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Calibration and Performance Evaluation of the APSIM-Wheat Model in Foot Hills of Western Himalayas

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ABSTRACT

The APSIM-Wheat model was calibrated and validated for the Western Himalayan foothills using field data from wheat varieties HD-2967 and PBW-502 under varied sowing dates (15th November, 25th November, and 5th December) and irrigation levels (three, four, and five irrigations). Calibration involved adjusting phenological, genetic, radiation, and water-use parameters to align simulated outputs with observed data from 2017-18. Key phenological stages like emergence, anthesis, and maturity showed close agreement, with RMSE values ranging from 2.02 to 9.03 days and percentage RMSE from 2.99% to 31.97%. For biological and grain yields, the model slightly overestimated values with RMSEs of 3.50 to 5.34 q/ha. Validation using 2018-19 data confirmed the model's reliability, as it accurately simulated crop performance with acceptable RMSEs. These results demonstrate the model's potential for simulating wheat growth and yield under different management practices.

Keywords: APSIM-Wheat, Calibration, Validation, Wheat, Sowing date & Simulation

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INTRODUCTION

Wheat is the world's second most significant cereal crop, thriving across a wide range of latitudes. It grows optimally in regions with moderate temperatures and sub-humid to semi-arid climates, tolerating both low and moderately high temperatures. The crop is cultivated near the equator and extends to latitudes of 60°N and 40°S. A model is a mathematical representation, typically involving equations, that simulates the behaviour of a system (Graves *et al.,* 2002). Crop simulation models are critical for bridging the agronomical-information in to mathematical form. Because of the mathematical and conceptual relationship that regulates plant growth, simulation was made possible with these crop models. Crop simulation models describe how crops interact with their surroundings in a multiple way. As a result, we can measure the impact of elements of climate and soil on crop growth and sustainability (Timsina *et al.*, 2008 and Kumar *et al*., 2014). For such researches, models are applied after calibration and validation under local conditions.

Crop modelling, which expresses the response of crops to meteorological, edaphic and biological conditions, aids in the creation of innovative crop management strategies and agricultural sustainability in a continually changing climate (Martina *et al.,* 2014). Crop simulation models based on physiology have been effectively employed for crop yield forecasting at the field level to better understand complicated biophysical systems (Holzworth *et al.*, 2011 and Nain *et al.*, 2004). Various models have been created with the primary goal of understanding yield gaps and optimizing yield potential. These include APES (Donatelli *et al.*, 2002), CERES (Ritchie *et al.*, 1998), DAISY (Sayre *et al.*, 1997), DSSAT (Bassu *et al.,* 2009), CropSyst (Rosenzweig and Parry, 1994; Willmott *et al*., 1985), CROPGRO (Godwin and Singh, 1998), SPASS (Wang and Engel, 2002), HERMES (Asseng *et al.*, 2014), SWAP (Chen *et al.*, 2010; Eitzinger *et al.*, 2004; Ma *et al.*, 2015), SOYGRO (Monsi and Saeki, 2005) and WOFOST (Eitzinger *et al.,* 2004). The APSIM wheat crop growth simulation model has been proven effectively under a variety of environmental circumstances (Ahmed *et al.,* 2011). Crop simulation models are site and crop specific until and unless validated under local conditions therefore should not be applied in other regions without performing calibration and validation. APSIM (Agricultural Production Systems Simulator) is software that simulates agricultural systems by connecting various sub-models (or modules) (McCown *et al.*, 1996). APSIM's classification system categorises numerous modules as Plant, Environment and Management. It simulates crop growth, soil processes and a variety of crop management options beginning from the sowing of the crop. The APSIM-

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Wheat module employs daily time steps and area-based simulations to better understand wheat crop progress (per square meter, not single plant). The APSIM-Wheat module necessitates inputs related to weather, soil properties, crop characteristics, and management practices. (Mohanty *et al.,* 2012). In this module, wheat growth and development are affected by climate, soil moisture, and nitrogen availability. Daily interactions occur with the Soilwat (soil water) and SoilN (soil nitrogen) modules, where the module provides updates on its water and nitrogen uptake (Zhao *et al.,*2014). The Soilwat module receives crop cover data to evaluate evaporation rates and runoff. At harvest, wheat stover and root residues are incorporated into the Residue and SoilN surface modules. In APSIM, soil water content is assessed daily, with various other processes calculated sequentially. The SoilN module describes the dynamics of carbon and nitrogen in the soil, while the APSIM Met module supplies daily weather data to all components within an APSIM simulation (Keating *et al.,* 2003). Keeping the above facts in mind, the current study has been designed to utilize the APSIM-Wheat crop simulation model, calibrated and validated under local conditions, to assess the effects of climate, soil, and management practices on wheat growth and development, with the aim of optimizing crop yield and promoting agricultural sustainability.

