Calibration and Validation of CERES-wheat model for wheat (cv. GW-496) in middle Gujarat region

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INTRODUCTION

- Natural resources become scarce in a large segment of agricultural production region, the need for farm managers and regional policy planners to have tools including crop simulation models, to help support their decision-making process becomes more and more critical.
- Crop growth simulation models are quantitative tools based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrological and agronomic factors on crop growth and yield.
- Boote *et al*. (1996) classified the application of crop simulation models into three primary categories: (i) for research knowledge synthesis, (ii) for crop production decision management and (iii) for policy analysis.
- Crop yield simulation modeling in any crop helps to have target oriented approach in achieving regional food security.
- Crop simulation models have been used to determine potential yield of any crop in which possibilities for the yield improvement can be assessed.
- Aggarwal (2000) studied climatically potential grain yield of wheat and yield gaps in India.
- Crop simulation modeling after thorough calibration helps in various agronomic decision in reference to yield improvement such as selection of optimum sowing window coupling with different irrigation regimes.
- Aggarwal and Kalra (1994a) examined the effect of sowing date on yield of wheat in India using WTGROW model.

Materials and methods

- Design: Split plot
- Replication: Four
- Spacing: 22.5 cm
- Fertilizer: 120+60+0 NPK/ha

Experimental details

(1995-96 to 2007-08)

Dates of sowing	Three
D1	1st Nov.
D2	15th Nov.
D3	30th Nov.
Irrigation	Four
I1 (3)	CRI,BT and ML
I2 (4)	CRI,TL,FL and DS
I3 (5)	CRI,TL,BT,FL and ML
I4 (6)	CRI,TL,BT,FL, ML and DS

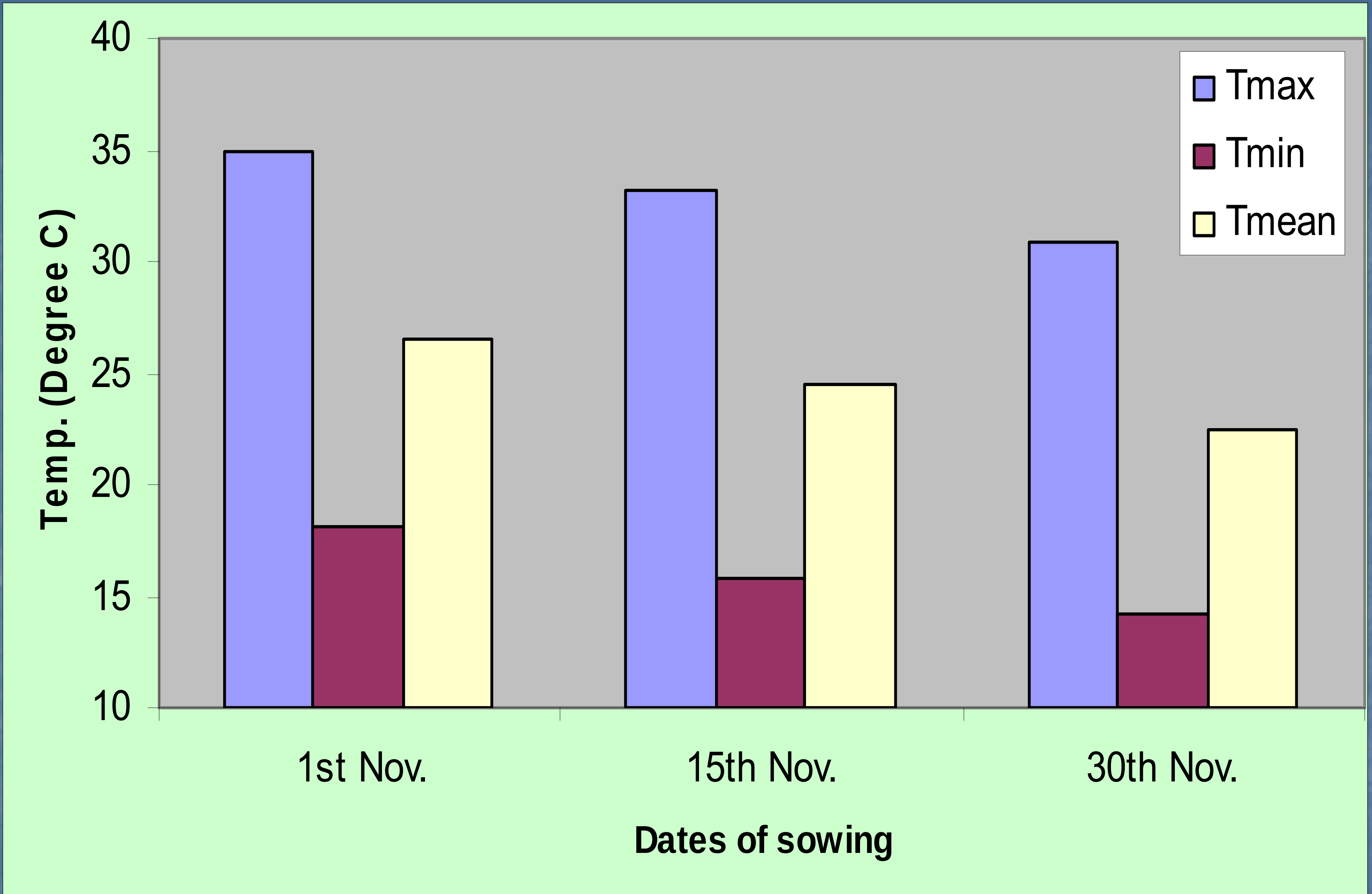


Fig.1: Prevailing mean sowing temperatures in different dates of sowing (Data base: 1995-96 to 2007-08)

Table 2 : Effective temperature range for sowing in different dates of sowing

1st Nov.	
Tmax	35 ± 1.1
Tmin	18.1 ± 1.7
Tmean	26.5 ± 0.9
15th Nov.	
Tmax	33.2 ± 1.2
Tmin	15.8 ± 1.7
Tmean	24.5 ± 1.2
30th Nov.	
Tmax	30.9 ± 1.0
Tmin	14.2 ± 1.8
Tmean	22.5 ± 0.8

