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On-farm Agro-meteorological evaluation of late sown wheat (*Triticum aestivum*) under irrigated agro-ecosystem of Upper Indo-Gangetic Plains

M SHAMIM[1], A S PANWAR[1], N RAVISANKAR[1], PC JAT[1], A K PRUSTY[1], M P SINGH[1], POONAM KASHYAP[1], NISHA VERMA[1], SHIV DATT[2], M A ANSARI[1]* and SUNIL KUMAR[1]

ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh 250 110, India

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ABSTRACT

In Indo-Gangetic Plains (IGP, ~18 mha geographical area), wheat (*Triticum aestivum* L.) is a predominant crop grown in *rabi*. Improving the productivity of wheat in a rice-based farming system through a suitable cultivar in IGP is necessary to evaluate under the agro-ecological condition of IGP of India. A farmer's participatory field experiment was studied at three villages Saunta, Sathedi and Bhangela situated in Khatauli block of Muzaffarnagar (Uttar Pradesh) under two crop environments (low rainfall and high temperature, LRHT and heavy rainfall and low temperature, HRLT) with four wheat varieties during *rabi* of 2017–18 and 2018–19. In this study we have evaluated the productivity in isolation as well as in combination of prevailing weather scenario (2017–18 and 2018–19) under irrigated agro-ecosystems of Western Plain Zone of Uttar Pradesh. Interaction studied between crop environments and varieties indicated that PBW-550 and PBW 658 registered higher grain yield of 5514 and 5475 kg/ha respectively than farmers practice (PBW-226, 4659 kg/ha) and DBW-90 (4647 kg/ha) in LRHT. However, under HRLT, PBW-658 performed better (5326 kg/ha) over other cultivars. Mean grain yield of all four cultivars were recorded significantly higher under LRHT with 5074 kg/ha compared to HRLT where mean grain yield was 4710 kg/ha. A highly significant (P=0.01) negative association was found between grain yield and monthly rainfall (except December month) and cumulative rainfall of the crop season (-0.322**). Prevailing mean monthly air temperature during grain filling to maturity phenophase was found to be positively associated with grain yield (r = -0.322*).

Keywords: Crop Environment, Growing degree days, Indo Gangetic Plains, Productivity, Wheat

The total geographical area of Western Plain Agroclimatic Zone (WPACZ) is 16.37 lakhs ha where the prominent soil type is alluvial with normal to alkaline *p*H and minimum to medium organic matter. This agro-climatic zone is characterized as the food and sugar basket of the state. Relative share of food grain crops in the Gross Cropped Area was around 80% which contributed about 45% of all food grain production and nearly 60% of sugar production in the state (Anonymous 2020). Under cropping system component, bread wheat (*Triticum aestivum* L.) is an important cereal food crop. During last decade (2008–09 to 2017–18) area and productivity of wheat in Uttar Pradesh were reported as 9.7 million ha and 2950 kg/ha, respectively, (Ramadas *et al.* 2019) which has contributed 32.56 and 31.46% to the national area coverage and production respectively. Muzaffarnagar is an important district in terms of wheat production in WPACZ. During last 10 years (2007–08 to 2016–17), the district has 17.9 and 16.7% contribution in the total wheat area and production to the WPACZ of the state. But productivity remained 5% lower compared to the yield (3594 kg/ha) of the WPACZ in the same period. A number of factors including land preparation, time of sowing, fertilizer application, irrigation scheduling and weed management are responsible for the variation in grain yield of wheat, but all these factors are agronomic and are greatly influenced by rainfall, temperature and humidity and these climatic changes produce large annual variations in productivity of wheat crop (Kaur and Behl 2010). Due to climate change, the incidence of extreme weather events has increased (Sandhu and Dhaliwal 2017). Therefore, development of potential improved cultivars, under above constraints and its evaluation becomes urgent need of the hour to address the projected demand and supply gap of the wheat production in major growing parts of the country. Therefore, with an objective, on-farm agro-meteorological evaluation of late sown wheat in integrated farming system is worth in addressing the projected wheat demand under changing climate *vis-à-vis* year-to-year variable climate.