Table 1: Experimental details

S. No.	Component	Symbols
A	Season of experiment	*Rabi*, 2017-18 & 2018-19
B	Crop	Wheat
C	**Date of sowing**	
1	D_1	15th November
2	D_2	25th November
3	D_3	5th December
D	**Variety**	
1	V_1	HD-2967
2	V_2	PBW-502
E	**No. of Irrigation**	
1	I_1	5 Irrigation (at CRI, Tillering, Booting, Flowering and Milking Stage)
2	I_2	4 Irrigation (at CRI, Tillering, Flowering and Milking Stage)
3	I_3	3 Irrigation (at CRI, tillering and Flowering Stage)
F	**Details of layout**	
1	Design	Factorial RBD
2	Variety	2
3	Date of sowing	3
4	No. of Irrigation	3 levels
5	Treatment combination	18
6	Total no of plots	54
7	Spacing	20cm (R × R)
8	Plot size	5m × 4m

MATERIALS AND METHODS

Field experiments for the wheat crop were conducted in the C6 block of the Norman E. Borlaug Crop Research Center at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, in the Udham Singh Nagar district of Uttarakhand, during the rabi seasons of 2017-18 and 2018-19. The site is located in the Tarai region, at the base of the Himalayan Shivalik range, with coordinates 29°00'N latitude, 79°28'E longitude, and an elevation of 244 meters above sea level. The experiment included three sowing dates (15th November, 25th November, and 5th December) and three irrigation levels (three, four, and five irrigations). Daily meteorological data, such as minimum and maximum temperatures, sunshine hours, relative humidity, rainfall, and pan evaporation, were obtained from the agro-meteorological observatory at the research center.

The soil of experiment site was described under the Mollisol order, sub-order udoll with great group hapludoll and soil series Haldi (Deshpande *et al*. 1971) developed from calcareous parent material having moderate to course soil texture under predominance effect of long grasses in poorly to well drained condition. Generally, these soils are originated from alluvial sediments. A soil sample was taken from a depth

Table 2: Physio-chemical properties of the soil of experimental field

Characters	Soil depth (cm)				
	0-15	15-30	30-60	60-90	90-120
Sand (%)	60.6	62.6	63.6	66.3	67.4
Silt (%)	21.2	20.8	20.2	18.4	18
Clay (%)	18.2	16.6	16.2	15.3	14.6
pH	6.4	6.8	7.4	7.1	7.5
SCEC (meq+/100g)	18.8	17.9	17.4	17.4	17.1
SOC (%)	0.46	0.38	0.33	0.3	0.28
BD (gcm^{-3}	1.51	1.47	1.47	1.46	1.44
SAT (cm^3cm^{-3})	0.41	0.42	0.42	0.42	0.44
LL (cm^3cm^{-3})	0.12	0.11	0.1	0.1	0.1
DUL (cm^3cm^{-3})	0.25	0.26	0.23	0.22	0.22

SCEC-soil cation exchange capacity; SOC-soil organic carbon; SOC-soil organic carbon; BD-bulk density; SAT-saturation, LL-lower limit; DUL-soil drained upper limit.

of 15 cm for analysis of its physio-chemical properties. The composite soil samples were taken from the experimental site to a depth of 25 cm for gravimetrically determining the moisture percent.

RESULTS AND DISCUSSION

Calibration of the APSIM-Wheat

Calibration is the process of standardizing the input parameters of a model until the simulated output matches the observed set of data. Calibration is an elementary aspect of verification. It is necessary for the determination, checking or rectifying of the graduation of model giving quantitative measurements. Model parameters related to phenology, genetics, radiation and water use adjusted during calibration. The parameter values were adjusted systematically based on their practical range, literature values, recommended conservative estimates, and local conditions, such as crop characteristics, duration, soil, and climate. The simulation was executed after preparing input data files that included meteorological data, precipitation, evaporation, irrigation, and information on plant and soil conditions for the 2017-18 growing season. The calibrated parameters for crop growth, phenology, and other management aspects are presented in Table 3. The APSIM -wheat model was calibrated using the experimental field dataset of 2017-18 for two wheat cultivars, HD-2967 and PBW-502 for three sowing dates (November 15th, November 25th and December 5th) and three irrigation levels (number of irrigations three, four and five).

Anthesis

The comparison between observed and simulated values for the days to anthesis across different sowing dates (15th November, 25th November, and 5th December) during the rabi season of 2017-18, as well as varying irrigation levels (three, four, and five irrigations), is shown in Table 4 and illustrated through bar diagrams in Fig. 1 and 2.

It can be seen from the data, days taken to anthesis ranged between 77 to 85 for observed and 81 to 87 for simulated data for wheat variety HD-2967. Among dates of sowing and different level of irrigation, the simulated data for attaining anthesis stage showed close agreement with the observed values (RMSE = 4.24%).For wheat variety PBW-502, observed data showed that days taken to anthesis ranged 78 to 87 and 81 to 90 for observed and simulated results respectively. For all the dates of sowing and level of irrigation crop growth model overestimated the days taken to anthesis. The simulated days for attaining anthesis stage was close to the observed data (percent RMSE =4.78%) and represented in Table 4. Mohanty *et al*. (2012) also found a close agreement between observed and predicted days to achieve anthesis. Zhao *et al*. (2014) has

Table 3: Parameterization of crop genotype used in the model for wheat cultivar HD-2967 and PBW-502 using APSIM model

