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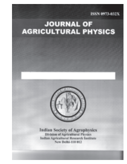

Research Article

Multistage Wheat Yield Estimation using Biophysical Parameters under Different Weather Condition at Semi-arid Region of India

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ABSTRACT

An experiment was conducted at research farm of ICAR-Indian Agricultural Research Institute, New Delhi during *Rabi* 2017-18 and 2018-19. Three wheat varieties PBW-723, HD-3086 and HD-2967 were sown on three different dates. Periodic observations of different biophysical variables at different phenological stages were measured. Yield and yield attributes were measured after harvest. Results showed that timely sown crop had better growth parameters and yield compared to late sown crops. Model was developed using different biophysical parameters, intercepted photosynthetically active radiation for estimating wheat yield at flowering and grain filling stage for different varieties of wheat sown under different sowing condition at research farm of ICAR-IARI, New Delhi during *Rabi* 2017-18. Model developed were used for estimating yield at flowering and at grain filling stage during *Rabi* 2018-19. Results showed that the dominant variables for yield estimation at flowering stage were biomass at 80 DAS and plant height at 90 DAS, while biomass at 80 and 100 DAS were dominant variables for yield estimation at grain filling stage. The percentage deviation of estimated yield done at flowering stage and grain filling stage by observed yield was -1.95, -3.27, 2.3% and -2.49, -5.68, -1.47% respectively for crop sown at different dates.

Key words: Stepwise multiple linear regression, Biophysical parameters, Flowering stage, Grain filling stage

Introduction

The variation in crop yields in location to location as well as year to year is due to the change in crop growth and development influenced by weather variability, which makes yield estimation a baffling process. Crop yield estimation is required at farm, village, district, state or national level. Plant biophysical parameters have significant influence on determining crop yield, statistical technique like Stepwise multiple linear regression can be used as a simplified tool for assessing the relationship between biophysical parameters and yield.

Leaf area index (LAI) is one of the most important biophysical parameters used for the evaluating crop status index, it is also used in prediction of models (Krishnan *et al*., 2016). Precise measurement of LAI is necessary for better crop vigour monitoring, modelling purpose and overall crop management practices (Wallach *et al*., 2001). Productivity of crop and rate of photosynthesis is greatly affected with alteration in leaf area of a crop canopy therefore, it has a considerable influence on yield of the crops. Quality and intensity of intercepted radiation by the crop controls the growth, development, and yield, therefore RUE has been considered to be constant for a given crop species (Yang *et al*., 2004; Sinclair, 1986), it varied during plant growing seasons (Werker and Jaggard, 1998; Lecoeur and Ney, 2003), it is mostly dependent on climatic parameters like abiotic stresses and can significantly reduce both the interception of

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photosynthetically active solar radiation and RUE. Variation in biomass accumulation were observed due to differences in radiation interception, which is dependent primarily on LAI (Lindquist *et al*., 2005). Biomass production and Harvest index (HI) are the two major factors influence on grain yield (White and Wilson, 2006). Biomass is a noteworthy factor determining wheat yields. Increasing wheat yields were observed as coinciding with increasing biomass yields.

Relatively simpler data requirements for empirical or regression model make it easy to use in large-scale prediction of yield for different locations. (Jain *et al*., 1984, 1992b) developed statistical models by collecting biophysical data from experiments for forecasting crop yield for different regions of the country. Application of principal component analysis model based on biometrical characters, provided wheat yield forecast, which are very near to the actual yield in both normal and late sowing conditions, with percent standard errors of the forecast yield within the range of 2.16 to 4.96 percent respectively, and percent RMSE below 1.11 percent (Sisodia and Rai, 2017). Thus, application of such statistical technique has provided a suitable forecast model using biometrical characters. The objective of this study is to develop yield estimation model using different biophysical parameters and intercepted photo-synthetically active radiation for estimating wheat yield at different growth stage.