[1]ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh; [2]ICAR-Krishi Anusandhan Bhawan-II, New Delhi. *Corresponding author email: merajiari@gmail.com

MATERIALS AND METHODS

Experiments at farmer field were conducted to assess the performance of late sown wheat in integrated farming system under varied environment of 2017–18 and 2018–19. The study was undertaken in farmers participatory mode at three villages Saunta, Sathedi and Bhangela which are situated in Khatauli block of Muzaffarnagar (Uttar Pradesh). These villages are located at 29.4479° N and 77.4487° E, 29.2654° N and 77.7030°, and 29.2339° N, 77.7215° E latitude and longitude, respectively with altitude of 238–248 m amsl in Western Plain Agroclimatic Zone (WPACZ) of Uttar Pradesh (Upper Gangetic plains), India. The experiments were conducted in randomised block design with nine replications under two crop different environments i.e. crop environment with low rainfall and high air temperature (LRHT) and crop environment with heavy rainfall and low air temperature (HRLT) during two consecutive *rabi* of 2017–18 (LRHT) and 2018–19 (HRLT). LRHT has received 30.0 mm rainfall during the crop season while HRLT received 196.7 mm rainfall during the crop season. The mean maximum and minimum temperature under LRHT were 24.3 and 9.8ºC whereas under HRLT were 22.8 and 8.1ºC respectively. The climate is categorised as hot, dry and semi-arid subtropical with moderate summer and severe cold winters. The average annual rainfall is about 869 mm and potential evapo-transpiration of 1545.9 mm. Prevailing weather parameters under LRHT and HRLT during the crop seasons have been presented in Fig 1. The soil of the experimental field was typic Ustochrepts, sandy loam, deep and mildly alkaline (*p*H 8.2) with low to medium fertility (OC–0.40%, available P_2O_5–32.5 kg/ha and K_2O–125 kg/ha). For performing statistical analysis, data pertaining to grain yield and its attributes, plant height was collected at the time of harvest from the farmers' field. All the data sets were analysed using SPSS software (trial version).

RESULTS AND DISCUSSION

Plant height, yield attributes, viz. number of effective tillers per plant, ear length (cm), number of grains per ear, test weight (g/1000 seeds) and grain yield (kg/ha) of cultivars usually grown by farmers like PBW-226 and newly introduced late sown varieties like PBW-550, PBW 658 and DBW-90 were compared and presented in Table 1. Results clearly depicted that the crop environment with low rainfall and high temperature (LRHT) during *rabi* 2017–18 was most congenial and had significant effect on the varieties in terms of number of effective tillers (6.67/plant), ear length (9.31 cm), higher test weight (33.70 g 1000/seeds) and grain yield (5073.9 kg/ha). However, HRLT was good enough to attain more plant height (88.2 cm) and higher number of grains (60.1/ear). Higher grain yield under LRHT might be due to lower monthly as well as total rainfall precipitated during crop season, particularly during grain filling period (February with 110.7 mm lower) and free from rainy days during physiological maturity in comparison to HRLT. The mean maximum air temperature during grain filling to physiological maturity period (February and March) in LRHT was 27.1ºC and minimum temperature was 12.8ºC, however it was recorded as 24.25ºC and 10.90ºC under HRLT respectively. The maximum and minimum air temperature under HRLT was found to be in higher proximity with the findings of Singh *et al.* (2008) where they have reported that temperature of 25.6°C and minimum temperature of 10.8°C during grain filling period (February and March) revealed significant effects on

