ALTAR-84//(AOS) AWNED-ONAS/3/Milan/ KAUZ/4/HUITES and WH 1105-Milan/S87230//BABAX. The crop was raised according to standard agronomic practices. Four irrigations (each of 75 mm) were given at critical phenological stages during the crop cycle in all the studied years. Plant stand was measured as emergence count per m^2.

Agro-meteorological indices, viz. growing degree days (GDD), helio-thermal units (HTU), photothermal units (PTU) and phenothermal index (PTI) were calculated at earing and maturity stages on the basis of meteorological parameters during the crop season (Rana *et al.* 2014). Number of ear heads were counted from 1 m row length and presented as per m^2. The yield contributing parameters such as grains per earhead, 1000-grain weight etc. were recorded after manual threshing of five randomly chosen ears from each subplot. Days to earing and days to maturity were recorded when 75% of the plants in a given plot achieved the respective stage. Crop biomass and grain yield were recorded at the time of maturity and represented as q/ha using standard procedures (Rana *et al.* 2014). The tolerance indices of studied genotypes were calculated by comparing grain yield of timely sown with late sown environment;

$$\text{Yield stability index (YSI)} = Y_L/Y_T$$

(Bouslama and Schapaugh 1984)

Stress tolerance index was measured by the formula: $Y_L \times Y_T/(\bar{Y}_T)^2$, where Y_L is mean grain yield of a genotype under late sown condition, Y_T is mean grain yield of a genotype under timely sown conditions and $\bar{Y}_L$ was mean grain yield of all genotypes in timely sown conditions. The data were analysed in split-plot design at $P \leq 0.05$.

RESULTS AND DISCUSSION

Weather conditions and rust reaction of varieties under timely and late sown conditions: Significant variation was observed in temperature across all the years. Late sown crop experienced low temperature conditions at initial stages of growth along with higher temperatures at reproductive phases. Minimum air temperatures were also higher than normal at tillering, jointing as well earing stages of wheat growth under late sown environment. The crop season suffered from erratic rainfall during 2014–15 and 2015–16. Rainfall pattern also showed uneven distribution at critical growth stages from December to March. Maximum rainfall of 84.6 mm was observed at grain filling stages in 2014-15. The highest yellow rust score (50-60 in 2014-15, 50S in 2015-16 and 60-80S in 2016-17) was recorded in PBW 343 in all the years under timely and late sown conditions. It was due to susceptibility of this variety to yellow rust. The minimum rust reaction was recorded in *Unnat* PBW 343 which was 5 MS in both the dates and all the years. Only medium rust resistance (10-20S) was recorded in varieties PBW 621 and WH 1105. Under late sown conditions, comparatively 10S less rust score was recorded than timely sown conditions in PBW 343, PBW 621 and WH 1105.

Effect of sowing dates

Phenology, agro-meteorological indices, growth, yield attributes and grain yield: Significant reduction in days to earing and maturity were observed in late sown than timely sown crop (Table 1). In contrast, GDD, HTU, PTU and PTI at earing and maturity were significantly higher in timely sown conditions than late sown. It might be due to higher number of days taken in completion of different phenophases in timely sown crop. Emergence count declined significantly in late sown crop. The decreased crop stand under delayed sown condition could be due to low temperature and very less sunshine hours.. The delayed sowing resulted in significant reduction in effective tillers (13%) and test weight (14.3%). The pooled mean showed 11.6% higher grains per earhead under delayed sown conditions. It might be due to compensation exerted by wheat plants to sustain the productivity under delayed sown conditions. Under timely sown conditions, a significantly higher 1000-grain weight was recorded which was 14.3% higher than delayed sown conditions. The higher 1000-grain weight under timely sown conditions might be due to expansion of earing to maturity period and accumulation of high agro-meteorological indices.

Timely sown crop recorded significantly higher grain yield than late sown crop (Table 2). Reduction in grain yield under delayed sowing was 6.1, 41.2 and 19.4% over timely sown conditions in consecutive years of study. The overall reduction in grain yield was 23.8%. Reduction in yield was due to less number of days to complete various phenophase, less agro-meteorological indices and less yield attributing characters. Similarly, biomass was greatly affected with delay in sowing time. The magnitude of biomass reduction was 21.8%.

Performance of Unnat PBW 343 in comparison to check varieties

Phenology and agrometeorological indices: New variety *Unnat* PBW 343 recorded highest days to earing which was at statistically at par with PBW 343 and HD 2967 (Table 1). Similar trend was observed in days to maturity. The GDD, HTU, PTU and PTI were statistically similar in *Unnat* PBW 343, PBW 343 and HD 2967. However at maturity, these agro-meteorological indices did not differ among varieties

Growth, yield attributes and yields: The emergence count and effective tillers all varieties were similar. However, *Unnat* PBW 343 recorded 0.9–3% higher earheads than all other varieties. The *Unnat* PBW 343 had bolder grains

Table 1 Effect of sowing date and varieties on crop emergence count and yield contributing parameters of wheat growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU) and pheno-thermal index (PTI) of wheat at earing and maturity stage