Materials and Methods

Field experiment was conducted for wheat crop during *Rabi* 2017-18 and 2018-19 at the research farm main block 4-C of Division of Agricultural Physics, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, located at 28°38′23″ N and 77°09′27″ E with altitude of 228.6 meter above MSL.

Soil is deep sandy loam in texture and well drained. Split plot design was used in the experiment, with date of sowing as main treatment with three varietal sub-treatment. Three prominent wheat varieties (HD-3086, HD-2967, PBW 723) commonly cultivating in the north-west plains of India were sown on 20th November (timely sown), 5th December (late sown) and 20th December (very late sown), respectively. The seed rate was 100 kg/ha, with average sowing depth 4 cm, having spacing of 22.5 cm × 5 cm with plot size 5m × 5m. Recommended dose of irrigation and fertilizer was applied. Periodic observation of leaf area index, biomass, photosynthetically active radiation, plant height, number of leaves and number of tiller per plant were taken at different phenological stages. Yield and yield attributes were measured after harvest. IPAR, FPAR and RUE were derived from photosynthetically active radiation. LAI was measured at 10 days interval using LAI-2000 Plant Canopy Analyzer.

For plant biomass observations, five plants were randomly selected from each plot, oven dried at 65°C for 48 hours and weighed by using electronic weighing balance. The dry matter production was expressed in kg/ha. Randomly selected five plants in each treatment at periodic interval of 10 days were used for analysing plant height, number of tiller, number of spikes per plant, number of grains per spike and length of spike. Average of these five plants was the final reading in each treatment. Spike and grain parameters were taken during the maturity stage of the crop. After the harvest of crop, thousand grain weight was measured in each treatment with three replications by using weighing balance. Crop grain yield was measured with hand balance after drying the crop for 3 days under bright sunshine

Incoming as well as outgoing photosynthetically active radiation (PAR) values were measured using line quantum sensor (LICOR-3000) at top, middle and bottom of the crop throughout the crop growing season at 10 days interval. These measurements were taken between 11:30 and 12:00 hours IST on clear days when disturbances due to leaf curling, leaf shading and solar angle were minimum.

Radiation use efficiency (RUE) of the crop was estimated using the following equation:

$$\text{RUE} = \frac{\text{Amount of dry matter produced (g m}^{-2}\text{)}}{\text{Amount of total IPAR (MJ m}^{-2}\text{)}}$$

Absorbed Photosynthetically Active Radiation (APAR) by the whole canopy = {Incident radiation on the top of the canopy – reflected radiation by the top of the canopy– incident radiation at the bottom (transmitted radiation) + reflected from the ground}.

Intercepted Photosynthetically Active Radiation (IPAR = {(Incoming PAR at top –reflected from the canopy –incoming PAR at bottom)}/ (Incoming PAR at the top).

Statistical technique

Stepwise multiple linear regression model was developed and calibrated for *Rabi* 2017-18 crop sown at ICAR-IARI New Delhi research farm. Model validation was done by different observation, at different growth stage during *Rabi* 2018-19 sown crops. For crop yield estimation at flowering stage, model was developed by biophysical parameters and IPAR data up to flowering stage and for crop yield estimation at grain filling stage, model was developed by biophysical parameters and IPAR, data up to grain filling stage. Percentage deviation of estimated yield was calculated from observed yield after harvest of the crop during *Rabi* 2018-19.

Results and Discussion

Leaf area index, plant height and biomass production under different sowing condition

Leaf area index (LAI) profile showed a typical pattern of first increasing during vegetative phase, reaching the peak at flowering stages and then decreasing, due to senescence in all the treatments (Fig. 1). Timely sown crop showed highest LAI as compared to the late and very late sown crop. The peak LAI values were 4.19, 4.54, 4.48 under timely sown crop, 3.88, 4.07, 3.97 under late sown crop and 2.36, 2.84, 2.72 under very late sown crop in PBW-723, HD-3086 and HD-2967 respectively. It