Fig. 2: Prevailing mean weather condition in 1st Nov. sowing

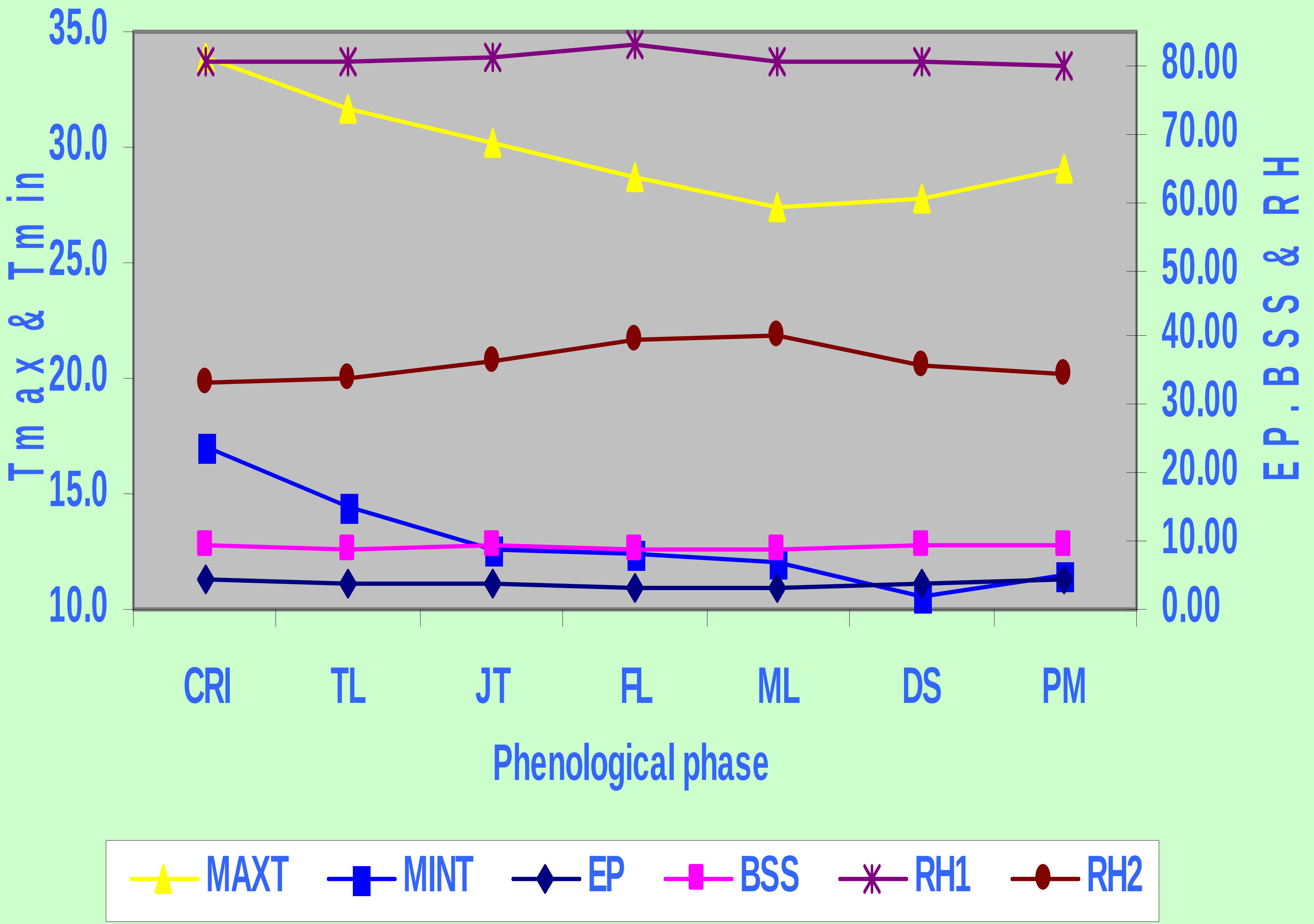


Fig. 3 : Prevailing mean weather condition in 15th Nov.sowing

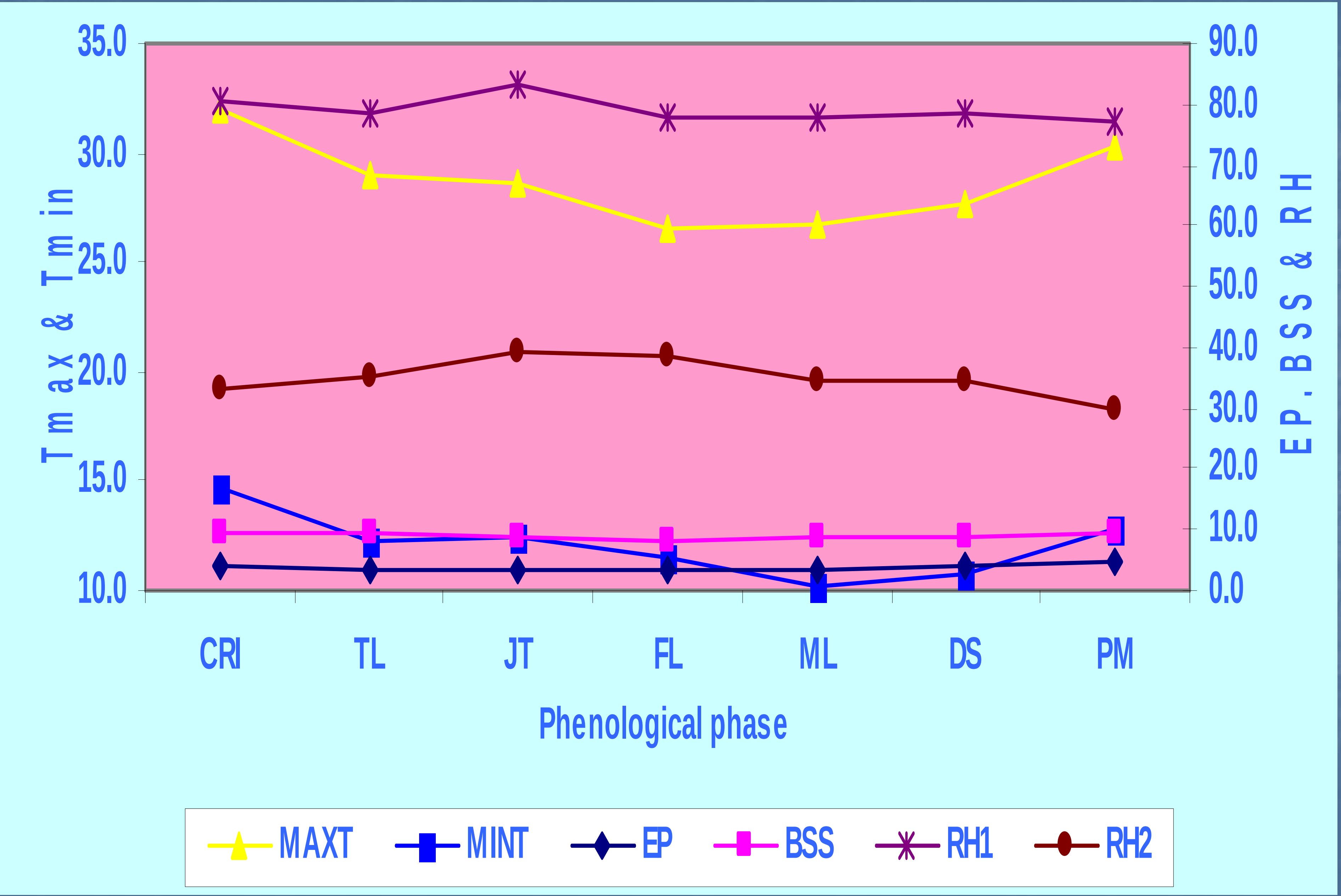
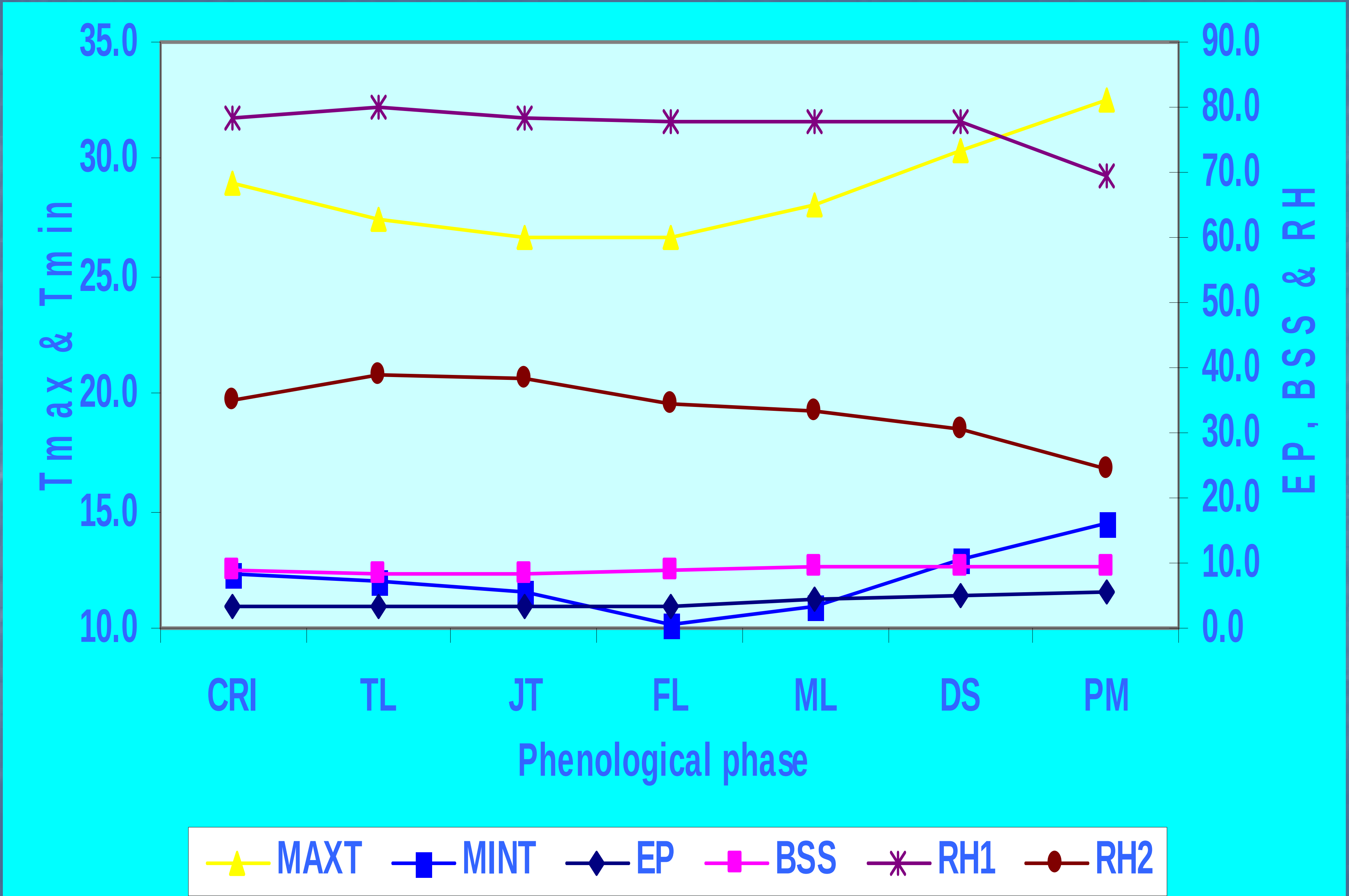