Parameters or variables	Acronym	Value		Units
	Name	HD-2967	PBW-50	
Phenology				
Emergence: end of juvenile	TT_EMERG_TO_ENDJUV	890	892	^{0}C days
End of juvenile: floral initiation	TO_ENDJUV_TT_INTI	54	54	^{0}C days
Floral initiation: flowering	TT_INTI_TT_START_GRAIN	460	468	^{0}C days
Flowering: start grain filling	TT _START_END_GRAIN	150	155	^{0}C days
Start grain filling: end grain	TT _START_TO_END_GRAIN	385	390	^{0}C days
End grain: maturity	TT _END_GRAIN_TO_MATURITY	50	52	^{0}C days
Maturity: harvest ripe	TT _ MATURITY_TO_RIPE	1	1.2	^{0}C days
Genetic				
Potential grain growth rate during grain filling	POTENIAL_GRAIN_FILLING_RATE	0.002	0.001	g grain^{-1}day^{-1}
Potential grain growth flowering to grain filling	POTENIAL_GRAIN_GROWTH_RATE	0.001	0.001	g grain^{-1}day^{-1}
Leaf development	PHYLLOCRON	105	98	
Vernalization sensitivity	VERN_SENS	1.85	1.45	
Photoperiod sensitivity	PHOTO_SENS	3.0	2.3	
Radiation and water use				
Radiation use efficiency	RUE	1.28	1.16	g MJ^{-1}day^{-1}
Transpiration use efficiency coefficient	TRANSP_EFF_CF	0.007	0.007	kPa
Wheat water lower limit	LL	0.2	0.2	m^{3}m^{-3}
Rate of soil water extraction	KL	0.08	0.08	

Table 4: Comparison between observed and simulated values to anthesis (DAS) for HD-2967 and PBW-502

Dates of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	85	87	83	81	79	77	87	90	85	82	81	82
25-Nov	82	80	81	82	78	82	85	83	83	80	79	77
05 –Dec	80	83	79	77	77	81	83	85	81	82	78	81
RMSE (days)	3.78						4.51					
% RMSE	4.24						4.78					

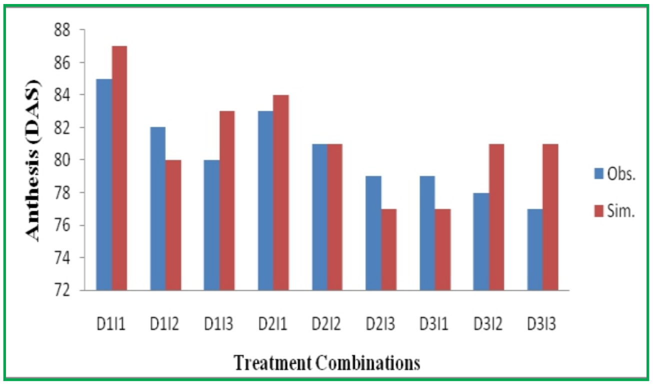

Fig. 1: Comparison between observed and simulated values to anthesis (DAS) for HD-2967 variety

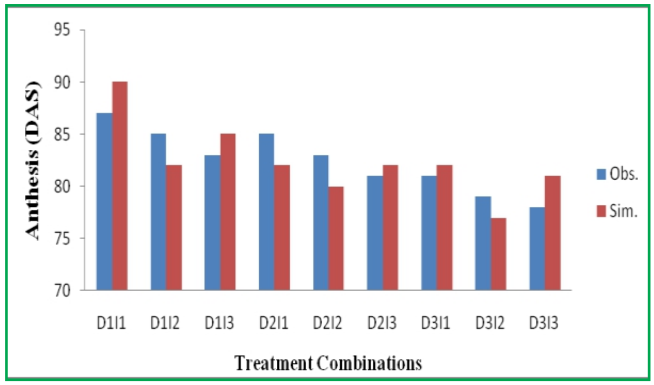

Fig. 2: Comparison between observed and simulated values to anthesis (DAS) for PBW-502 variety

also observed close agreement between observed and simulated anthesis date for different dates of sowing and irrigation levels. Ahmed *et al*. (2016) also found the good agreement between simulated and observed for anthesis.

Physiological maturity

The comparison of observed and simulated days to physiological maturity for HD-2967 and PBW-502 varieties, across different sowing dates (15th November, 25th November, and 5th December) and varying irrigation levels (three, four, and five irrigations), is presented as follows.

Critical analysis of the data reveals, days taken to attain physiological maturity ranged between 127 to 138 days and 129 to 144 days for observed and simulated scenarios, respectively for HD-2967 variety. RMSE and percent RMSE were found to be 5.89 and 6.35% respectively.