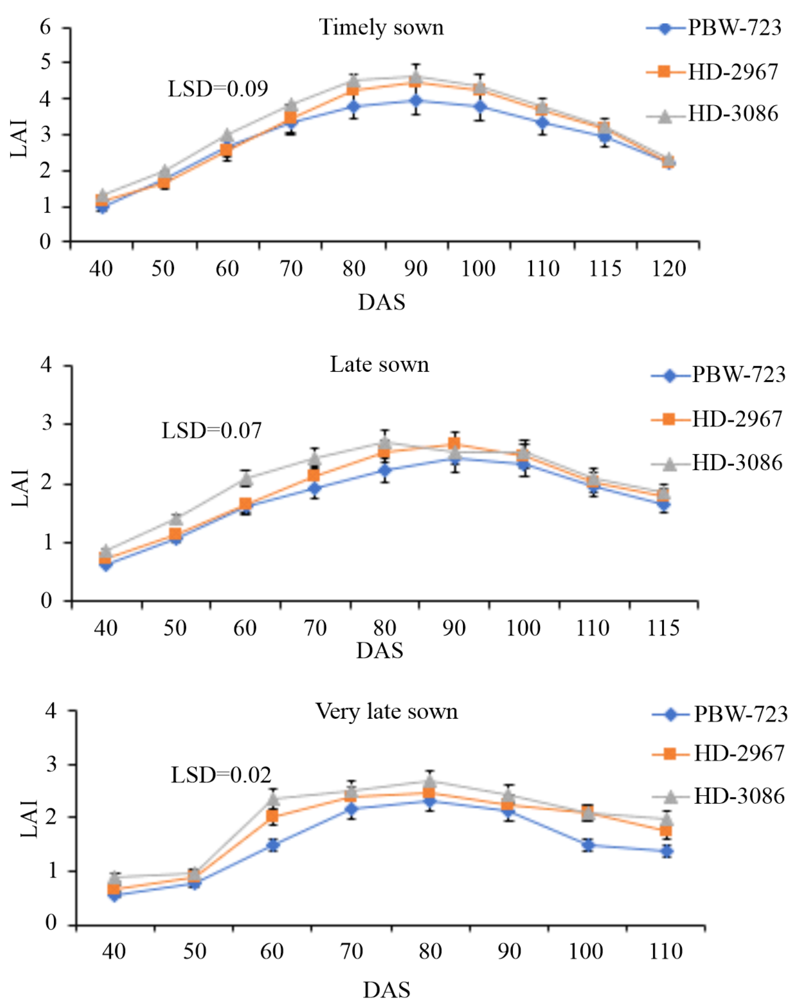

Fig. 1. Leaf Area Index of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

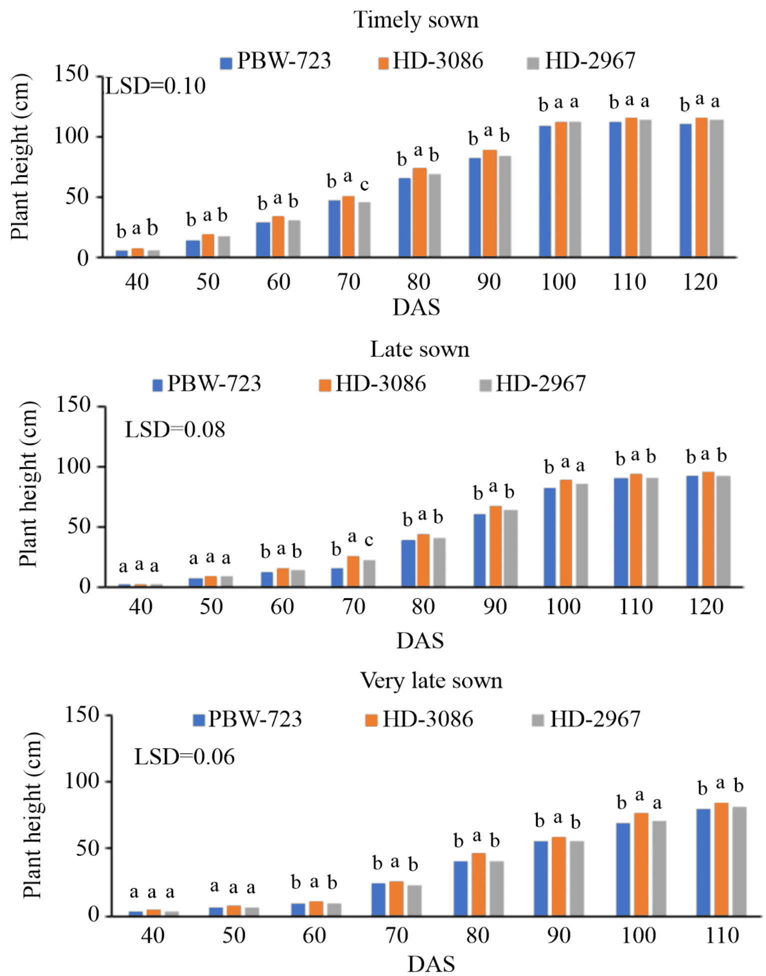

Fig. 2. Plant height of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

was observed that the leaf area index (LAI) was higher in HD-3086 followed by HD-2967 and PBW-723. HD-3086 had 7.6, 10.3 and 9.1% more value of LAI than PBW-723. This indicates that delay in sowing resulted in significant growth loss and shortening of length of crop growing period.

Plant height was increased continuously up to flowering stage, slight increased up to milking stage, afterward the height remains constant in all the treatments (Fig. 2). Height of HD-3086 was more than HD-2967 and PBW-723 in all the sowing condition. Number of leaves per plant was 25-30 in timely sown crop, 23-24 in late sown crop and 13-16 in very late sown crop in different varieties sown under different sowing conditions. Number of tillers per plant was 4-5 in timely sown crop, 3-4 in late sown crop and near to 3 in very late sown crop, respectively.

Biomass production at different growth stages during 50 days after sowing (DAS) to 135 days after sowing varied from 852 to 16769, 1031 to 19180 and 919 to 18532 kg/ha under timely sown crop in PBW-723, HD-3086 and HD-2967, respectively. The variation in biomass production at different growth stages was, 372.5 to 10758, 503 to 13261 and 439 to 12416 kg/ha under late sown crop during 30 to 120 days after sowing and 122 to 8560, 176 to 9970, 151 to 9144 kg/ha under very late sown crop during 30 to 115 days after sowing in PBW-723, HD-3086 and HD-2967 respectively. Changes in biomass were significantly decrease in very late sown crop as compared to the late and timely sown crop. Biomass production varied from 25 to 56, 22 to 50 and 22 to 52% in PBW-723, HD-2967, HD-3086 under very late sown as compared to the timely sown crop with a mean value of 39.1, 36.9 and 37.0% in different