Treatment	Emergence count/m^2	Effective tillers/m^2	Grains/ ear	Test weight (g)	Days to earing	Days to physiological maturity	GDD (°C day) E	GDD (°C day) M	HTU (°C day hour) E	HTU (°C day hour) M	PTU (°C day hour) E	PTU (°C day hour) M	PTI (°C days/day) E	PTI (°C days/day) M
Sowing date														
Timely	196.0	382.0	33.5	42.1	104.8	153.2	1077	1870	5763	12162	11328	20947	10.3	12
Late	168.7	332.3	37.4	36.1	95.3	131.2	935	1609	5329	11230	10098	18480	9.8	12
CD(P=0.05)	16.3	14.7	2.1	2.2	1.0	1.2	13.9	31.88	87.6	319.9	165.0	415.5	0.05	NS
Varieties														
Unnat PBW 343	184.1	362.2	33.0	42.6	100.8	142.2	1016	1738	5641	11683	10829	19693	10.06	12
PBW 343	182.2	356.3	34.0	37.6	101.3	142.4	1022	1744	5666	11737	10897	19770	10.07	12
HD 2967	179.0	351.4	35.9	37.7	100.7	142.6	1014	1749	5599	11776	10802	19830	10.06	12
PBW 621	178.6	358.8	37.3	38.2	99.5	142.1	998	1735	5495	11650	10617	19658	10.02	12
WH 1105	187.7	357.2	37.1	39.5	97.9	141.8	980	1732	5330	11634	10420	19617	10.01	12
CD(P=0.05)	NS	NS	3.04	2.9	0.7	NS	10.0	NS	83.9	NS	117.6	NS	0.03	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

E, Earing stage; M, Maturity stage.

Table 2 Grain yield and biomass yield as influenced by sowing dates and varieties of wheat

	Grain yield (t/ha)			Biomass yield (t/ha)		
	Timely	Late	Mean	Timely	Late	Mean
			2014-15			
Unnat PBW 343	4.76	4.38	4.57	11.81	10.88	11.34
PBW 343	4.48	3.53	4.01	11.81	9.14	10.48
HD2967	4.07	4.29	4.18	10.53	10.76	10.65
PBW 621	4.44	4.31	4.38	11.34	10.76	11.05
WH 1105	4.51	4.40	4.46	11.92	11.23	11.57
Mean	4.45	4.18	4.32	11.48	10.56	11.02
			2015-16			
Unnat PBW 343	6.30	3.42	4.86	17.52	10.56	14.04
PBW 343	6.20	2.90	4.55	15.95	9.69	12.82
HD2967	5.74	3.58	4.66	16.03	10.61	13.32
PBW 621	6.01	4.08	5.05	17.03	12.68	14.86
WH 1105	6.08	3.88	4.98	15.10	10.56	12.83
Mean	6.07	3.57	4.82	16.33	10.82	13.57
			2016-17			
Unnat PBW 343	6.37	5.24	5.81	17.70	13.87	15.79
PBW 343	5.46	4.76	5.11	16.50	13.72	15.11
HD2967	6.25	4.30	5.28	17.32	12.45	14.89
PBW 621	6.34	5.17	5.75	18.37	15.22	16.80
WH 1105	6.48	5.42	5.95	17.62	14.92	16.27
Mean	6.18	4.98	5.58	17.50	14.04	15.77
			Pooled			
Unnat PBW 343	5.81	4.34	5.08	15.68	11.77	13.72
PBW 343	5.38	3.73	4.56	14.75	10.85	12.80
HD2967	5.35	4.06	4.71	14.63	11.28	12.95
PBW 621	5.60	4.52	5.06	15.58	12.89	14.24
WH 1105	5.69	4.57	5.13	14.88	12.24	13.56
Mean	5.57	4.24	4.91	15.10	11.80	13.45

CD (P=0.05)		*2014-15*	*2015-16*	*2016-17*	*Pooled*
Grain yield	Sowing time	0.173	0.230	0.293	0.192
	Varieties	0.273	0.364	0.444	0.191
	Interaction	0.386	0.515	NS	0.269
Biomass yield	Sowing time	0.366	0.761	2.712	0.610
	Varieties	0.578	1.203	1.138	0.558
	Interaction	0.818	NS	NS	NS