Fig. 4: Prevailing mean weather condition in 30th Nov. sowing



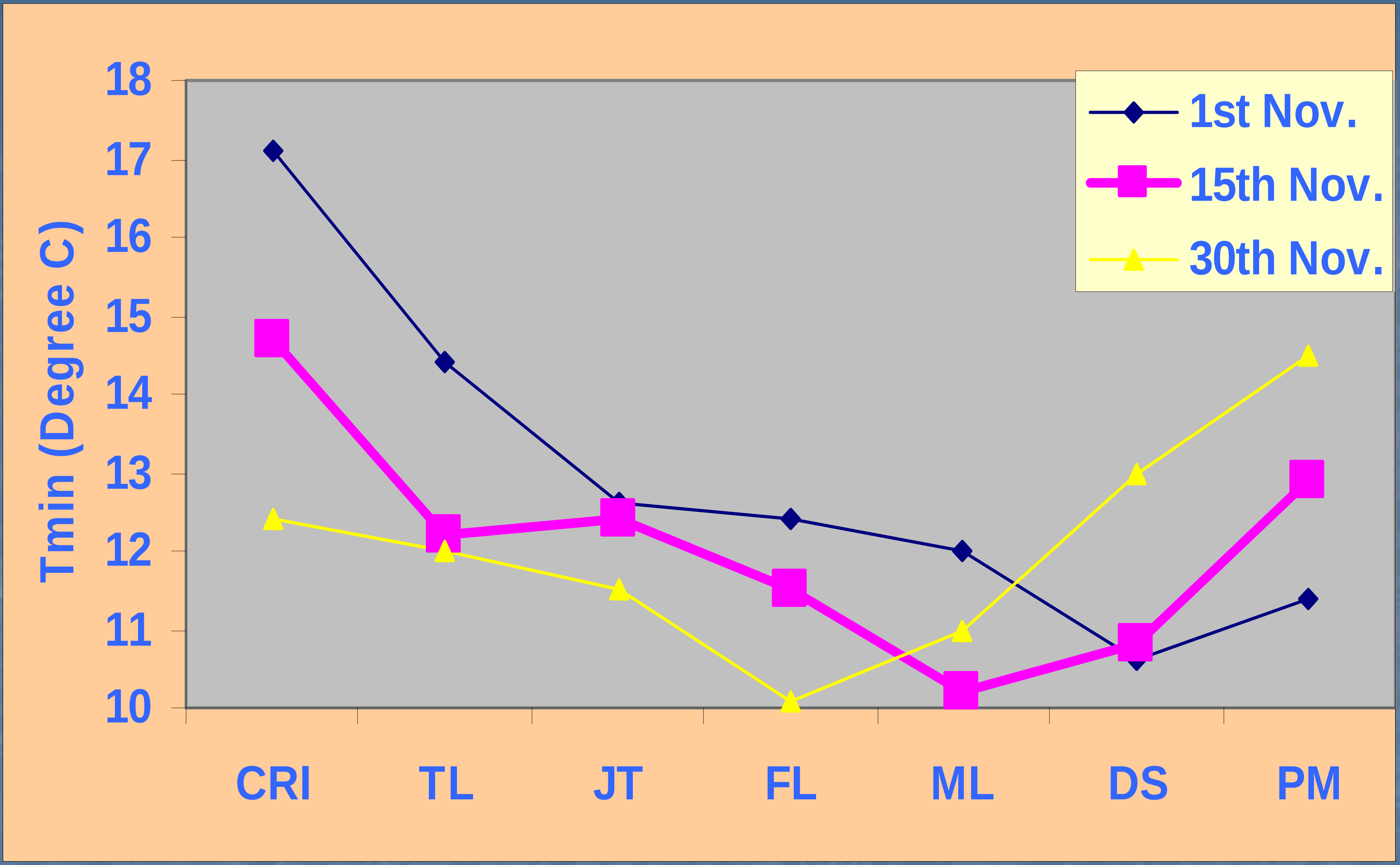


Fig. 5: Prevalence of mean Tmin in different sowing dates

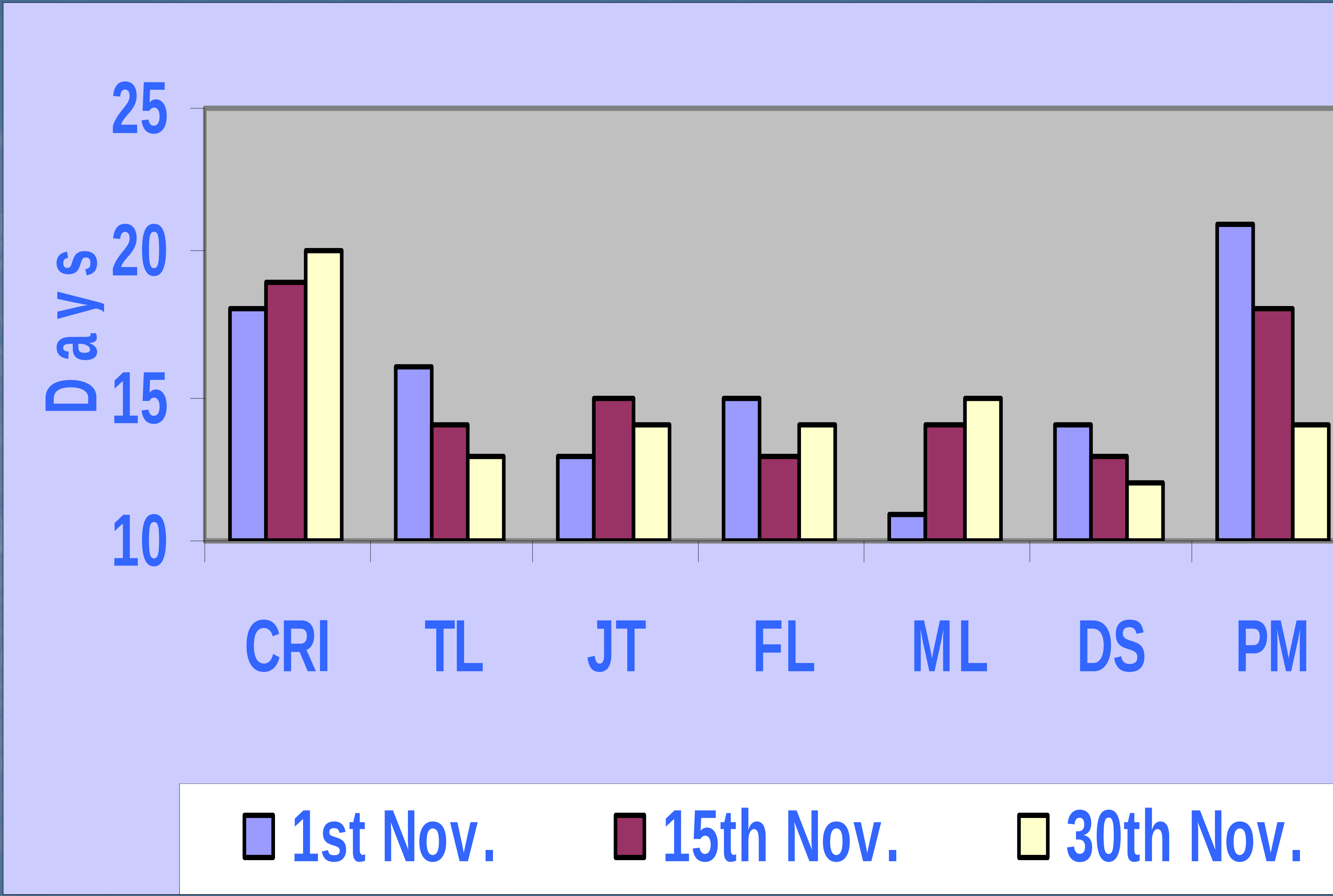


Fig. 6: Normal phenological duration in different sowing dates

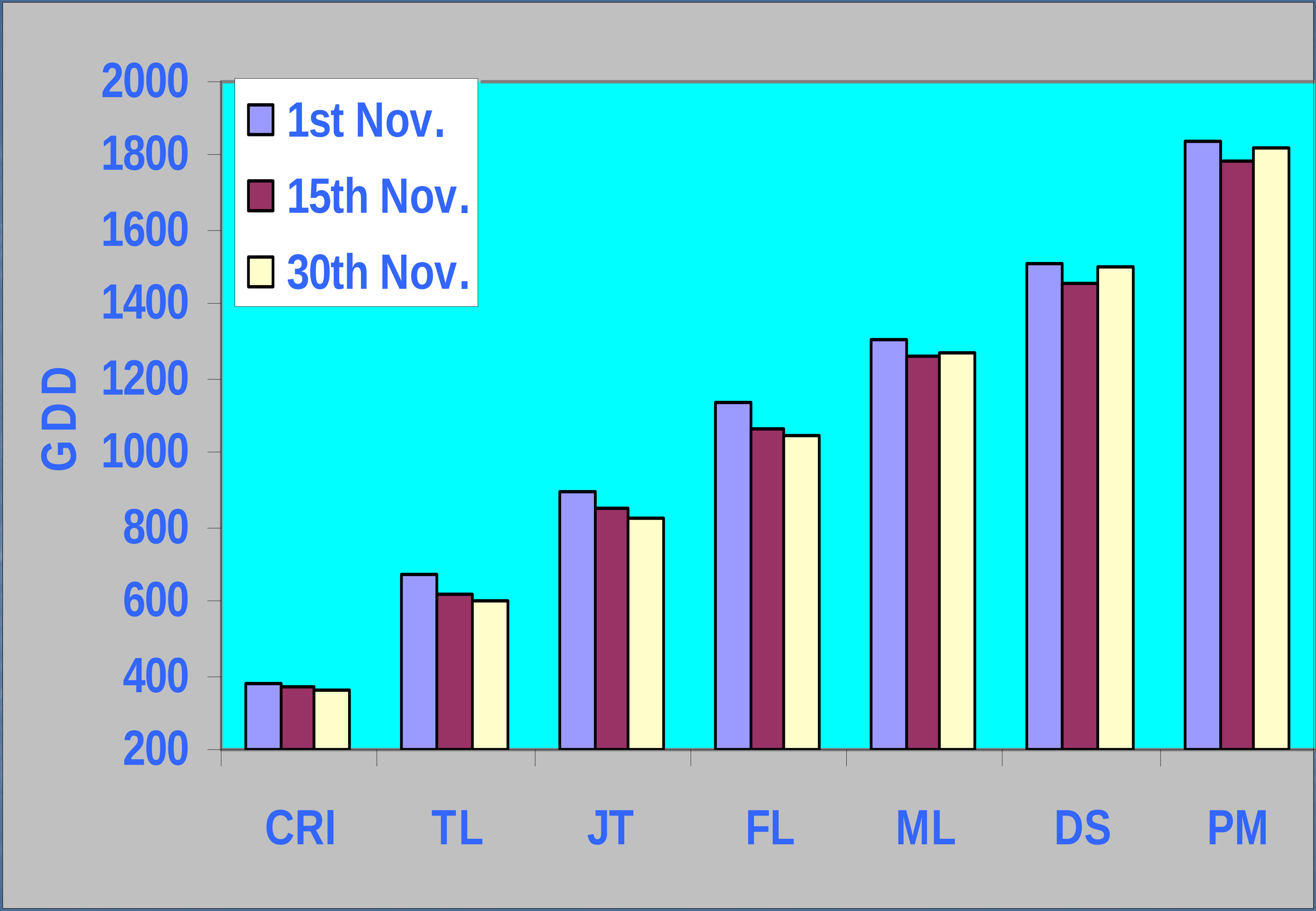


Fig. 7: Mean Acc. GDD in different sowing dates

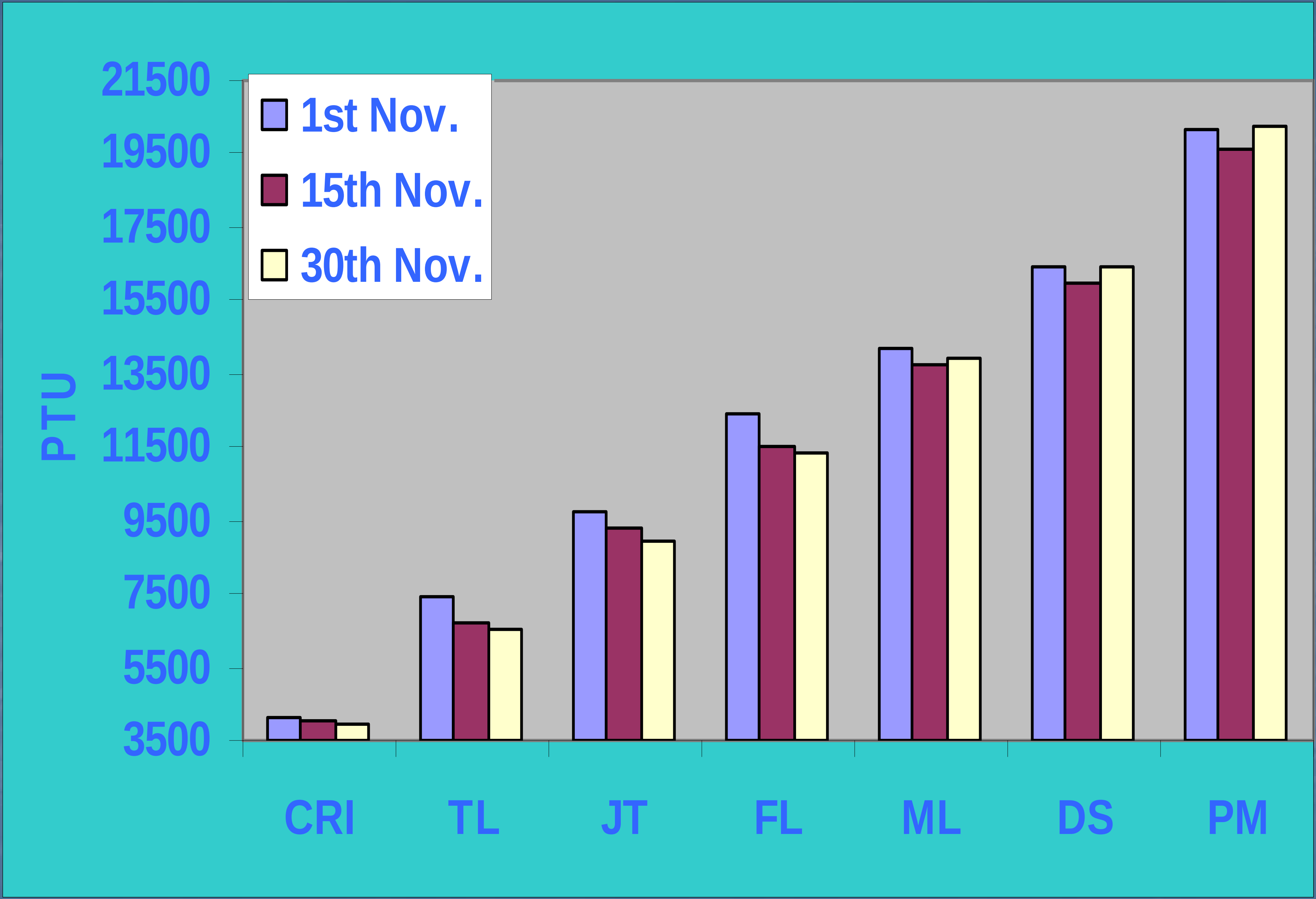


Fig. 8: Mean Acc. PTU in different sowing dates

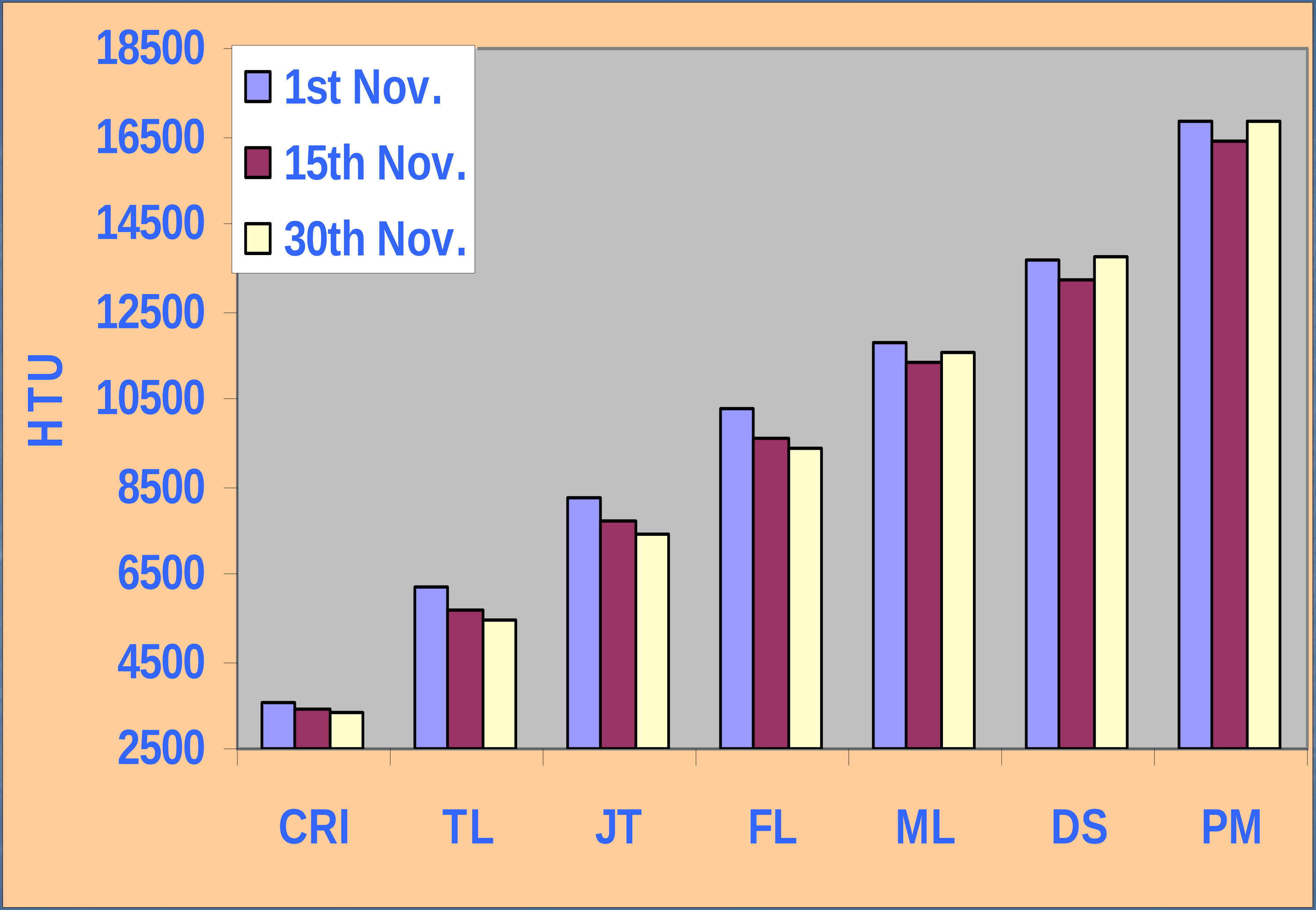


Fig. 9 : Mean Acc. HTU in different sowing dates

Table 3: Correlation coefficients between wheat yield and weather parameters in D1 sowing

Phenological phase	Tmax	Tmin	RH1	RH2
Crown root initiation	0.13	0.44	0.36	0.16
Tillering	0.36	-0.31	0.06	-0.60
Jointing	0.23	-0.28	-0.06	-0.30
Flowering	0.35	-0.84**	0.05	-0.51
Milking	-0.19	-0.92**	0.10	-0.64
Dough	0.57	0.58	0.02	0.23
Physiological maturity	-0.40	0.01	0.13	0.19
December		-0.66		
