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Recovery potential and yield of selected wheat (*Triticum aestivum*) varieties exposed to unseasonal rainfall stress

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Wheat (*Triticum aestivum* L.) is an important cereal crop used as the staple food by the majority of world's populations and is cultivated over a wide range of areas. In India, wheat contributed an annual production of 88.94 Mt from an area of 30.9 Mha with a productivity of 2.87 Mt/ha during 2014-15 (MoA and FW 2015-16). Currently agriculture is facing multi-dimensional challenges including climate change. In India, wheat is challenged by climatic risks such as early and terminal heat stress, and unseasonal rainfall with heavy winds. These stresses are projected to increase further in south Asia (IPCC AR5 2014) and for wheat season (Naresh Kumar 2013). Presently farmers grow short, medium and long duration varieties of wheat. Since the duration of preceding crop influences the succeeding one, it is essential to know the region specific variety. This sort of information becomes important in changing climatic conditions where there is a possibility of shift in sowing times to maximize the yield. In wheat, conversion of late sown areas into timely sown areas could significantly improve yield even with the existing varieties in the future (Naresh Kumar *et al.* 2014). Several low-cost technologies can reduce the negative impacts of climate change (Easterling *et al.* 2007). These adaptation strategies include improved varieties (Chapman *et al.* 2012) and improved or altered agronomy (Ingram *et al.* 2008) along with efficient input use. Delay in sowing caused early maturity resulting drastic reduction in yield as compare to normal sowing which has a longer growth duration which consequently provides an opportunity to accumulate more biomass. Growing of suitable varieties at an appropriate time is an essential for ensuring optimum crop productivity. However, increasing events of unseasonal rainfall is affecting wheat yield. Rainfall couples with heavy winds, even for a short period cause lodging and crop loss. Thus it is important to know not only resistance to lodging but also recovery potential so that the yield loss is minimized. Being a thermo-sensitive crop, choice of suitable variety for different seeding time further gets prime importance (Amrawat *et al.* 2013). Recommendation of several varieties will also help farmers to select suitable. Genotypic adaptation is the most important intervention for sustaining wheat productivity in climatic stress conditions. Thus there is a need to identify best wheat varieties for sustainable production at regional level. In this paper we focus on the recovery potential and yield capability of six major wheat varieties exposed to unseasonal rainfall and consequent lodging.

Field experiment was conducted during *rabi* season of 2014-15 and 2015-16 in the Research Farm of ICAR- Indian Agricultural Research Institute, New Delhi. Geographically, Delhi is situated between latitude of 28°37' and 28°39' N and longitude of 77°9' and 77°11' E at an altitude of 225.7 m above mean sea level. It has semi-arid, sub-humid and sub-tropical climate with hot dry summer and severe cold winter. The soil of experimental field is slightly alkaline with low electrical conductivity and is well drained. The soil is sandy loam in texture with pH 7.5 and has about 0.43% soil organic carbon. Experiment was laid out in a homogenous field with six varieties differing in duration. Two short duration (K 9423, K 7903), two medium (WR 544, HD 2985) and two long duration (HD 2967, HD 3086) varieties were grown in a randomized block design with four replications. Crop was sown on 16 November in 2014 and on 27 November in 2015. The uniform dose of fertilizers were applied (120 N:60 P_2O_5:40 K_2O) with 50% N applied at the time of sowing, 25% N each at 25 and 45 days after sowing. Total six irrigations were given at all the important physiological growth stages (at pre-sowing, crown root initiation, tillering, flowering, milk and at dough stage) of wheat. The mean maximum temperature during the crop season was 22.93°C and 25.18°C in 2014-15 and 2015-16 respectively while the mean minimum temperature was