Table 5: Comparison between observed and simulated values to physiological maturity for HD-2967 and PBW-502

Dates of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	138	144	135	135	132	133	139	145	136	139	133	133
25-Nov	135	135	133	134	129	126	136	139	133	133	130	132
05 –Dec	132	133	130	127	127	129	134	131	131	132	128	130
RMSE (days)	5.89						5.02					
% RMSE	6.35						5.92					

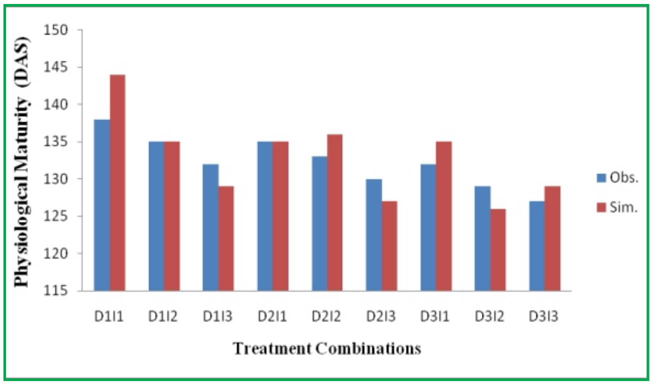

Fig. 3: Comparison between observed and simulated values to physiological maturity for HD-2967 variety

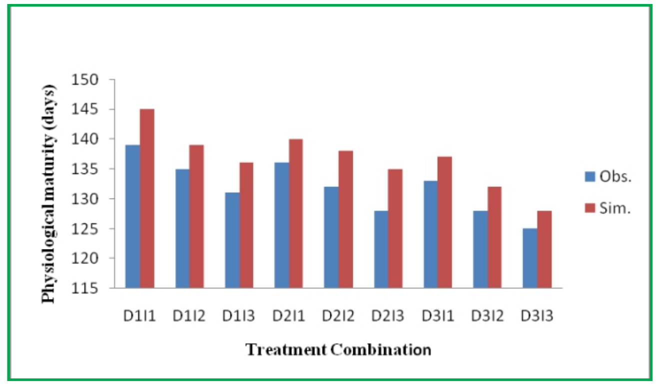

Fig. 4: Comparison between observed and simulated values to physiological maturity for PBW-502 variety

Comparison between observed and simulated values for physiological maturity at different dates of sowing and different levels of irrigation for variety PBW-502 has been presented in Table 5. A close inspection of the values indicated thatday taken to attain physiological maturity ranged 128 to 139 days for observed and 130 to 145 days for simulated data respectively. For all the treatments of sowing dates and levels of irrigation, the simulated values for attaining physiological maturity stage were near to the observed data (RMSE=5.02 and percent RMSE =5.92%). It indicates a good agreement between simulated and observed values for days required for physiological maturity. Number of days required to attain physiological maturity was decreased as sowings of the crop delayed **Ahmed *et al*. (2011).**

Biological yield

The comparison of observed and simulated biological yield for HD-2967 and PBW-502 varieties, across different sowing dates (15th November, 25th November, and 5th December) and varying irrigation levels (three, four, and five irrigations), is as follows.

Table 6: Comparison between observed and simulated values of biological yield for HD-2967 and PBW-502

Date of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Five Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	116.75	119.02	109.92	113.05	97.32	104.54	109.30	113.65	106.24	107.06	94.74	97.05
25-Nov	111.42	116.75	105.74	109.67	93.01	97.20	105.20	108.64	101.65	103.45	90.83	93.72
05 –Dec	101.56	110.42	95.09	97.32	84.92	88.92	95.72	98.72	90.80	104.62	82.72	84.15
RMSE (q/ha)	5.34						4.93					
% RMSE	5.25						5.06					