January		-0.55		

Table 4: Correlation coefficients between wheat yield and weather parameters in D2 sowing

Phenological phase	Tmax	Tmin	RH1	RH2
Crown root initiation	-0.20	-0.31	0.06	-0.51
Tillering	0.14	-0.56	-0.22	-0.41
Jointing	0.44	-0.68*	-0.37	-0.63
Flowering	-0.47	-0.79*	-0.02	-0.27
Milking	0.18	-0.14	0.12	-0.04
Dough	-0.56	-0.67*	0.08	-0.15
Physiological maturity	0.35	-0.39	0.00	-0.46
December		-0.71*		
January		-0.90**		

Table 5 : Correlation coefficients between wheat yield and weather parameters in D3 sowing

Phenological phase	Tmax	Tmin	RH1	RH2
Crown root initiation	0.37	-0.64	-0.47	-0.68*
Tillering	0.47	-0.34	-0.02	-0.53
Jointing	-0.35	-0.63	0.22	-0.10
Flowering	0.38	0.50	0.28	0.23
Milking	-0.56	-0.40	-0.26	-0.24
Dough	0.37	-0.14	-0.41	-0.69*
Physiological maturity	0.68*	-0.41	0.25	-0.39
December		-0.64		
January		-0.39		

Table 6: Correlation coefficients between wheat yield and weather parameters in all dates of sowing