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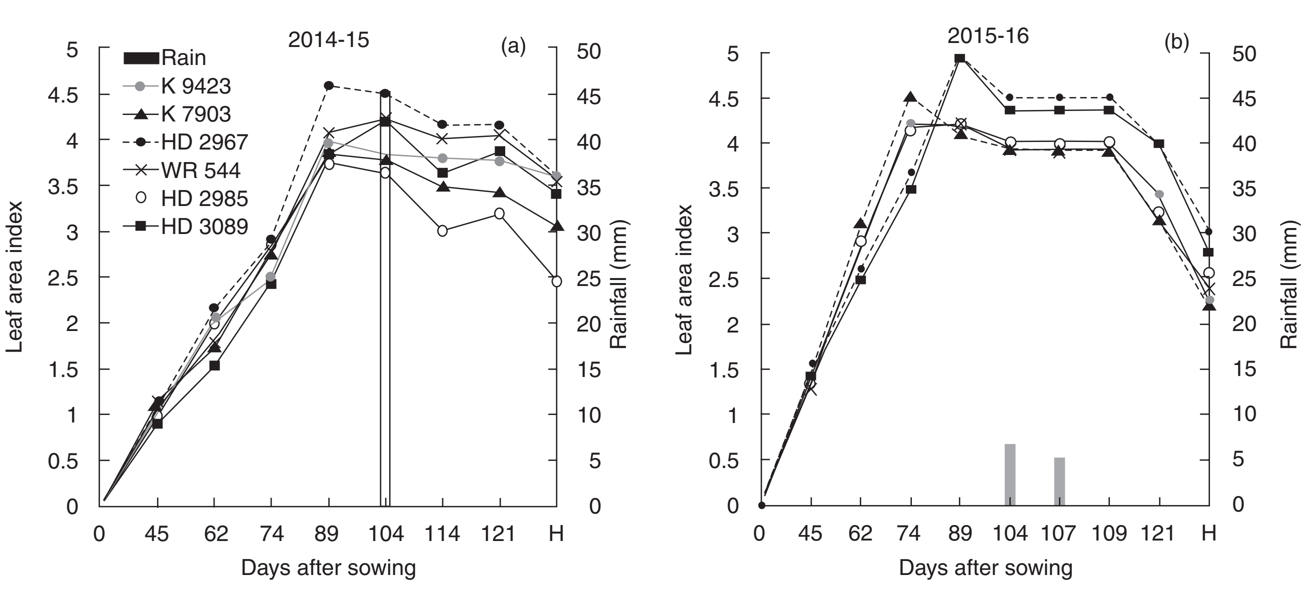
9.28°C and 9.03°C during 2014-15 and 2015-16 respectively. Rainfall during the cop period was 263.62 mm (2014-15) and 17.8 mm (2015-16). The mean bright sunshine hours was 4.3 (2014-15) and 5.5 (2015-16). The mean wind speed was 4.51 (2014-15) and 3.95 km/hr (2015-16). Leaf area index (LAI) was recorded using plant canopy analyzer at weekly interval. Five readings in each plot were taken at every observation time. Rain with heavy wind occurred on 8 March 2015. The following day, overall lodging in the field was observed. Then after a gap of 6 days of the event, the lodging was scored. Further, observations were done on the number of hills that remained straight, lodged and recovered in a square meter area by 10th day. The hills which had started to grow upward are designated as recovered hills. After that, the number of tillers/hill was again analysed in straight, lodged and recovered in a hill. Data on grain yield/ net plot were recorded. Finally, grain yield of each plot was converted in to grain yield/ha by multiplying it with appropriate conversion factor. The straw yield/plot was determined by subtracting grain yield (economical yield) of each plot from biological yield (bundle weight) of the same plot. This was later on converted into straw yield/ ha by multiplying with the same conversion factor which was used in case of grain yield/ha. Then, harvest index was calculated for each treatment using the formula:

Harvest Index = (Seed yield /Total dry matter)*100

All data were subjected to statistical analysis using SPSS 16.0.

Leaf area index (LAI): The maximum LAI (LAI_{max}) was observed at 89 DAS (flowering stage) in both the years (Fig 1). In 2014-15, the highest LAI was found in 45 DAS in the variety WR 544 followed by K 7903 (Fig 1a). At 62 DAS, varieties significantly differed and the variety HD 2967 had highest LAI and the variety HD 3086 showed least LAI. Maximum LAI exhibited in all varieties at flowering time. The LAI_{max} was highest in HD 2967 followed by WR 544. Among varieties, LAI significantly differed at flowering stage of the crop. After flowering, the LAI significantly reduced. By 104 DAS, the highest LAI was found in HD 2967 followed by WR 544. Among the varieties, the LAI was higher in HD 2967 at most of the growth stages followed by WR 544. In 2015-16, LAI_{max} among the different varieties was 4.94, while in 2014-15 it was 4.59. In both the years at flowering stage, LAI_{max} was more in HD 2967, HD 3086 and WR 544 as compared to other varieties. The long duration varieties (HD 2967 and HD 3086) maintained significantly higher LAI than other varieties till physiological maturity. Interaction effect between year and varieties was significant in both years. The LAI formation and its performance depends on varietal characteristics, seed sowing density and effects of management (Bavec *et al.* 2007).Climatic stresses such as high rainfall affects LAI due to lodging in wheat.

