Bakshi S and Bhagwat SG. 2010. Assessment of germplasm of Indian bread wheats for polymorphism at *Xgwm261* locus: Microsatellite analysis, sequencing and relationship with agronomic traits. *In:* Physiological and Molecular Interventions for Yield and Quality Improvement in Crop Plants, Sardar Vallabhbhai Patel University of Agric & Tech, Meerut, India, 17-18 September, 2010. Book of Abstracts, p. 145.

Bakshi S and Bhagwat SG. 2011. Microsatellite marker analysis of Indian bread wheat genotypes showing variation for acquired thermotolerance. *In:* Proc 3rd Internat Group Meet on Wheat productivity enhancement under changing Climate, 9-11 February, 2011, University of Agricultural Sciences, Dharwad, India. Book of Abstracts, p. 111.

Chang CM and Bhagwat SG. 2010. Salinity induced inhibition of amylase stimulation in aleurone layers of *Triticum dicoccum*. *In:* Proc Natl Conf of Plant Physiol on Physiological and Molecular Approaches for Crop Improvement under Changing Environment, 25-27 November, 2010, Banaras Hindu University, Varanasi, India. Book of Abstracts, p. 81.

Chang CM and Bhagwat SG. 2010. Response of aleurone layers from *Triticum dicoccum* genotypes to gibberellic acid (GA3): Time course of amylase stimulation. *In:* Physiological and Molecular Interventions for Yield and Quality Improvement in Crop Plants, Sardar Vallabhbhai Patel University of Agric & Tech, Meerut, India, 17-18 September, 2010. Book of Abstracts, p. 146.

Das BK and Bhagwat SG. 2011. Marker assisted breeding for attaining durable rust resistance in Indian wheat under changing climate. *In:* Proc 3rd Internat Group Meet on Wheat Productivity Enhancement under Changing Climate, during 9-11 February, 2011, University of Agricultural Sciences, Dharwad, India. Book of Abstracts, pp. 98-99.

DIRECTORATE OF WHEAT RESEARCH
Regional Research Station, PB No. 158, Karnal-132 001, Haryana, India.

Performance of timely and late-sown cultivars under different sowing times.

S.C. Tripathi and O.P. Dhillon.

Summary. A field experiment was conducted during winter seasons of 2005–06 to 2006–07 at the Directorate of Wheat Research, Karnal, to evaluate the timely sown and late sown recommended cultivars under normal, late, and very late sowing conditions. A clear picture will be provided as to whether or not timely sown cultivars perform equally good under late and very late sowing conditions. A pooled analysis of two years data revealed a reduction grain yield of 14.4% as sowing was delayed from normal to late sown conditions. Cultivar differences were observed for anthesis, maturity, spike length, grain-filling period, grain production rate, and yield and yield attributing parameters. The interaction between sowing time and cultivars was significant for grain yield. Three timely sown cultivars (PBW 343, HD 2687, and PBW 502) performed better under normal sowing condition whereas the late-sown cultivar UP 2425 produced a maximum grain yield (42.24 q/ha) under late sowing conditions and Raj 3765 produced a maximum grain yield (42.79 q/ha) under very late sowing conditions, which was significantly higher than other cultivars. The resultsshowed that timely sown cultivars did not perform better across the sowing time and that there is a need to develop different cultivars for various sowing conditions.

Introduction. Wheat is the second most important crop after rice in India and in 2008–09 occupied approximately $28x10^6$ ha with a production of $78.4x10^6$ metric tons. India ranks second in wheat production after China. The area, productivity, and production of wheat have increased 119, 236, and 634%, respectively, since 2005 compared with 1965–66 (base year). Weather is cool and dry in the early part of wheat-growing season (November to February) whereas temperature rises during the grain-filling period (March–April), which is more pronounced in eastern part of Indo-Gangetic plain, resulting in a reduced wheat-growing period. Wheat is grown under different agroclimatic conditions each having variable productivity levels. In India, wheat is generally grown under three sowing conditions, i.e., normal (November sown), late (December sown), and very late sown (January sown) conditions. The normal sown wheat crop is generally preceded by crops such as upland rice, soybean, sorghum, bajra, or even grown after fallow. The late sown wheat crop is generally preceded by crops such as basmati rice, low land rice, cotton, and pigeon pea and very late-sown wheat is grown after toria, pea, potato, and sugarcane ratoon. Delayed wheat sowing (normal to late, mid-November to the first two weeks of December) resulted in a decrease in yield by 15.5, 32.0, 27.6, 32.9, and 26.8 kg/ha/day under NHZ, NWPZ, NEPZ, CZ, and PZ, respectively, for the timely sown cultivars. For the late-sown cultivars, a delay in sowing (late to very late, first two weeks of December to the first two weeks of January) decreased the grain yield by 42.7, 44.8, 51.6, and 44.2 kg/ha/day under NWPZ, NEPZ, CZ, and PZ, respectively (Tripathi et al. 2005).