Phenological phase	Tmax	Tmin	RH1	RH2
Crown root initiation	0.01	-0.20	-0.04	-0.30
Tillering	0.15	-0.44*	0.02	-0.49**
Jointing	-0.04	-0.48*	0.02	-0.19
Flowering	0.05	-0.28	0.04	-0.18
Milking	-0.17	-0.61**	0.12	-0.33
Dough	0.11	-0.09	-0.17	-0.32
Physiological maturity	0.22	-0.03	0.18	-0.09
December		-0.61**		
January		-0.54**		

Table 7 : Yield prediction models

Yield prediction model (1995-96 to 2003-04)	R^2	SEE
D1- 1st November sowing		
Y= 8348.23 - 355.06 Tmin(ML)	0.84	284.31
Y= 7127.16-392.12 Tmin(ML) +148.72(49.28)Tmin(PM)	0.93	193.53
D2- 15th November sowing		
Y= 10877.30-558.30Tmin(Jan)	0.81	259.48
Y=12014.11-432.373Tmin(Jan)- 206.133 Tmin(Dec)	0.92	170.37
Y= 11337.26-520.66Tmin(Jan)- 25.95RH2(CRI)	0.96	131.87

continue

D3- 30th November sowing		
Y= -2928.96-97.32RH2(DS) + 327.60Tmax(DS)	0.79	393.18
Y= -18683.1-140.66RH2(DS)-527.18Tmax(DS) + 389.35Tmax(JT)	0.97	152.76
For all the dates of sowing (Overall)		
Y=10710.61-321.44Tmin(Dec)-214.6750Tmin(ML)	0.60	456.77
Y=8859.54-377.98Tmin(Dec)-221.00 Tmin(ML)+32.61RH1(TL)	0.67	424.43
Y=6780.28-457.27Tmin(Dec)- 203.39 Tmin(ML)+ 39.57RH1 (TL)+28.47RH1(JT)	0.73	394.36

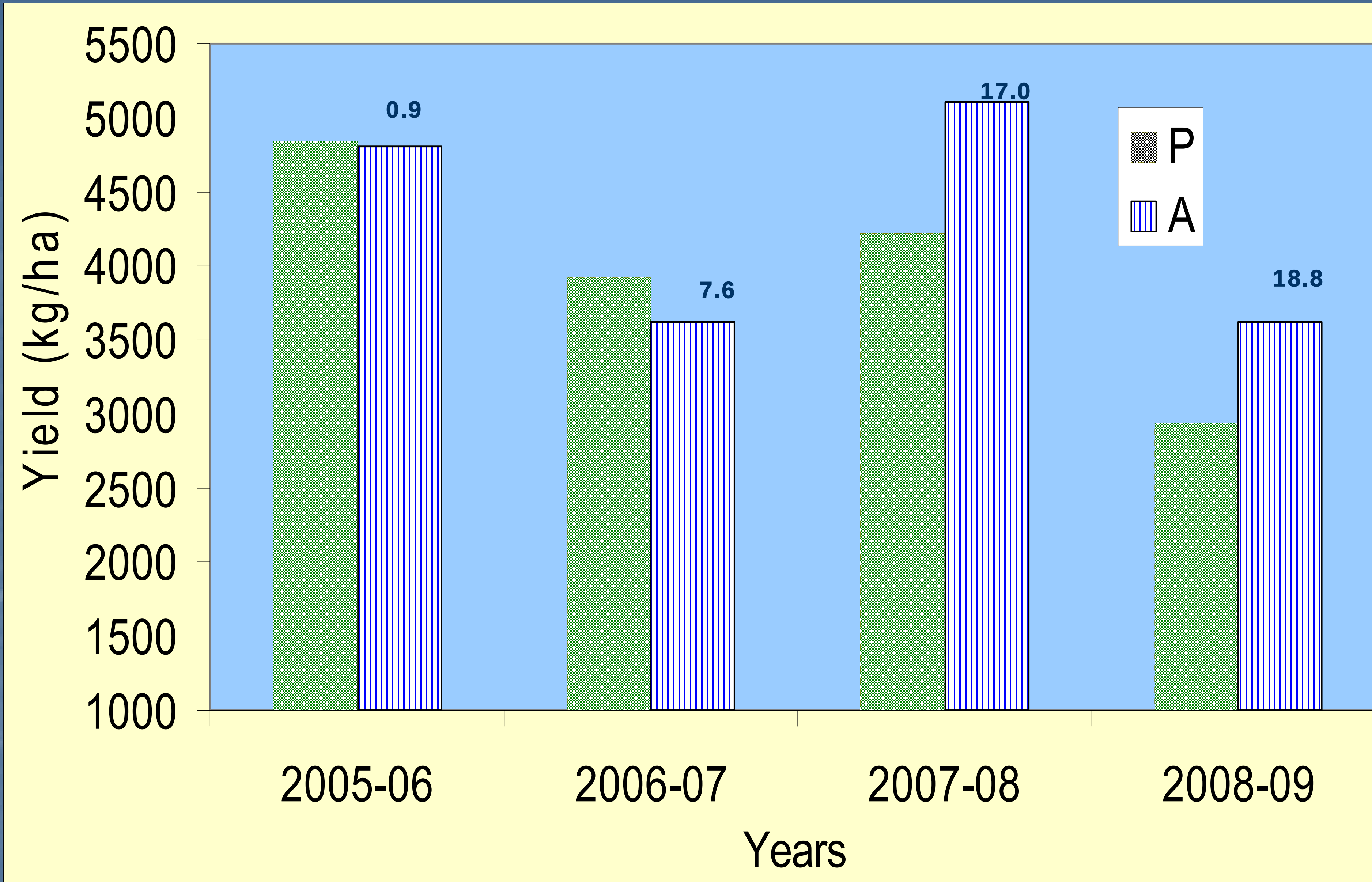


Fig.11: Comparison of actual and regression model predicted yield of wheat during 15th Nov. sowing

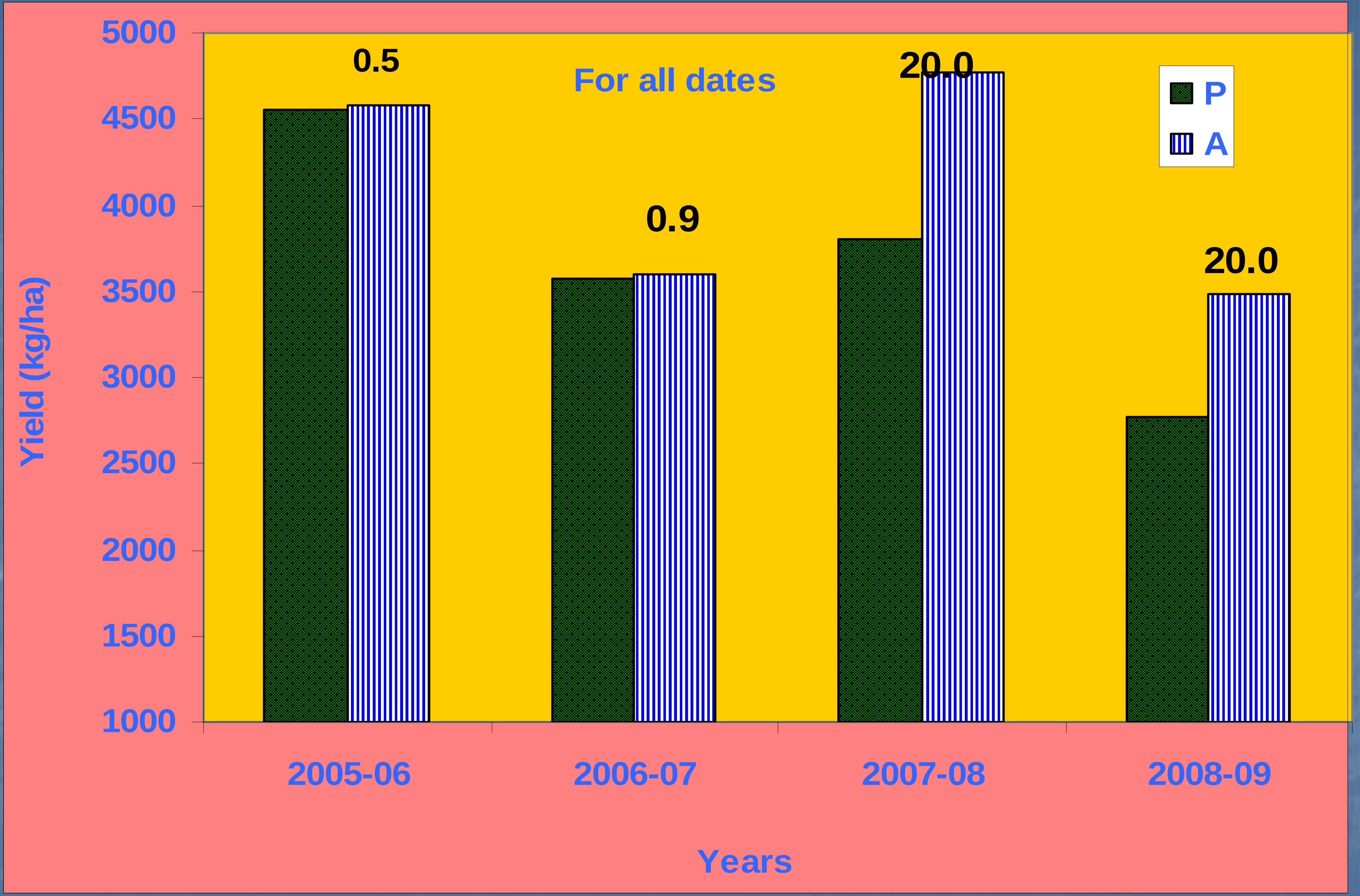


Fig.12: Comparison of actual and model predicted yield of wheat for all the dates of sowing