The number of hills/m^2 significantly varied in different varieties. The highest number of tillers were observed in variety HD 2967 followed by variety WR 544. Analysis of each hill indicated that HD 2967 had more number of tillers/hill while K7903 had the least number. Since the lodging happened during 2014-15 season, lodging data for that season is presented. Unseasonal rainfall with heavy wind on 8 March 2015 affected the wheat yields as it coincided with panicle development and mid-filling period. Following day, overall lodging in the field was scored (Table 1). Lodging ranged from 12-83 % among the varieties. The highest lodging was observed in HD2985 and lowest was in HD2967. Further, from 6-10 days after the event, observations were done on the number of hills that remained straight, lodged and recovered in a square meter area. The hills which had started to grow upward were



Where, H is the harvesting time

Fig 1 Leaf area index of six wheat varieties of 2014-15 and 2015-16 as influenced by climatic stress such as high rainfall and wind.

Table 1 Overall lodging, total number of hills/m^2 and number of tillers/hill (2014-15) in six varieties of wheat

Varieties	Lodging in overall field (%)	Study of hills				Study of tillers			
		Total number of hills/m^2	Straight (hills/m^2)	Lodged (hills/m^2)	Recovered (hills/m^2)	Number of tillers/ hill	Straight (tillers/ hill)	Lodged (tillers/ hill)	Recovered (tillers/ hill)
K 9423	37.5	48	22	9	18	15	6	6	3
K 7903	54.3	48	15	15	18	14	6	3	5
HD 2967	12.0	51	34	4	13	17	8	5	4
WR 544	25.0	50	25	15	10	13	8	3	3
HD 2985	83.8	45	3	37	5	15	1	10	4
HD 3086	33.8	46	18	6	22	15	6	6	3
CD (P=0.05)	32.1	3.5	2.3	1.9	2.5	1.48	1.21	1.00	0.85
SEM	10.53	1.15	0.75	0.62	0.82	0.48	0.40	0.33	0.28

designated as recovered hills. Maximum lodging occurred in HD 2985 with 82% of the hills lodged while the lease was in HD 2967 (7%). Consequently, about 66% of the hills remained straight in HD 2967 while it was only 7% in HD 2985. The maximum recovery of hills was observed in HD 3086 (48%). Lodging can be a limiting factor for wheat production under irrigated and high input condition, it can be influenced by many factors like higher nitrogen application, growing of tolerant and susceptible varieties, application of growth retardants and sowing methods (Tripathi 2013). The basal culm plays an important role in lodging resistance as it provides a lever to hold the plant upright and generally lodging in wheat occurs due to structural failure (Neenan 1975) rather than loss in anchorage. Hill-wise analysis for straight, lodged and recovered tillers indicated that variety HD 2967 had more number of straight tillers/hill followed by WR544 and the least was in HD 2985 (Table 1). Lodged tillers was more in the variety HD2985 (67%) followed by HD 3086 (40%) and K9423 (40%), while the least was observed in WR 544 and K 7903 (18%). The recovered tillers/hill was highest in the variety K7903 (38%) followed by HD 2985 (24%). Least recovery of tillers was in K 9423 and HD 3086 (17%).