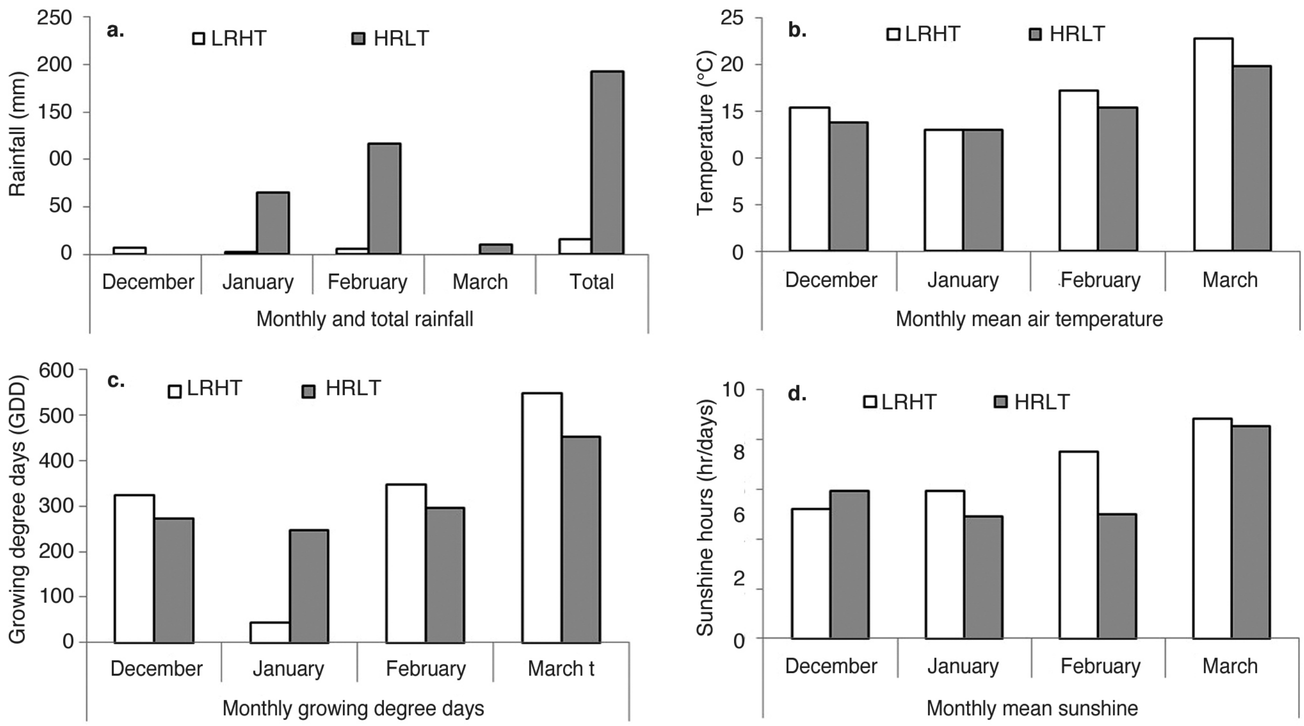

Fig 1 a) Prevailing monthly and total rainfall (mm), b) monthly mean air temperature (ºC), c) monthly growing degree days (GDD) and d) monthly mean sunshine hours (h/day) under LRHT and HRLT.

Table 1 Interaction of crop environments and variety on growth and yield attributes of late sown wheat varieties

	Plant height (cm)	Effective tillers/plant	Ear length (cm)	Grains/ ear	100-seed weight (g)	Grain yield (kg/ha)
Variety						
PBW-226(V_1)	91.4^{b}	5.2^{a}	6.9^{a}	52.7^{a}	3.0^{a}	4516.1^{a}
PBW-550 (V_2)	80.2^{a}	7.2^{c}	8.6^{b}	59.8^{b}	2.9^{a}	5084.4^{b}
PBW 658 (V_3)	98.3^{c}	7.4^{c}	9.9^{c}	62.3^{b}	3.8^{b}	5400.6^{c}
DBW-90 (V_4)	76.2^{a}	6.2^{b}	8.7^{b}	50.9^{a}	3.1^{a}	4567.8^{a}
SEM±	1.89	0.25	0.31	1.40	0.09	78.40
Crop Environments						
2017–18 (LRHT)	84.8^{a}	6.67^{b}	9.31^{b}	52.8^{a}	3.37^{b}	5073.9^{b}
2018–19 (HRLT)	88.2^{b}	6.31^{a}	7.78^{a}	60.1^{b}	3.08^{a}	4710.6^{a}
SEM±	1.34	0.18	0.22	0.99	0.06	55.00
Variety × Crop Environments						
V_1LRHT	93.0^{cd}	5.9^{b}	8.2^{b}	48.9^{ab}	2.9^{ab}	4658.9^{a}
V_2LRHT	79.9^{b}	7.4^{b}	9.6^{b}	58.0^{c}	3.0^{ab}	5514.4^{b}
V_3LRHT	99.2^{d}	7.4^{b}	11.3^{c}	58.2^{c}	3.9^{c}	5475.6^{b}
V_4LRHT	67.1^{a}	5.9^{b}	8.1^{b}	46.0^{a}	3.2^{b}	4646.7^{a}
V_1HRLT	89.9^{bc}	4.4^{a}	5.7^{a}	56.6^{bc}	3.0^{ab}	4373.3^{a}
V_2HRLT	80.4^{b}	6.9^{b}	7.7^{b}	61.7^{cd}	2.7^{a}	4654.4^{a}
V_3HRLT	97.4^{d}	7.3^{b}	8.6^{b}	66.4d	3.7^{c}	5325.6^{b}
V_4HRLT	85.2^{bc}	6.6^{b}	9.2^{b}	55.8^{bc}	3.^{b}	4488.9^{a}
SEM±	1.48	0.16	0.23	0.98	0.16	63.69
ANOVA						
Variety	**	*	**	**	**	**
Crop Environments	**	*	**	**	**	**
Variety x Crop Environments	**	*	**	**	*	**