Some of the scientists think that timely sown recommended varieties do equally well under late and very late sown conditions even under Indian subcontinent where hot and dry wind prevails during the grain-filling period. If this holds true, then the separate breeding programs for late sown conditions are not neede. To test this hypothesis, we selected a set of timely sown and late sown recommended cultivars and grew them under normal, late, and very late sown conditions.

Materials and methods. A field experiment was conducted during the 2005–06 and 2006–07 winter seasons at the Directorate of Wheat Research, Karnal (Latitude 290 43' N, longitude 760 58' E and altitude 245 m). Six culivars, three timely (PBW 343, HD 2687, and PBW 502) and three late sown (PBW 373, UP 2425, and Raj 3765), were evaluated under normal, late, and very late sown conditions. The experiment was conducted in split-plot design and replicated three times. Three sowing times in main plot, i.e., normal (11 and 12th November in 2005 and 2006), late sown (9th and 12 th December in 2005 and 2006), and very late sown (5th and 6th January in 2006 and 2007). After harvesting rice as a fore crop, the field was prepared with a cultivator and disk and in each subplot 250 viable seeds were planted. Fertilizer (150 N, 60 P_2O_5, 40 K_2O) was applied to the crop. A one-third dose of nitrogen in the form of urea, full phosphorous in the form of diammonium phosphate, and potash in the from of muriate of potash was applied as basal, i.e., before sowing and the remaining nitrogen was top dressed in two splits at the first node stage (DC 31) (Zadoks et al. 1974) and at boot stage (DC 41). Irrigation was applied as needed. Weeds were controlled with an application of sulfosulfuron 25 g/ha in 400 liters of water 30 days after sowing. Observations were recorded on biomass, anthesis, maturity, grain-filling period, and grain-production rate, yield and its component characters. Standard statistical methods of analysis were followed for the parameters under study (Gomez and Gomez 1984).

Results and discussion. Delayed sowing from normal to late and very late increased the canopy temperature depression significantly, whereas other parameters such as anthesis, maturity, spike length, and grain-filling period were reduced as sowing was delayed. The difference between the time taken for anthesis under normal and very late sown situations was about 25 days, whereas for grain-filling period, the difference was only 5 days. Canopy temperature depression under very late sown conditions was almost double that of the timely sown plants, whereas spike length was reduced about 1.5 cm when very late sown. Yield and yield-attributing parameters also were significantly different due to sowing time in both the years. From mean of two years, grain yield was reduced to 14.4 % as sowing was delayed from normal to late sown conditions. This observation is in agreement with findings of Tripathi et al. (2005). Protein content increased in delayed sowing.

Cultivar differences were observed for anthesis, maturity, spike length, grain-filling period, grain production rate, and yield and yield-attributing parameters (Table 1 and Table 2, p. 27). PBW 343 took 90 days for anthesis,

Table 1. Effect of sowing time and cultivar on anthesis, maturity, canopy temperature depression (CTD), spike length, grain-filling period, and grain production rate.

Treatment	Canopy temperature depression		Anthesis (days)		Maturity (days)		Spike length (cm)		Grain-filling period (days)		Grain production rate (kg/ha/day)	
Sowing time	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**
Normal	1.98	1.93	101	100	134	134	8.7	8.5	33	34	130	141
Late	2.13	2.07	88	90	119	119	7.6	7.5	31	30	136	122
Very late	4.29	3.86	76	78	106	106	7.2	7.0	30	28	130	140
C D at 5 %	0.38	0.42	0.1	0.6	0.9	0.9	0.2	0.3	0.8	0.3	8.5	11.6
Cultivar												
PBW 343	2.80	2.62	91	90	122	121	7.3	7.0	31	31	136	134
HD 2687	2.86	2.64	89	90	121	119	7.9	7.7	31	29	130	142
PBW 502	2.96	2.63	90	90	121	121	7.4	7.2	30	31	143	132
PBW 373	2.79	2.76	89	89	121	121	7.0	6.8	32	32	134	131
UP 2425	2.71	2.52	86	89	116	119	8.9	8.9	30	30	136	129
Raj 3765	2.70	2.56	84	87	118	119	8.5	8.3	34	31	115	138
CD at 5 %	NS	NS	0.1	0.6	0.3	1.0	0.5	0.4	0.3	1.0	5.5	10.7

Table 2. Effect of sowing time and cultivar on yield, yield-attributing parameters, and protein content.