Grain yield among the varieties ranged from 3.04 to 5.72 and 3.30 to 6.12 tonnes/ha during 2014-15 and 2015-16, respectively (Table 2). In both years, HD 2967 had higher grain yield than other varieties. The least yield was observed in HD2985. In 2015-16, significant differences for grain yield were observed among the varieties. Late duration varieties had higher yield, followed by the medium and early duration varieties. Straw yield among the varieties ranged from 6.83 to 9.39 and 6.79 to 9.61 tonnes/ha in 2014-15 and 2015-16, respectively (Table 2). In both years, HD 2967 had higher straw yield than other varieties. The minimum straw yield was observed in HD2985. Interaction effect of year and varieties was insignificant. The harvest index among the varieties ranged from 30.80 to 37.86 and 32.74 to 39.03%, in 2014-15 and 2015-16, respectively (Table 2). In 2014-15, HD 2967 had higher HI than other varieties while the least HI was observed in HD2985. In 2015-16, significant differences were observed between the varieties. The highest HI was observed in the variety HD2967 followed by K9423 and least in HD2985. In 2015-16, the varieties WR 544 and HD 3086 were statistically at par, and highest test weight was observed in HD 2967 and least in HD 2985. Previous studies on wheat cultivars have found a significant increase in both the harvest index (HI) and kernel number in long duration cultivars (Tian *et al.* 2011, Xiao *et al.* 2012). Difference in yield among modern well adapted cultivars were closely related to their biomass

Table 2 Yield influenced by different wheat varieties

Varieties	Grain yield (t/ha)			Straw yield (t/ha)			Harvest Index (%)		
	2014-15	1015-16	Pooled	2014-15	1015-16	Pooled	2014-15	1015-16	Pooled
K 9423	4.2	3.8	4.0	7.1	7.0	7.1	36.2	35.3	35.7
K 7903	4.0	3.7	3.8	7.1	6.9	7.0	35.8	34.8	35.3
HD 2967	5.7	6.2	5.9	9.4	9.6	9.5	37.9	39.0	38.4
WR 544	4.4	4.2	4.3	7.6	8.1	7.9	36.8	34.3	35.5
HD 2985	3.0	3.3	3.2	6.8	6.8	6.8	30.8	32.7	31.8
HD 3086	5.1	4.6	4.9	8.4	9.2	8.8	37.8	33.4	35.6
CD (P=0.05)	0.83	1.09	0.96	1.09	1.33	1.21	0.75	0.64	0.69
SEM	0.27	0.36	0.32	0.36	0.44	0.40	0.25	0.21	0.23

rather than to their harvest indices, as recently found within elite material in durum wheat (Pedro *et al*. 2011).

In 2014-15 leaf area index of varieties reduced at 114 DAS due to lodging caused by heavy rainfall and wind. The highest straight hills found in HD 2967 due to its minimum lodging. This variety out yielded others due to minimum lodging and thus more number of straight tillers. Even though number of recovered hills was more in the variety HD 3086 followed by K 9423, their yield is lesser than HD 2967.

SUMMARY

A field experiment was conducted during winter (*rabi*) season of 2014-15 and 2015-16 at IARI, New Delhi to evaluate the performance of wheat varieties exposed to unseasonal extreme rainfall and wind stress. Six wheat varieties differing in duration, viz. two short duration (K 9423, K 7903), two medium (WR 544, HD2985) and two long duration (HD 2967, HD 3086) were grown in a randomized block design with four replications. Unseasonal rainfall with heavy wind on 8 March 2015 affected the wheat yields as it coincided with panicle development and mid-filling period. In context of recovery potential of wheat varieties, the overall highest lodging observed in variety HD 2985, and highest number of straight hills/m^2 was observed in variety HD2967. Further, observations were done on the number of hills that remained straight, lodged and recovered in a square meter area. Lodged tillers was more in the variety HD2985 (67%) followed by HD3086 (40%) and K 9423 (40%), while the least was observed in WR 544 and K 7903 (18%). More number of straight hills/m^2 was observed in HD2967, whereas lodged hills/m^2 were highest in HD2985. The variety HD 2967 had highest leaf area index, number of tillers/m^2, weight of grains/m^2, number of grains/ear head, weight of grains/ear head, and test weight. The highest yield and harvest index also were observed in HD 2967.Hence it can be concluded that the variety HD 2967 is highly resistant to lodging followed by HD 3086. Overall it is concluded that the variety HD 2967 is most suitable variety for capital and western region of India in climatic stress conditions such as heavy rainfall coupled with winds.

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