Within a column, numbers followed by different lowercase letters (a–d) are significantly different between treatments at P≤0.05 (Tukey's HSD test).

wheat yield in Southwestern region of Punjab. But in this situation with two most important weather parameters like temperature and rainfall, rainfall has pronounced negative effect on grain yield in comparison to temperature which earmarked that amount is not the deterring parameter but the distribution of rainfall, as correlation between rainfall during crop establishment phase (December month) had positive sign with grain yield but the rainfall of march month i.e. during maturity phase has negative association with the wheat grain yield (Table 2). This result corroborates that the total amount of rainfall in a season is not the criteria but, its distribution over a large area is critical (Nadew 2018).

Under LRHT, PBW 658 registered significantly higher plant height (99.2 cm) while, the least plant height was recorded by the DBW-90 (67.1 cm). Under HRLT, highest plant height (97.4 cm) was recorded by the PBW 658, and the least height was obtained in case of variety PBW-550 (80.4 cm). On pooled basis, variety PBW 658 registered significantly highest plant height (98.3 cm) and the varieties PBW-550 and DBW-90 (80.2 cm and 76.2 cm) recorded the lowest height respectively.

Number of effective tillers per plant is the major contributor to the productivity of cereal crops like rice, wheat etc. Prevailing weather parameters under LRHT were found to be highly favourable for more effective tillers per plant in comparison to weather parameters of HRLT. However, based on individual variety performance, it was the environment of HRLT which significantly reduces the number of effective tillers in PBW-226; otherwise, all varieties were statistically at par during both the years. Ignoring the prevailing weather conditions, there were three distinct group found in study of effective tillers, where PBW-550 and PBW 658 recorded the highest number i.e. 7.2 and 7.4 per plant respectively. Agrometeorological parameters like monthly average sunshine hours (SSH) prevailed during January to March months and were having positive association with the number of effective tillers whereas December month was correlated with negative sign (r=.384**). Ear length provides the base from which spikelets remain attached, so longer ear may contain higher number of spikelets bearing grains. Results of ear length showed that weather parameters prevailing under LRHT were more congenial in lengthening the ear of the crop where mean ear length was recorded in the magnitude of 9.31 cm. Interaction results of prevailing

Table 2 Correlation coefficients between yield attributes and agrometeorological parameters of crop environment

	Grain yield	Effective tillers	Length of ear head	Grains per rear head
December Rain	.322**	0.127	.384**	-.461**
January Rain	-.322**	-0.127	-.384**	.461**
February Rain	-.322**	-0.127	-.384**	.461**
March Rain	-.322**	-0.127	-.384**	.461**
Cumulative Rain	-.322**	-0.127	-.384**	.461**
December mean temperature	.322**	0.127	.384**	-.461**
January mean temperature	.322**	0.127	.384**	-.461**
February mean temperature	.322**	0.127	.384**	-.461**
March mean temperature	.322**	0.127	.384**	-.461**
December GDD	.322**	0.127	.384**	-.461**
January GDD	-.322**	-0.127	-.384**	.461**
February GDD	.322**	0.127	.384**	-.461**
March GDD	.322**	0.127	.384**	-.461**
December SSH	-0.127	-.384**	.461**	.240*
January SSH	0.127	.384**	-.461**	-.240*
February SSH	0.127	.384**	-.461**	-.240*
March SSH	0.127	.384**	-.461**	-.240*
Grain yield	1.00	.489**	.502**	.473**
Effective tillers	.489**	1.00	.611**	.241*
Length of ear head	.502**	.611**	1.00	0.098
Grains per rear head	.473**	.241*	0.098	1.00

**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level.

weather and variety clearly depicts three distinct groups where PBW 658 registered the highest ear length (11.3 cm) under LRHT whereas cultivar grown under farmers practice i.e. PBW-226 with 5.7 cm ear length remained the lowest scorer while rest other combinations represent themselves as the part of third (middle) group. Correlation study of the ear length with the agrometeorological parameters like total rainfall showed negative relationship (r=.384**) while monthly rainfall of December was positively associated. Monthly mean air temperature of all the months registered positive and highly significant association with the length of ear head (r=.384**). Similar to mean air temperature, growing degree days (GDD) was associated with the ear length. However, monthly average sunshine hours (SSH) of January and February months was negatively associated with this yield attributes (r=-.461**). The length of ear head was strongly associated with number of grains per ear head (r=0.611**) as more length provided more space to set the spikelets.