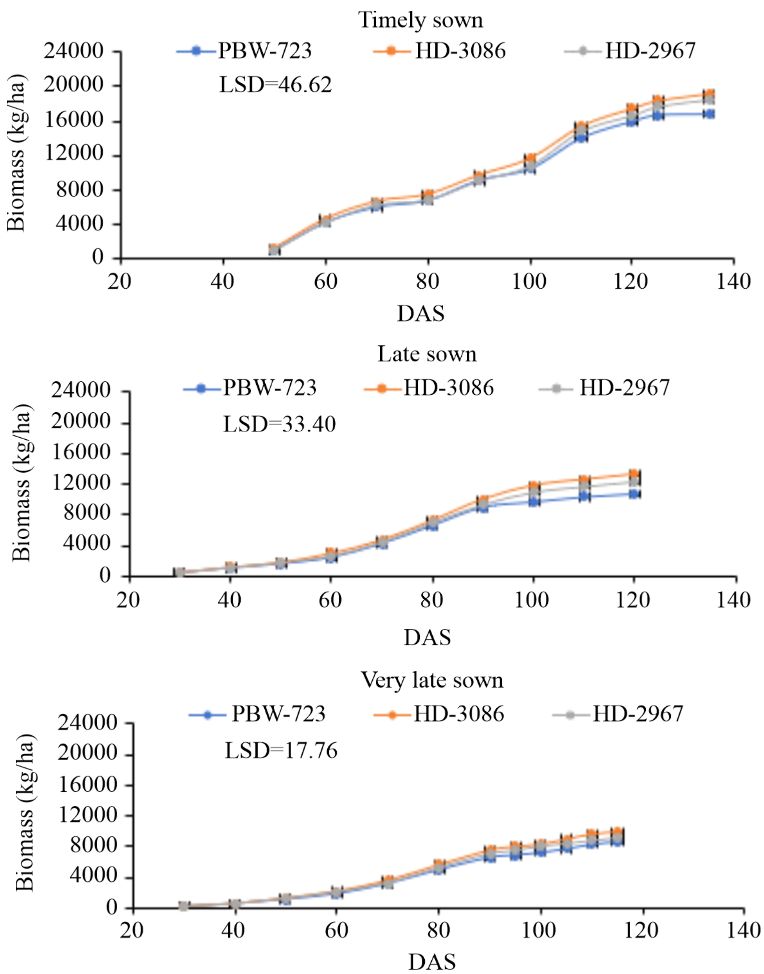

Fig. 3. Biomass of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

phonological stages. Greater reduction in biomass was observed in PBW-723 as compared to HD-3086 and HD-2967 in all sowing conditions (Fig. 3). The LAI and biomass production levels obtained in the present study and the reduction of biomass production due to late sowing are in conformity with the work done in other crops in earlier findings (Kar and Chakravarty, 2001; Vashisth *et al*., 2011, 2012).

Intercepted Photosynthetically Active Radiation (IPAR) and Radiation Use Efficiency (RUE)

The IPAR for timely sown crop was 642, 650 and 644 MJ/m². For late sown and very late sown crop, values of IPAR was 603, 621, 613 MJ/m² and 539, 562, 547 MJ/m², respectively in PBW-723, HD-3086 and HD-2967 (Fig. 4). The peak value of radiation use efficiency was 2.68, 2.95 and 2.90 g/MJ for timely sown crop, 2.38, 2.65, 2.43 g/MJ for late sown crop and 2.12, 2.44 and 2.35 g/MJ for very late sown crop in PBW-723, HD-3086 and HD-2967 respectively (Fig. 5). Radiation use efficiency was found to be highest in first sown crop followed by, late sown and very late sown crop. The percentage reduction in peak value of RUE in late sown crop as compared to corresponding value in timely sown crop was 18.6, 10.3 and 16.3% in PBW 723, HD-3086 and HD-2967, respectively. The reduction was further increased in very late sown crop as compared to timely sown crop by 20.8, 17.4 and 19.1% in PBW 723, HD-3086 and HD-2967, respectively. The reduction was less in HD-3086 followed by HD-2967 and PBW-723. These results are in conformity with those of the work done in earlier findings (Vashisth *et al*., 2020, 2022).