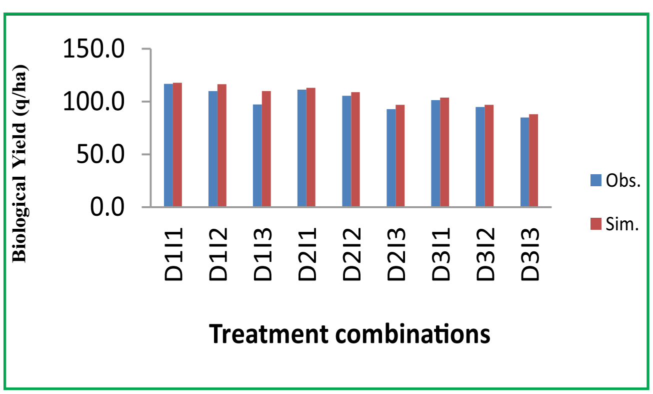

Fig. 5: Observed and simulated values of biological yield for HD-2967

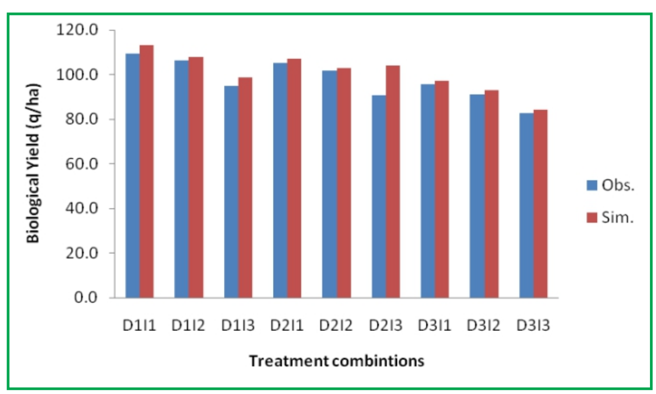

Fig. 6: Observed and simulated values of biological yield for PBW-502

The observed and simulated biological yield data have been presented in Table 6 and plotted in Fig. 5 depicted that biological yield in case of wheat variety HD-2967, ranged between 84.92 q/ha to 116.75 q/ha for observed data while, crop simulation model reported 88.92 q/ha to 119.02 q/ha biological yield. The model overestimated biological yield for all three date of sowing and three irrigation levels. RMSE and percent RMSE were found to be 5.34 and 5.25% respectively.In case of wheat variety PBW-502, observed and predicted data have been presented in Table 7 and plotted in Fig. 8 depicted that biological yield ranged between 82.72 q/ha to 109.30 q/ha for observed values while, crop simulated model reported 84.15 q/ha to 113.65 q/ha biological yield. The model overestimated biological yield for all the treatments of date of sowing and irrigation level. RMSE was found to be 4.93 (5.06%).

Grain Yield

The data pertaining to simulated and observed wheat yield during different dates of sowing (15th November, 25th November and 05thDecember) and different levels of irrigation (no. of irrigation 3, 4 and 5) for HD-2967 and PBW-502 varieties is presented in the Table 8.

Table 7: Comparison between observed and simulated values of grain yield (q/ha) for HD-2967 and PBW-502

Date of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Five Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	52.32	57.06	50.31	53.32	42.64	45.92	49.09	54.42	47.13	50.47	39.21	42.08
25-Nov	49.81	55.620	48.63	53.15	40.76	44.44	47.17	52.22	46.42	49.68	37.42	39.42
05 –Dec	45.40	52.4	43.04	43.67	35.66	40.65	42.09	48.28	40.44	43.42	32.84	34.64
RMSE (q/ha)	3.48						3.03					
% RMSE	3.18						3.66					

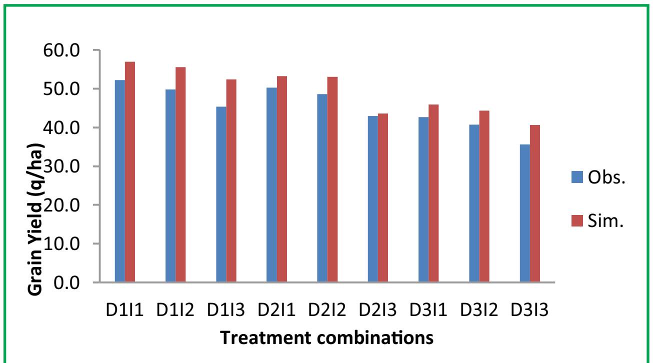

Fig. 7: Observed and simulated values of grain yield for HD-2967 variety

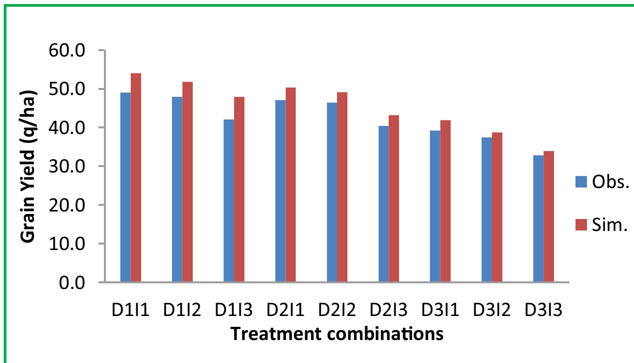

Fig. 8: Observed and simulated values of grain yield for PBW-502 variety

The grain yield ranged from 35.66 q/ha to 52.30 q/ha and 40.65 q/ha to 57.06 q/ha for observed and simulated data respectively for HD-2967 variety. RMSE was found to be 3.48 q/ha and percent RMSE calculated 3.18%. Comparison between observed and simulated values for grain yield has been depicted in Table 7 and shown through bar diagram in Fig. 7. In case of wheat variety PBW-502, grain yield ranged between 32.84 q/ha to 49.09 q/ha for observed dataset and 34.64 q/ha to 54.42 q/ha for simulated values, respectively. The value of RMSE was found to be 3.03 q/ha and percent RMSE calculated 3.66%. It indicates that model can simulate grain yield with acceptable accuracy. Comparison between observed and simulated values for grain yield (q/ha) at different dates of sowing and different levels of irrigation for PBW-502 variety has been mentioned in Table 7 and plotted in Fig. 8.

Validation of APSIM-Wheat model

Model validation involves comparing simulated values with observed data to assess its accuracy. If the simulated values fall within the predicted confidence interval, the model is considered valid. Validation serves as an evaluation of the model's practical utility. In this case, the APSIM-Wheat model was validated using field data from the 2018-19 season. This process ensures that the calibrated model accurately reflects real-world conditions by comparing the simulated results with observed data not used during calibration. Ideally, mechanistic models should be validated both for overall system outputs and for individual internal components and processes. While internal feedback loops can compensate for errors, validating all components is often not feasible due to the lack of detailed datasets, so only the key components are validated.