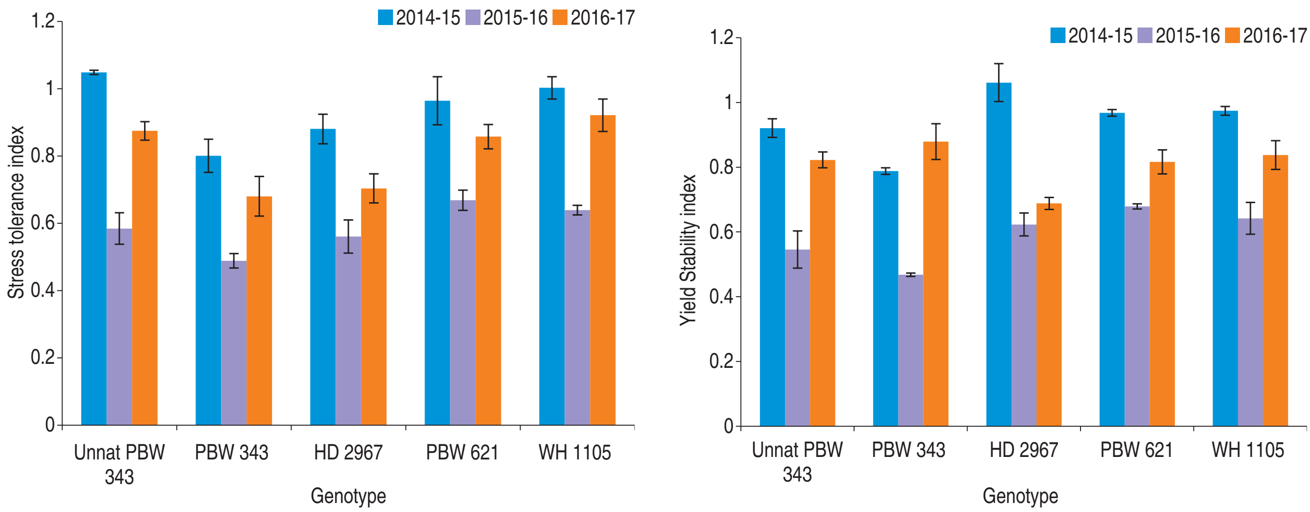

Fig 1 Stress tolerance index (a) and yield stability index (b) of wheat genotypes as influenced by two sowing dates. CD (P=0.05) for 2014-15: NS, 2015-16: 0.05, 2016-17: 0.16 CD (P=0.05) for 2014-15: 0.11, 2015-16: 0.08, 2016-17: NS. Interaction: Year: 0.06, Variety: 0.07, Year × Variety: NS Interaction: Year: 0.07, Variety: 0.06, Year × Variety: 0.10

and higher grain weight and was significantly higher than parent variety PBW 343. It might be due to higher incidence of yellow rust in other varieties. The grain yield of *Unnat* PBW 343 was the highest and statistically at par to PBW 621 and WH 1105 in different years and on pooled mean basis (Table 2). The increased grain yield percentage of *Unnat* PBW 343 over PBW 343 and HD 2967 was found to be 10.3% and 7.3% higher which shows the superiority of new variety over existing checks. Similar trend was also observed in crop biomass across the studied varieties. In 2014–15, the highest biomass yield was recorded in WH 1105 which was statistically at par with PBW 621 and *Unnat* PBW 343. In 2015–16 and on pooled mean basis, the highest biomass yield recorded in PBW 621 statistically similar to *Unnat* PBW 343. Higher biomass in *Unnat* PBW 343 and other varieties was due to higher tillers, 1000-grain weight, higher grain yield and higher agrometeorologcal indices.

Present study depicted the maneuverability of newly developed MABB variety *Unnat* PBW 343 to combat terminal stress under late sown environment and also estimated its yield performance in comparison to locally adapted checks. It is well known that under late sown conditions, wheat crop get exposed to sub-optimal temperatures in vegetative phase and supra-optimal temperatures (heat stress) in reproductive phase. Further, every 1^0C increase in temperature above than the optimal affects the duration of grain filling by 2.8 days (Streck 2005). Our data showed similar trend of reduced grain yield and other yield attributes under late sown condition. Higher canopy temperature and early leaf senescence in late sown crop also decreased the carbohydrate availability towards reproductive sink tissue and developing grain (Choudhary and Suri 2014). Yield stability index (YSI) and stress tolerance index (STI) differed significantly among the genotypes (Fig 1). In 2015–16, yield indices in *Unnat* PBW 343 were less in comparison to WH 1105 and PBW 621. However, pooled analysis depicted, yield stability of *Unnat* PBW 343 was statistically on par with WH 1105 and PBW 621. YSI and STI of this MABB variety were significantly higher than PBW 343 and HD 2967.

Interaction effect (sowing date × varieties): The grain yield of wheat variety *Unnat* PBW 343 was found to be highest in all years except 2016-17 where interaction effect was non-significant (Table 4). The grain yield recorded in *Unnat* PBW 343 was the highest under timely sown conditions and was significantly better than HD 2967 in 2014–15 and 2015–16; however on pooled mean basis, *Unnat* PBW 343 was statistically at par with PBW 621 and WH 1105. The highest grain yield recorded in *Unnat* PBW 343 under timely sown conditions in 2014–15 was also statistically at par *Unnat* PBW 343 and WH 1105 under late sown conditions. On pooled mean basis, the highest grain yield under late sown conditions was recorded in WH 1105 which statistically at par with *Unnat* PBW 343 and PBW 621. It was due to higher yield attributes and less incidence of yellow rust under the respective conditions. The highest biomass yield recorded in WH 1105 in 2014–15 was significantly better than HD 2967 under timely sown conditions and statistically at par with WH 1105 under late sown conditions.

The wheat variety *Unnat* PBW 343 significantly out yielded its recipient variety PBW 343 and two of high yielding checks varieties HD 2967 and PBW 621 in terms of mean performance over two dates of sowing.This variety can be sown under timely sown conditions for better grain yield.

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