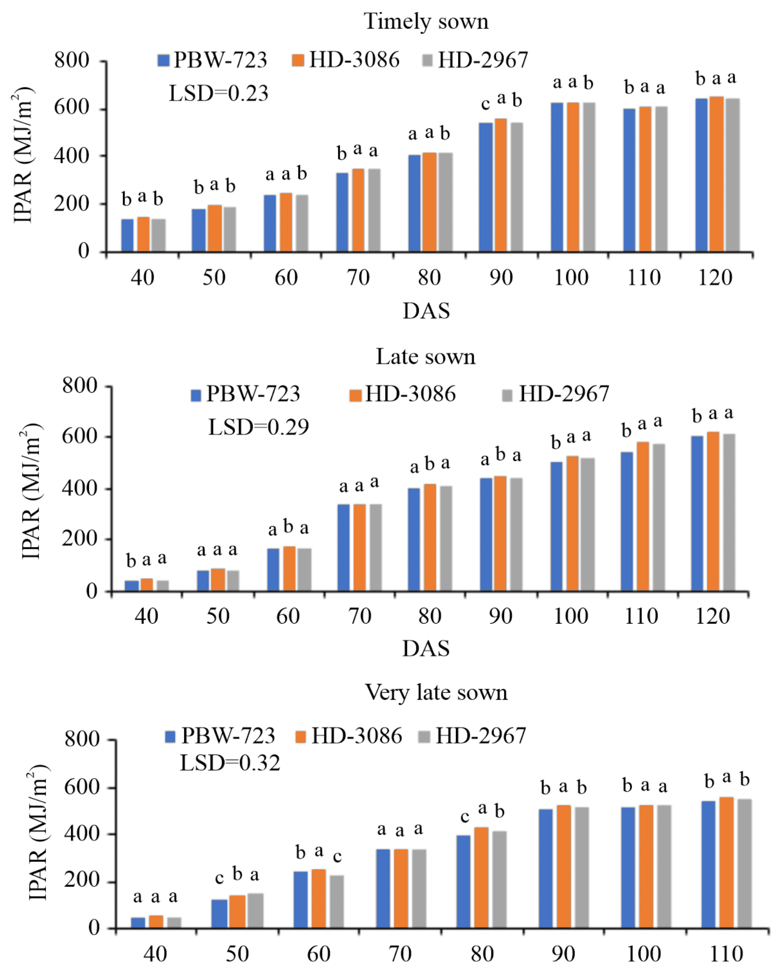

Fig. 4. Intercepted PAR of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

Yield and yield attributes

Length of spike varied from 15.2, 16.0, 15.8 cm for timely sown crop, 14.6, 15.7, 14.9 cm for late sown crop and 13.8, 15.0, 14.0 cm for very late sown crop in PBW-723, HD-3086, HD-2967, respectively. Maximum spike length was found in HD-3086 followed by HD-2967 and PBW-723. Percentage reduction was more in PBW-723 cultivars in all sowing conditions. This was due to higher temperature during reproductive stage reduced biomass yield as well as spike length (Table 1).

Grain number per spike was 28, 30.3, 29.3 in timely sown crop, 25, 29, 28 in late sown conditions and 23, 26.3, 26 in very late sown conditions in PBW-723, HD-3086 and HD-2967, respectively. Percent reduction in number of seeds per spike as compared to the timely sown crop in late sown crop was 10.7, 4.5 and 4.6% and in very late sown crop was 17.9, 13.2 and 11.4% in PBW-723, HD-3086 and HD-2967, respectively. Percentage reduction was more in PBW-723 cultivars. HD-3086 had the maximum number of seeds per spike followed by HD-2967 and PBW-723 (Table 1).

Thousand seed weights were 59.3, 63, 61.3 g in timely sown crop, 54, 58.3, 56 in late sown conditions and 50.7, 56, 54 in very late sown conditions in PBW-723, HD-3086 and HD-2967, respectively. Thousand seed weight was found maximum in HD-3086, while percentage reduction was more in PBW-723 cultivars (Table 1).