Comparison between observed and simulated values
1. Anthesis

Table 8: Comparison between observed and simulated values to anthesis (DAS) for HD-2967 and PBW-502

Dates of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	85	90	83	87	81	84	86	88	84	81	81	78
25-Nov	83	80	81	84	78	78	84	81	82	84	79	79
05 –Dec	81	84	79	79	76	80	82	84	80	82	77	77
RMSE (days)	5.77						4.14					
% RMSE	6.21						5.67					

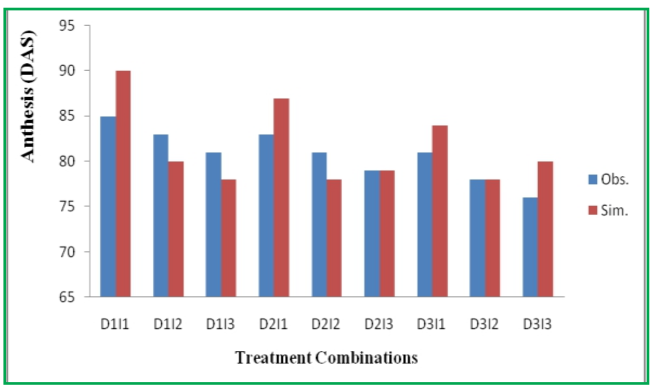

Fig. 9: Comparison between observed and simulated values to anthesis (DAS) for HD-2967 variety

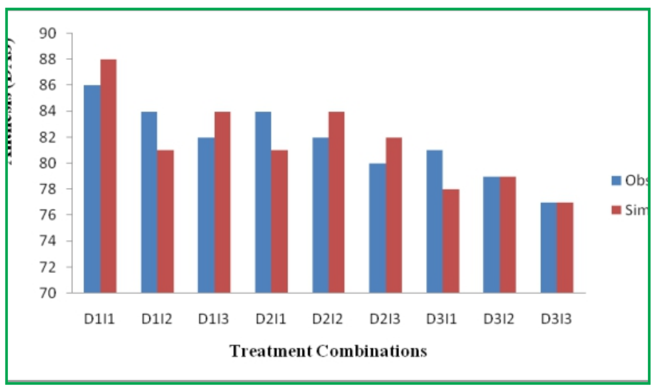

Fig. 10: Comparison between observed and simulated values to anthesis (DAS) for PBW-502 variety

The comparison of observed and simulated values to anthesis for different sowing dates (15th November, 25th November and 5th December) during *rabi* season of 2018-19 and different levels of irrigations (number of irrigations five, four and three) has been presented in Table 8 and depicted through bar diagram in Fig. 9. It can be seen from the data that days taken to anthesis ranged 76 to 85 for observed and 80 to 90 for simulated data for wheat cultivar HD-2967. For all the treatments of sowing dates and irrigation levels model overestimated the days taken to anthesis. RMSE and percent RMSE were found to be 5.77 and 6.21 respectively.For wheat variety PBW-502, observed data depicted that days taken to anthesis ranged 77 to 86 and 77 to 88 for observed and simulated data respectively. For the treatments of the dates of sowing and levels of irrigation, the simulated days for attaining anthesis stage was close to the observed data (RMSE =4.14 and percent RMSE=5.67%) have been presented in Table 8 and plotted in Fig.10. Carberry *et al.* (2009) also discovered a high degree of agreement between observed and predicted days to anthesis

Physiological maturity

Comparison between observed and simulated values for physiological maturity at different dates of sowing and different levels of irrigation for variety HD-2967 has been presented in Table 11 and shown through bar diagram in Fig. 15.

Table 9: Comparison between observed and simulated values to physiological maturity for HD-2967 and PBW-502

Date of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	137	142	135	138	132	134	138	143	136	139	133	131
25-Nov	133	130	131	131	129	132	135	138	132	132	130	134
05 –Dec	131	131	129	132	126	129	132	132	130	134	128	130
RMSE (days)	4.82						5.68					
% RMSE	5.13						5.82					

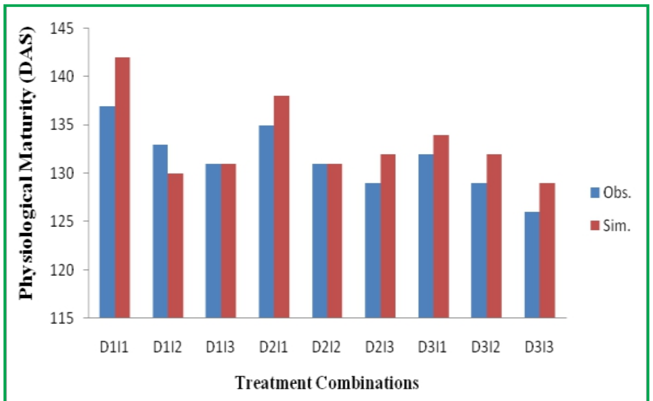

Fig. 11: Comparison between observed and simulated values to physiological maturity for HD-2967 variety