Treatment	Spikes/m^2		1,000-kernel weight (g)		Grains/spike		Yield (q/ha)		Biomass (q/ha)		Protein (%)	
Sowing time	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**	**05–06**	**06–07**
Normal	339	337	41.22	45.15	32.2	32.7	43.32	48.29	109.12	111.72	9.55	11.00
Late	393	389	40.89	32.07	26.5	30.0	42.15	36.25	108.79	88.81	9.01	11.58
Very late	335	330	35.89	39.79	33.3	31.2	39.17	39.54	100.59	80.81	11.03	11.53
C D at 5 %	48	39	0.91	2.39	5.11	4.8	1.87	3.76	7.99	7.16	1.13	0.54
Cultivar												
PBW 343	352	349	38.67	36.95	31.6	33.9	42.12	42.22	100.86	95.21	9.83	11.32
HD 2687	342	339	37.00	35.26	33.1	34.8	40.56	41.61	107.67	101.39	8.95	11.07
PBW 502	368	362	40.89	40.72	29.2	28.9	42.87	40.59	105.09	99.38	10.08	11.41
PBW 373	374	376	39.22	43.77	29.7	26.3	43.21	42.09	106.61	101.54	10.16	11.51
UP 2425	335	331	39.00	39.43	32.3	30.9	40.72	39.12	110.32	91.97	10.15	11.58
Raj 3765	361	355	41.22	37.89	28.1	32.6	39.79	42.51	106.48	89.19	9.97	11.53
CD at 5 %	32	32	1.23	5.50	3.1	5.5	1.84	3.05	4.69	8.11	1.27	0.45

whereas the late sown cultivar Raj 3765 was 86 days. All cutivars matured in 119 to 121 days. Late sown cultivar UP 2425 possessed longest spike length, which was significantly higher than others. The greatest number of spikes/m^2 was observed in PBW 373 and the lowest in UP 2425. Thousand-kernel weight was greatest in PBW 502 and the lowest in HD 2687. PBW 373 produced the maximum grain yield (42.65 q/ha) followed by PBW 343 (42.17 q/ha); the minimum was in UP 2425 (39.92 q/ha).

A significant interaction between sowing time and cultivar was observed for grain yield. All the three timely sown cultivars (PBW 343, HD 2687, and PBW 502) performed better under timely sown conditions, whereas late sown cultivar UP 2425 produced the maximum grain yield (42.24 q/ha) under late sown conditions, which was significantly higher than yield obtained by timely sown cultivars HD 2687 and PBW 502 under late sown conditions. Under very late sown conditions, Raj 3765 produced the maximum grain yield (42.79 q/ha), which was significantly higher than other cultivars (Table 3). Thus, the hypothesis that timely sown cultivars will perform better under late and very late sown conditions was not true. The few late sown cultivars that exceeded the yield level over timely sown cultivars under late and very late sown situations provides a sound reason for developing cultivars separately for timely sown and for late sown conditions.

Table 3. Interaction between sowing time and cultivar on grain yield (q/ha, pooled basis). TS = timely sown recommended cultivar and LS = late sown recommended cultivar.

Cultivar	Sowing time			
	Normal	**Late**	**Very late**	**Mean**
PBW 343 (TS)	47.97	40.66	37.88	42.17
HD 2687 (TS)	47.68	36.73	38.86	41.09
PBW 502 (TS)	47.85	38.89	38.46	41.74
PBW 373 (LS)	47.09	42.24	38.63	42.65
UP 2425 (LS)	43.48	36.78	39.50	39.92
Raj 3765 (LS)	40.76	39.91	42.79	41.15
Mean	45.80	39.20	39.35	
CD at 5 % (sowing time)			2.00	
CD at 5 % (cultivar)			1.58	
CD at 5 % (sowing time x cultivar)			3.18	

References.

Gomez KA and Gomez AA. 1984. Statistical Procedures for Agricultural Research. John Willey & Sons, New York, NY. Pp. 97-107.

Tripathi SC, Mongia AD, Sharma RK, Kharub AS, and Chhokar RS. 2005. Wheat productivity at different sowing time in various agroclimatic zones of India. SAARC J Agric 3:191-201.

Zadoks JC, Chang TT, and Konzak CF. 1974. A decimal code for growth stages of cereals. Weed Res 14:415-421.