The grain yields were 4750, 5250, 4943 kg/ha for timely sown crop, 4363, 4893, 4590 kg/ha for late sown crop and 4023, 4591, 4223 kg/ha for very late sown crop in PBW-723, HD-3086 and HD-2967,

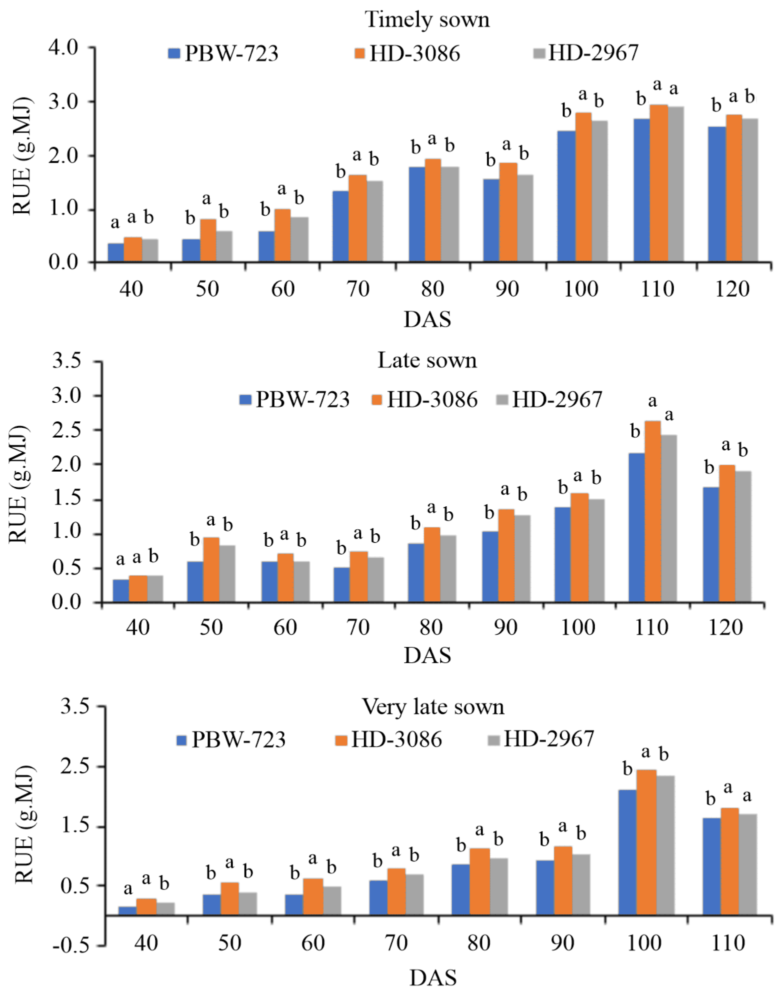

Fig. 5. RUE of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

respectively. The final grain yield production at harvest was significantly reduced in very late sown crop as compared to the timely sown and late sown crop. It was observed that the percent reduction of yield was 8.1, 6.3 and 7.1% in PBW-723, HD-3086, and HD-2967 under late sown crop compared to the timely sown crop. Maximum yield reduction occurred in PBW-723 under all sowing conditions followed by HD-2967 and HD-3086, this may be due to the higher temperature reduced total growing period in very late sown crops. Percent reduction in yield in the very late sown crop as compared to the timely sown crop was 15.3, 12.1 and 14.6% in PBW-723, HD-3086 and HD-2967, respectively (Table 1). The yield attributes and yield of wheat significantly decreased in late sown crop. Similar reduction in seed yield due to delay of week or fortnight from the normal sowing was reported in mustard and wheat crop (Vashisth *et al*., 2011, 2020, 2022)

Multistage wheat yield estimation using biophysical parameters

Model equation for yield estimation is shown in Table 2. These equations are used for estimating crop yield at flowering and at grain filling stage during *Rabi* 2018-19.