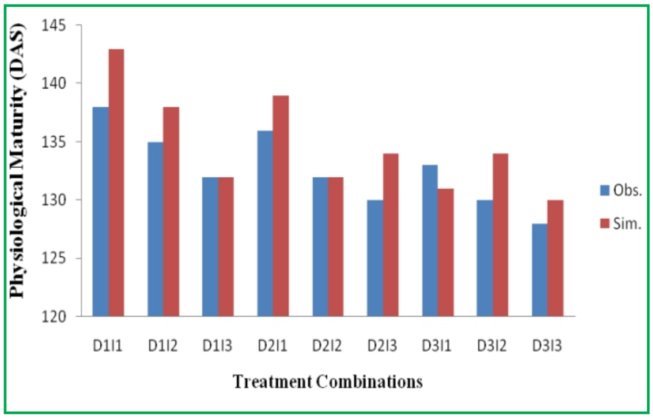

Fig. 12: Comparison between observed and simulated values to physiological maturity for PBW-502 variety

In case of wheat variety PBW-502, observed data were presented in Table 9 and plotted in Fig. 11, which depicted that the day taken to attain physiological maturity ranged from 121 to 137 days for observed data and from 126 to 145 days for simulated wheat data. The simulated times for attaining physiological maturity stage were close to the observed data (RMSE =5.68 and percent RMSE 4.35) for all the treatments of sowing dates and irrigation levels. It represents a high level of

Table 10: Comparison between observed and simulated values of biological yield (q/ha) for HD-2967 and PBW-502.

Date of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	115.52	118.26	107.42	104.24	101.82	103.07	107.72	108.25	104.32	102.06	98.42	99.98
25-Nov	104.25	101.04	102.86	102.18	95.71	95.70	103.41	103.44	102.71	102.24	91.81	92.74
05 –Dec	101.53	98.97	95.17	92.64	87.29	90.52	94.90	97.76	88.80	85.64	86.38	89.67
RMSE (q/ha)	3.14						2.06					
% RMSE	4.87						3.56					

agreement between simulated and observed values for the number of days required for physiological maturity. Data revealed that days taken to attain physiological maturity ranged between 121 to 137 days and 128 to 142 days for observed and simulated values, respectively for HD-2967 variety. RMSE and percent RMSE were found to be 6.10 and 4.69% respectively.

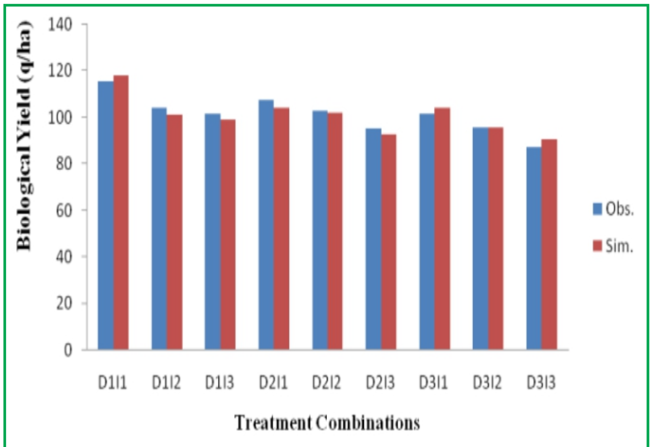

Fig. 13: Observed and simulated values of biological yield (q/ha) for HD-2967

The observed data is represented in Table 10 and plotted in Fig. 13 showed that biological yield for wheat cultivar HD-2967 ranged from 87.29 q/ha to 115.52 q/ha for observed data, while crop simulation model reported 90.52 to 118.26 q/ha. For all the three sowing dates and three irrigation levels, the model overestimated biological yield. The RMSE and percent RMSE were calculated to be 3.14 and 4.87% respectively.For wheat variety PBW-502, observed data presented in Table 10 and plotted in Fig. 14 showed that biological yield ranged from 86.38 q/ha to 107.72 q/ha for observed values, while crop model simulated yield lied between 89.67 q/ha to 108.25 q/ha.

Biological yield

The following Table compares observed and simulated biological yield values for HD-2967 and PBW-502 varieties at different sowing dates (15th November, 25th November and 5th December) and different irrigation levels (number of irrigations five, four and three).

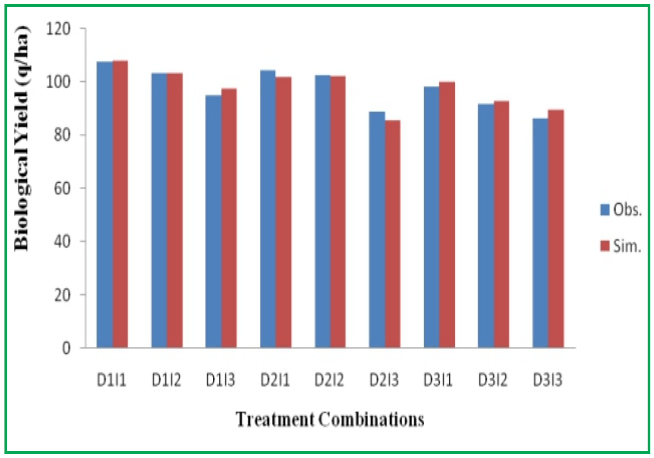

Fig. 14: Observed and simulated values of biological yield (q/ha) for PBW-502 variety

For all the treatments of sowing dates and irrigation levels, the model overestimated the biological yield. The RMSE and percent RMSE were found to be 2.06 and 3.56% respectively.