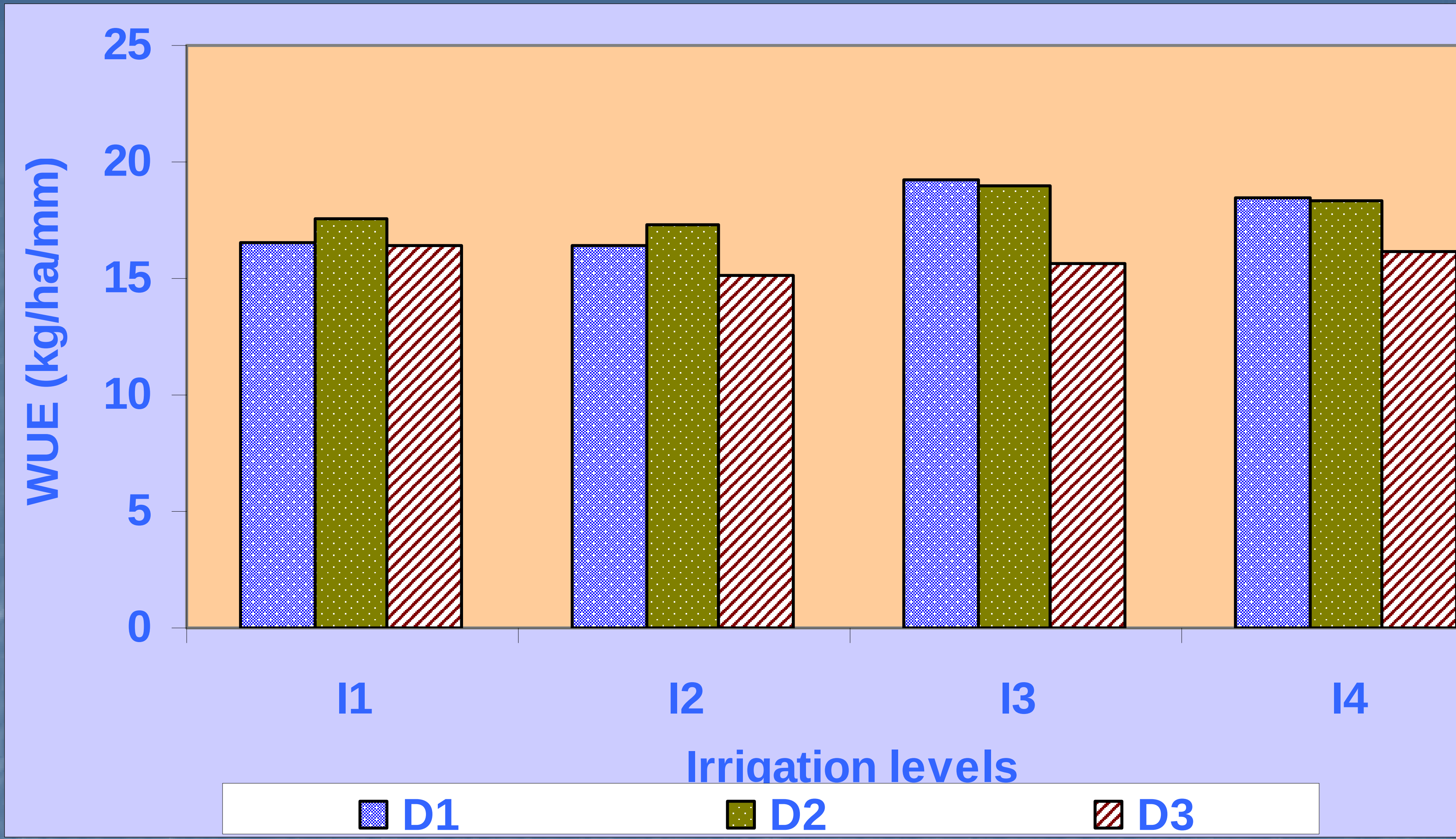


Fig. 10: Mean WUE of wheat in different irrigation treatments

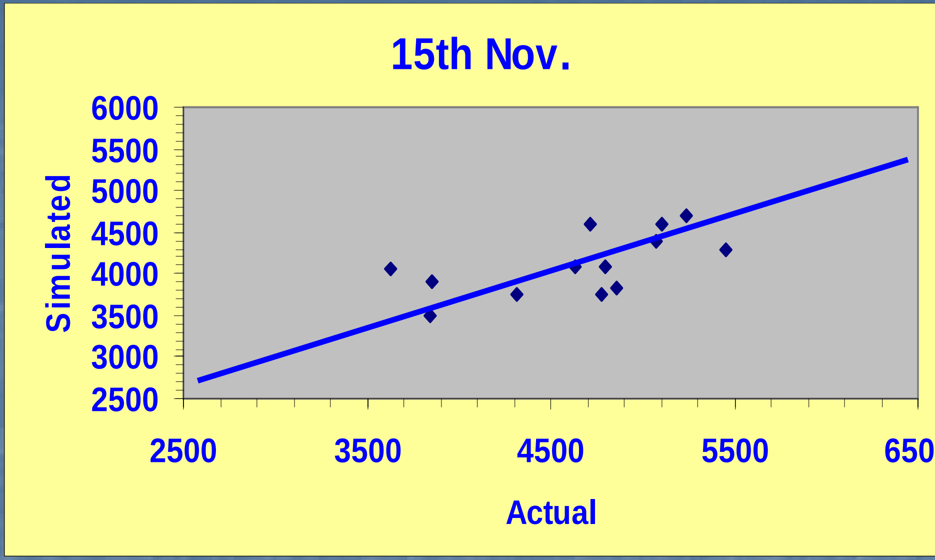
TABLE 8: CALIBRATED GENETIC COEFFICIENTS FOR WHEAT cv. GW-496 AT ANAND CONDITION

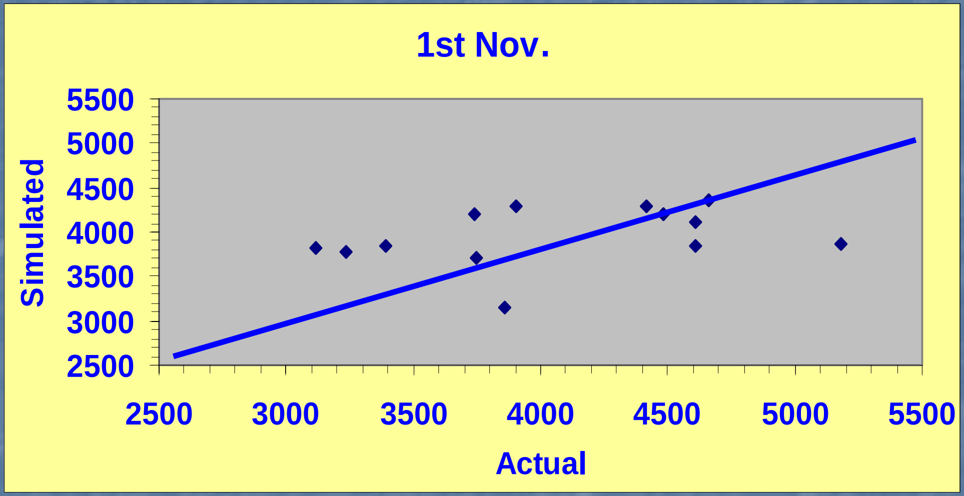
PARAMETERS	GENETIC COEFFICIENTS
PHINT Phyllochron interval)	**72.90**
P1V (Vernalization coefficient)	**0.5**
P1D (Photoperiodic coefficient)	**1.5**
P5 (Grain filling duration coefficient)	**3.5**
G1 (Kernel number coefficient)	**5.5**
G2 (Kernel weight coefficient)	**4.2**
G3 (Spike number coefficient)	**5.2**

Table 9: Categorization of genetic coefficients

Parameter	Description of parameter (Coefficients controlling development aspects)
PHINT	**Phyllochron interval**: it describes the thermal time required between emergence of two successive leaves and its value of 95 is used for spring wheat
P1V	**Vernalization coefficient**: it describes the relative amount of slowing down the development for each day of unfulfilled vernalization assuming that 50 days of vernalization are sufficient for all cultivars. It range varies from 0-9.
P1D	**Photoperiodism coefficient**: The coefficient governs the relative amount that development is slowed when plants are grown in photoperiod 1 hour shorter than the optimum (which is considered to be 16 hours).
P5	**Grain filling duration coefficient**: It related to thermal time in degree days above a base of 1°C where each unit increase above zero adds 20 degree days to the initial value of 430 degree days.
G1	**Kernel number coefficient**: The coefficients accounts for the kernel number per unit weight of stem (less leaf blades and sheaths) plus spike at anthesis (g).
G2	**Kernel weight coefficient**: It controls the kernel-filling rate under optimum conditions ($mgday^{-1}$).
G3	**Spike number coefficient**: It computes the non-stressed dry weight (g) of a single stem (excluding leaf blades and sheaths) and spike when elongation ceases.