Results showed that the dominant variables for yield estimation at flowering stage were biomass at 80 days after sowing and plant height at 90 days after sowing. The percentage deviation of estimated yield done at flowering stage by observed yield was -1.95, -3.27 and 2.3%, respectively for timely, late and very late sown crop. Dominant factors for crop yield

Table 1. Yield attributes of different wheat varieties during *Rabi* 2018-2019 under different sowing conditions

Varieties	Spike length (cm)	No of grain/ spike	1000 seed weight (g)	Grain yield (kg/ha)
		Date of sowing		
Timely sown (D1)	14.9	29.0	55.7	4937.7[A]
Late sown (D2)	15.3	25.5	56.5	4585.5[B]
Very late sown (D3)	14.7	26.0	58.8	4248.8[C]
LSD at 5%	NS	NS	NS	335.1
CV%	11.7	8.2	6.4	5.56
		Cultivars		
PBW-723 (V1)	14.5	25.3[B]	54.4[B]	4378.8
HD-3086 (V2)	15.5	28.4[A]	59.1[A]	4807.7
HD-2967 (V3)	14.8	27.7[A]	57.5[AB]	4585.5
LSD at 5%	NS	1.2	3.5	NS
CV%	7.2	4.31	6.10	7.97
		Date of sowing * varieties		
D1 V1	15.2	28.0[C]	59.3	4750.0[B]
D1V2	16.0	32.0[A]	63.0	5220.0[A]
D1V3	15.8	29.0[B]	61.3	4943.3[B]
D2 V1	14.6	25.0[E]	54.0	4363.3[D]
D2V2	15.7	29.0[B]	58.3	4893.3[B]
D2V3	14.9	28.0[C]	56.0	4590.0[C]
D3 V1	13.8	23.0[G]	50.7	4023.3[E]
D3V2	15.0	26.0[D]	56.0	4591.0[C]
D3V3	14.6	24.0[F]	54.0	4223.3[D]
p-Value	0.74	0.14	0.86	0.33
LSD at 5%	NS	2.13	NS	198.4

Table 2. Multistage wheat yield estimation using biophysical parameters for ICAR-IARI, New Delhi

Model equation for yield estimation	R^2	RMSE	nRMSE	Observed yield (kg/ha)	Estimated yield (kg/ha)	Percentage deviation (%)
			Wheat yield estimation at flowering stage			
Yield = 3841.064 + 0.074 × Biomass	0.92	268.95	5.85	4937.7	4834.8	-1.95
80 DAS + 4.22 × Plant height 90 DAS				4585.5	4430.8	-3.27
				4248.8	4338.2	2.30
			Wheat yield estimation at grain filling stage			
Yield = 3750.53 + 0.06 × Biomass	0.88	368.07	8.01	4937.7	4808.5	-2.49
80 DAS + 0.043 × Biomass 100 DAS				4585.5	4320.7	-5.68
				4248.8	4178.8	-1.47

estimation at grain filling stage were biomass at 80 and 100 days after sowing. The percentage deviation of estimated yield done at grain filling stage by observed yield was -2.49, -5.68 and -1.47%, respectively for timely, late and very late sown crop.

In our studies, model was developed using different biophysical parameters for estimating wheat yield at flowering and grain filling stage and it was found that percentage deviation of estimated yield by observed yield was less than 10%. Sisodia and Rai (2017) developed a model based on biometrical characters of wheat by applying principal component analysis. These models provided forecast yield values very close to the actual yield in both normal and late sowing condition. He proposed that model can be used to obtain reliable pre-harvest forecast of wheat yield in both the situations if the proper measurements on biometrical characters under consideration are available. Jain *et al*. (1980, 1984, 1992b) have developed statistical models for forecasting crop yield based on biometrical characters using experimental and survey data in different regions of the country.

Conclusions

Delay in sowing resulted significant decrease in the value of all biophysical parameters and shortening of length of crop growing period. IPAR and grain yield was higher in timely sown crop followed by late and very late sown crop in all three varieties. HD-3086 had higher growth parameters, seed yield followed by HD-2967 and PBW-723. Most influencing biophysical parameters for yield estimation at flowering stage was biomass at 80 days after sowing and plant height at 90 days after sowing and for grain filling stage was biomass at 80 and 100 days after sowing. Model developed using different biophysical parameters for estimating wheat yield at flowering and grain filling stage had percentage deviation less than 5.7%.

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