5. Grain Yield (q/ha)

The data pertaining to simulated and observed wheat yield during different dates of sowing (15th November, 25th November and 5th December) and different levels of irrigation (three, four and five irrigations) for HD-2967 and PBW-502 varieties is as follows.

Table 11: Comparison between observed and simulated values of grain yield (q/ha) for HD-2967 and PBW-502.

Dates of sowing	Irrigation levels (HD-2967)						Irrigation levels (PBW-502)					
	Five Irrigation		Four Irrigation		Three Irrigation		Five Irrigation		Four Irrigation		Three Irrigation	
	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.
15-Nov	52.46	55.42	47.84	52.72	43.55	46.84	47.92	52.42	46.12	52.20	42.72	45.32
25-Nov	48.19	51.31	50.47	54.14	40.36	44.22	46.84	48.81	47.50	50.10	40.57	40.31
05 –Dec	43.64	51.36	42.55	46.36	36.70	38.67	38.67	46.54	36.65	44.44	36.56	36.70
RMSE (q/ha)	5·14						4.06					
% RMSE	4·05						5.54					

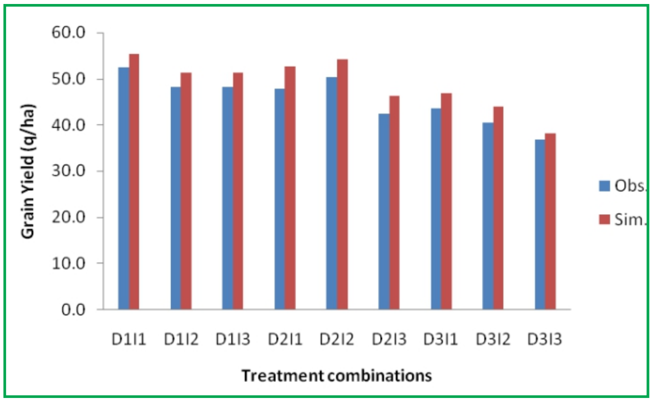

Fig. 15: Observed and simulated values of grain yield (q/ha) for HD-2967 variety

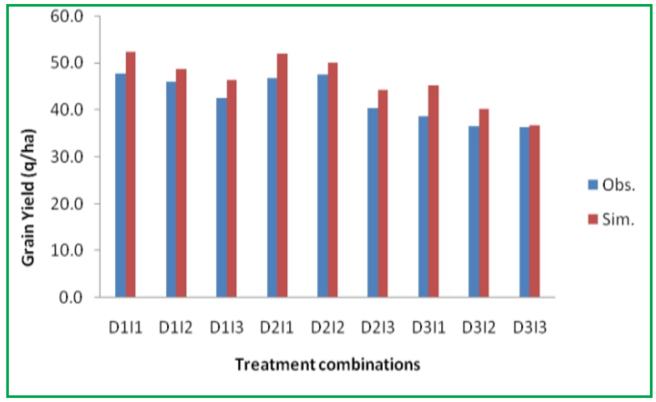

Fig. 16: Observed and simulated values of grain yield (q/ha) for PBW-502 variety

The grain yield of HD-2967 wheat variety ranged from 36.70 q/ha to 52.46 q/ha and 38.67 q/ha to 55.42 q/ha for observed and simulated data, respectively for HD-2967 variety. RMSE and percent RMSE were found to be 5.14 q/ha and 4.05% respectively. Comparison between observed and simulated values for grain yield has been depicted in Table 11 and shown through bar diagram in Fig. 15. In case of wheat variety PBW-502, grain yield ranged 36.70 q/ha to 52.42 q/ha for simulated and 36.56 q/ha to 47.92 q/ha for observed values. The value of RMSE and percent RMSE were found to be 4.06 q/ha and 5.54% respectively. Comparison between observed and simulated values for grain yield (q/ha) at different dates of sowing and different levels of irrigation for PBW-502 variety has been mentioned in Table 11 and plotted in Fig. 16.

CONCLUSION

The calibration and validation of the APSIM-Wheat model were conducted using experimental field data from 2017-18 and 2018-19 for wheat cultivars HD-2967 and PBW-502 under different sowing dates (15^{th} Nov, 25^{th} Nov, and 5^{th} Dec) and irrigation levels (3, 4, and 5 irrigations). Key parameters related to phenology, genetics, radiation, and water use were calibrated. The model underestimated days to emergence but simulated anthesis, physiological maturity, and yields with good accuracy, showing close agreement with observed data. RMSE values for biological yield ranged between 4.93-5.34 q/ha, and for grain yield, 3.50-4.51 q/ha. The percent RMSE for emergence, anthesis, and maturity were within acceptable ranges, demonstrating the model's reliability. APSIM effectively captured phenological stages and yield trends, proving to be a robust tool for wheat crop simulation under varying conditions.

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