The grain number is itself a function of the number of fertile shoots per unit area and the number of grains per ear. High light intensity and low air temperature have great influence on setting of grains on particular ears/spikes. Results of effect of prevailing weather scenarios on number of grains per ear or spike clearly showed that the most congenial crop environment prevailed during HRLT where consistently lower mean air temperature during emergence to grain filling duration (December to March) was recorded in comparison to HRLT in the similar crop phenophases. Henceforth significantly higher grains per ear (61.1 grains/ ear) were found in HRLT crop environment. Four statistically discrete groups were found from interaction results of variety and prevailing weather where PBW 658 (66.4 grains/ear) and PBW-550 (61.7 grains/ear) out yielded under HRLT crop environment over others combination while DBW-90 scored itself as the poorest performer with 46.0 grains per year under LRHT crop environment scenario. These two varieties PBW 658 and PBW-550 maintained their rank same in the results of pooled weather scenarios with 62.3 and 59.8 grains per ear. Cumulative rains during the season favoured the setting of grains on a ear head while monthly rainfall during the months of December showed negative association with this yield attribute. Monthly mean air temperature of all the months showed negative and highly significant association in setting of the grains on an ear head. Growing degree days was also having negative relation except of January month and total GDD. Monthly sun shine hours of January and February months showed negative association with the grains per ear head while more clear sky during the terminal crop phase was positively associated with the number of grains per ear head (Table 2).

Test weight refers to the average weight of 1000 seeds of bold grain cereals measured in gram. It is an important quality parameter used for prediction of milling yield for rice and flour extraction rate for wheat. Air temperature is a major determinant of wheat growth and its development, especially during milking and dough stage of grain development. Results of effect of different crop environment on yield clearly indicates that lower mean air temperature of terminal crop phenophase was more favourable for grain development and maturation under LRHT resulted in significantly higher test weight (33.70 g/1000 seeds) of the crop. On pooled basis, varieties were recorded and it was found that PBW 658 registered significantly higher test weight of 30.90 g/1000 seeds and remaining three varieties were fallen in lower group. Data of interaction Table showed that out of three categories, PBW 658 performed better over others in both crop environments.

Grain and stover yield represent the biomass productivity of the crop.Though both components are equally important in farming systems perspective, farmers always give priority to those varieties which give higher grain yield even at the cost of stover yield. Hence potential of higher grain productivity becomes parameter for selection by the farmers (Singh *et al*. 2012). Results of pooled data on grain yield of all four varieties clearly showed that weather parameters (Fig 1) were more favourable under LRHT where significantly higher grain yield of 5073.9 kg/ha was recorded over HRLT (4710.6 kg/ha). The lower grain yield under HRLT was due to extreme weather condition where flowering/anthesis phenophases was highly affected by heavy downpour (116.9 mm) besides continuous rain during very critical phenological stages in the months of January to March. Correlation coefficients studied clearly depict a strong and highly significant negative association (r=0.322**) between grain yield and rainfall amount precipitated in these months. Higher mean temperature was another additive factor in reduction of grain yield during HRLT as the milking and dough stage of the wheat crop is very crucial towards any single point elevation in mean air temperature. Performance evaluation of individual variety on pooled basis indicated that variety grown under farmers practices i.e. PBW-226 and another new introduced variety (DBW-90) were poor yielders in comparison to PBW-550 (5084.4 kg/ha) and PBW 658 (5400.0 kg/ha). It was also observed that, PBW 658 consistently performed better irrespective of crop environment scenarios. Correlation study revealed that grain yield was positively and highly significantly associated with yield attributing characters like number of effective tillers (r=0.489**), length of ear head (r=0.502**) and grain per ear head (r=0.473**).

This lower grain yield in HRLT was due to extreme weather and lower growing degree days, bright sunshine hours during flowering and grain filling phenophases and due to comparatively higher terminal heat stress (27.6°C) in grain maturation phenophase. Thus, under irrigated sugarcane-ratoon-wheat cropping system, introduced variety PBW 658 of wheat in late sown condition was found to be performing better under both low rainfall and heavy rainfall crop environment of western plain zone of Uttar Pradesh.

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