Fig. 13: Comparison of mean actual and simulated wheat yield under different dates of sowing





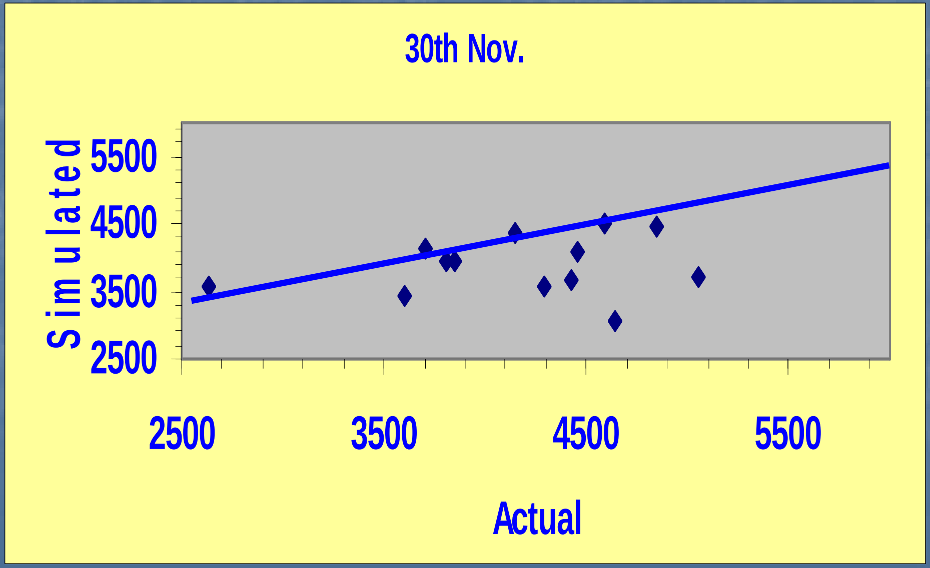
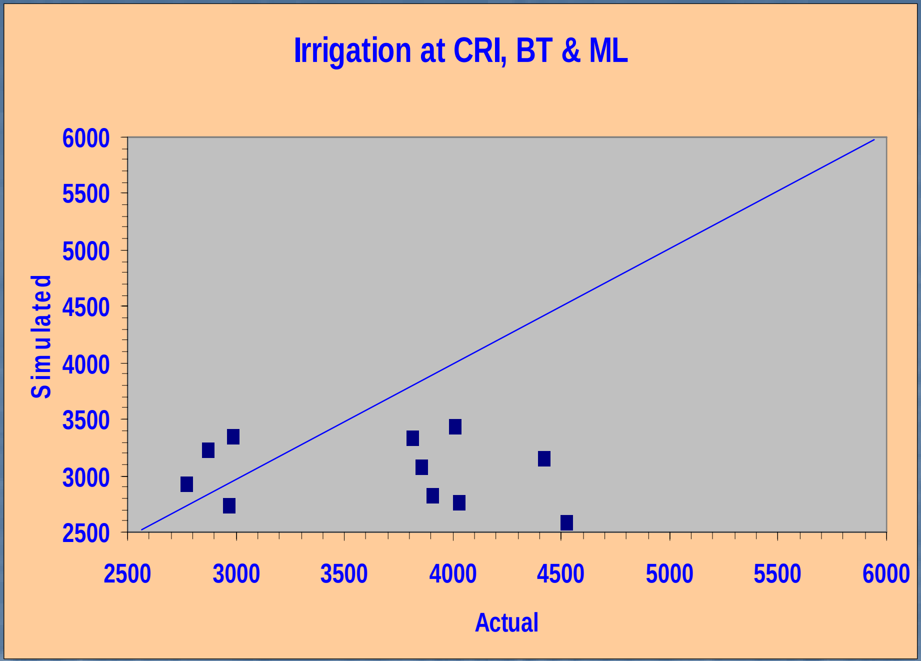
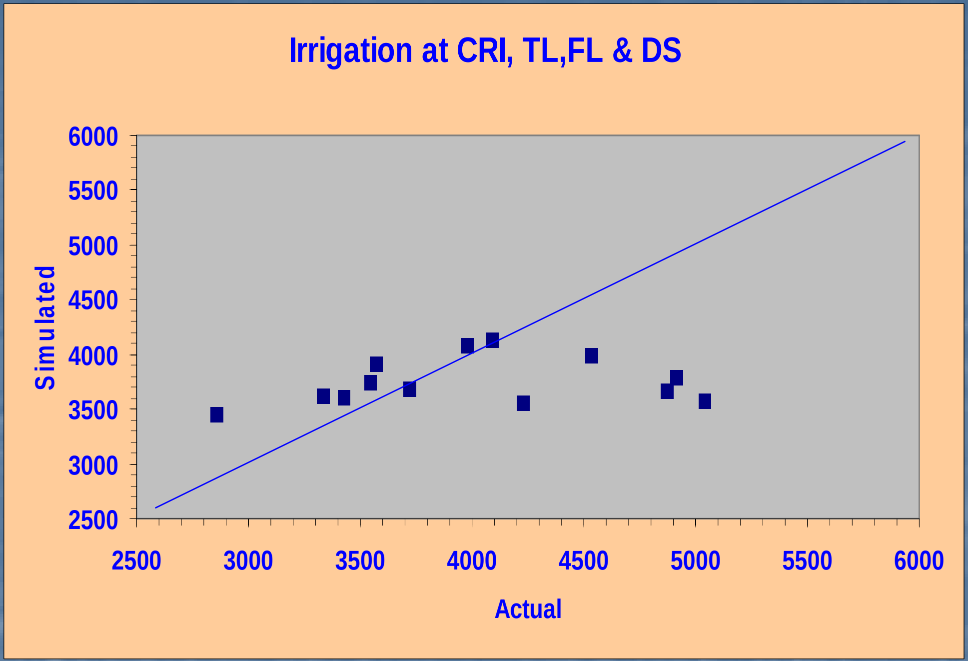
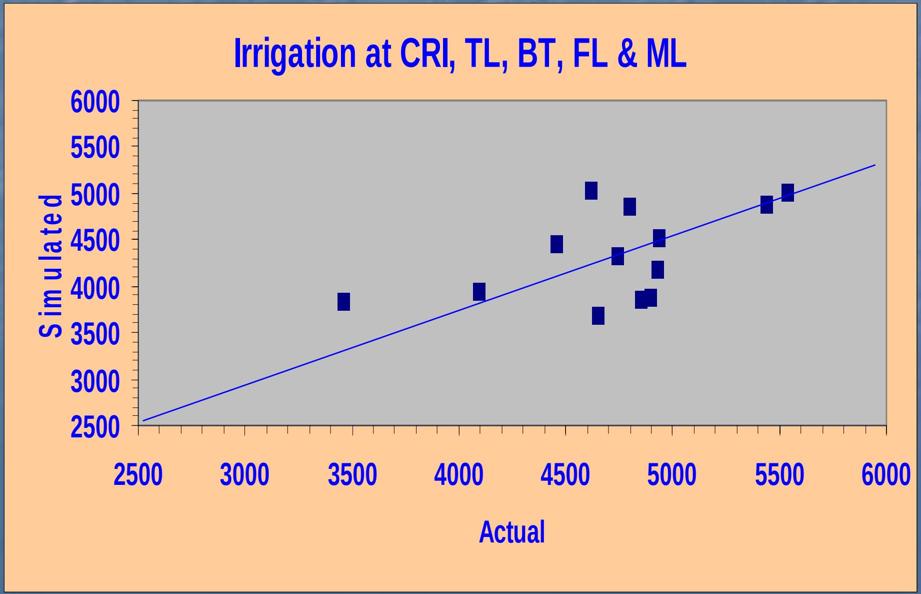


Fig. Comparison of actual and simulated wheat yield under different irrigation treatments







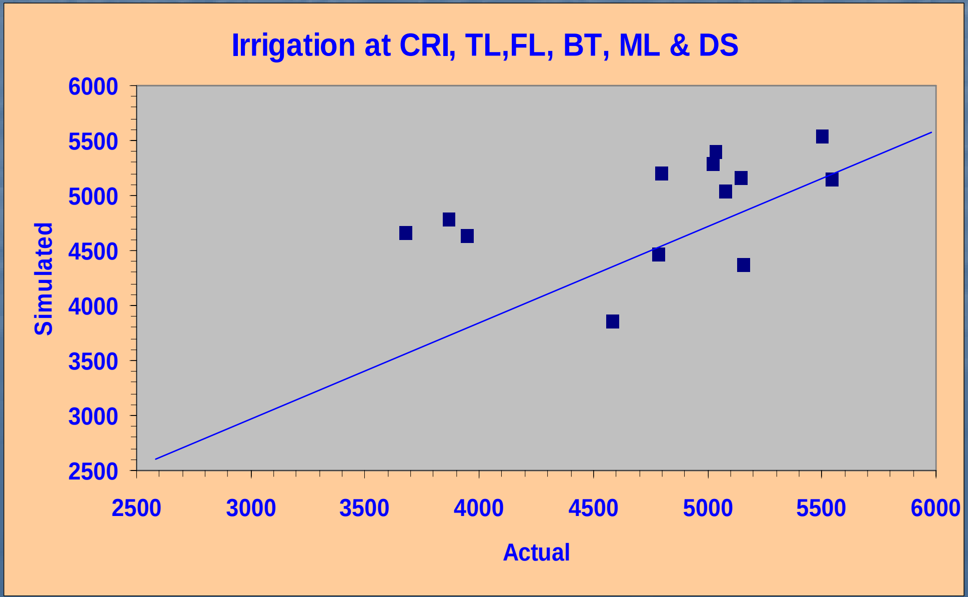
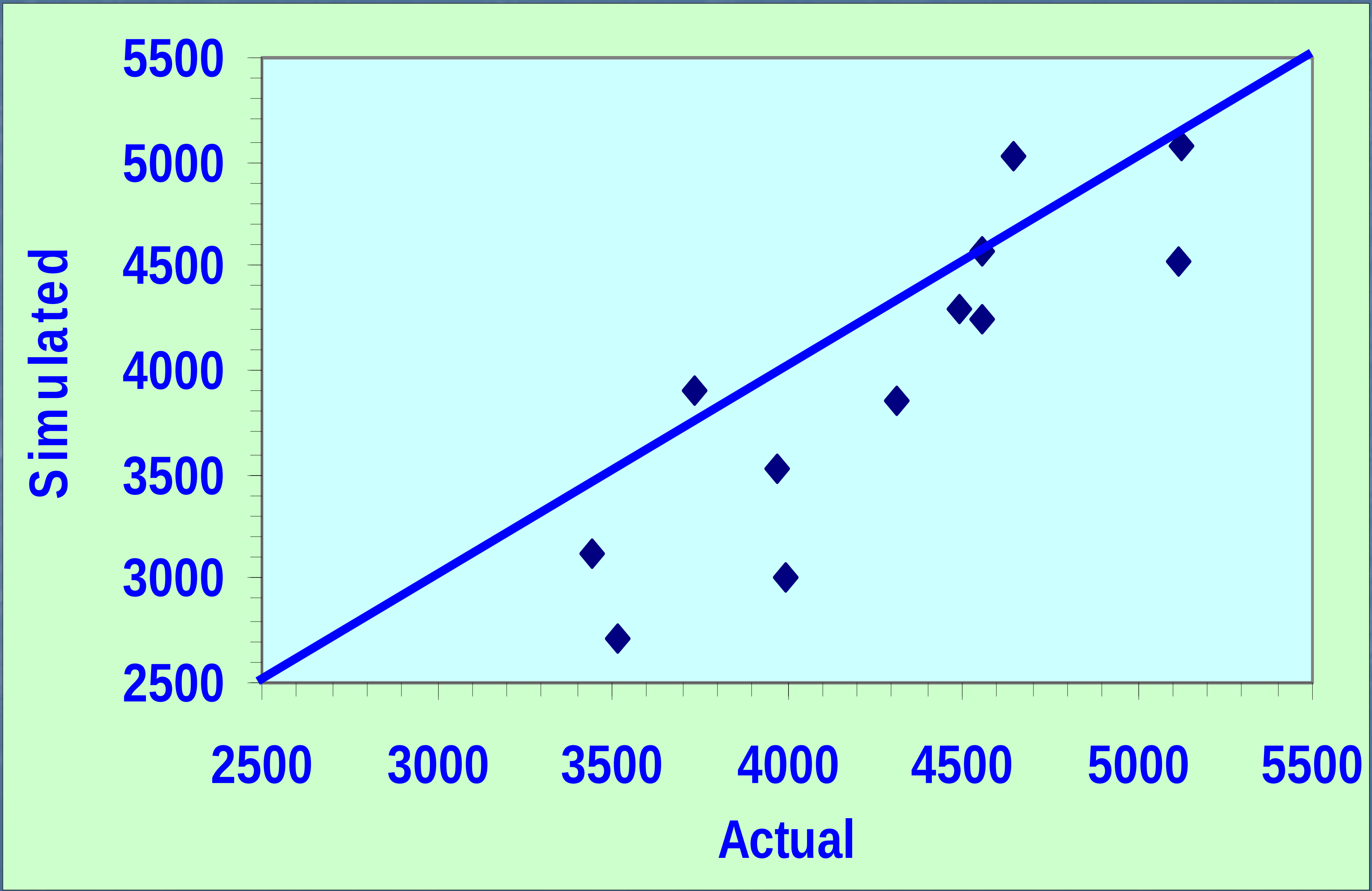


Fig. 15: Comparison of mean actual and simulated wheat yield under different treatments



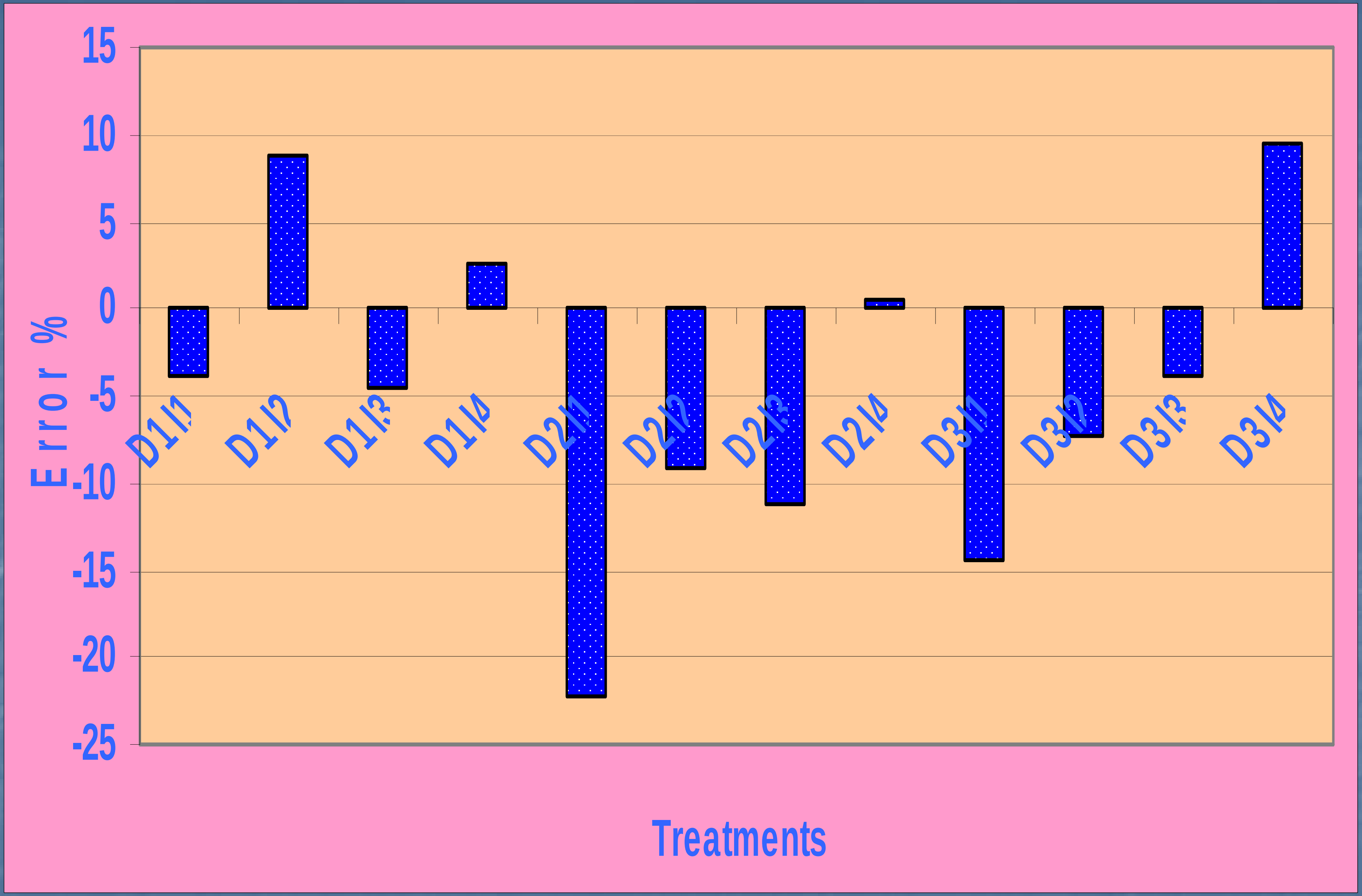


Fig. 16: Average error percent by CERES-wheat simulated grain yield from observed mean

Table: 10 Test criteria used for model validation

(i) D (Index of agreement)

$=1-[\Sigma(P_i-O_i)^2/ [\Sigma(IP'_iI +IO'_iI)^2]$

Where, P'_i=Pi-P and O'_i=Oi-O

(ii) MAE (Mean Absolute Error)

= Σ(IPi-OiI)/n

(iii) MBE (Mean Bias Error)

= Σ(Pi-Oi)/n

(iv) RMSE

$=[\Sigma(Pi-Oi)^2/ n]^{1/2}$

(V) Percent error

= [(Simulated-Observed)]/Observed)]*100

Table 11: Test criteria in evaluation of model with respect to seed yield of wheat (kg/ha)

Treat	OMY	SDo	SMY	SDs	r	Student 't' (Prob.)	MAE	MBE	RMSE	Index of agreement (D)
D1I1	3441.69	841.99	3120.69	333.07	-0.22	0.26^{NS}	765.92	-321.00	1157.38	0.89
D1I2	3732.08	808.82	3907.77	286.48	-0.07	0.48^{NS}	738.62	175.69	633.47	0.97
D1I3	4556.46	709.26	4240.92	473.66	0.24	0.16^{NS}	613.54	-315.54	1137.69	0.87
D1I4	4559.62	688.71	4572.38	626.51	0.12	0.96^{NS}	633.23	12.77	46.04	1.00
D2I1	3995.46	732.21	3010.85	476.44	0.14	0.00*	1061.54	-984.62	3550.08	-0.03
D2I2	4313.92	735.93	3849.92	330.74	0.50	0.02*	572.46	-464.00	1672.98	0.69
D2I3	5119.15	587.33	4525.69	590.06	0.55	0.00*	607.62	-593.46	2139.76	0.82
D2I4	5127.69	741.49	5078.54	548.44	0.43	0.81^{NS}	523.31	-49.15	177.23	1.00
D3I1	3518.69	1000.67	2711.31	396.00	-0.14	0.02^{*}	1160.00	-807.38	2911.06	0.71
D3I2	3970.08	791.30	3519.23	301.68	-0.06	0.08^{NS}	790.54	-450.85	1625.55	0.70
D3I3	4490.69	549.77	4288.00	638.87	0.44	0.27^{NS}	463.00	-202.69	730.82	0.46
D3I4	4647.00	579.82	5029.08	643.90	0.38	0.07^{NS}	601.77	382.08	1377.60	0.77

Table 12: Mean error percent by CERES-wheat simulated seed yield from observed during different years

Year	D1I1	D1I2	D1I3	D1I4	D2I1	D2I2	D2I3	D2I4	D3I1	D3I2	D3I3	D3I4
95-96	-16.86	**14.85**	49.30	50.19	-15.63	**0.59**	**-2.72**	20.70	17.85	-15.53	**-1.64**	**-6.89**
96-97	**-9.60**	**13.60**	**5.88**	34.56	-27.29	-22.52	-30.01	**-7.31**	-41.24	-19.38	**-13.82**	**5.72**
97-98	23.39	31.71	**2.04**	16.18	-38.97	**-10.04**	-16.33	21.12	55.58	53.36	**6.95**	46.42
98-99	-49.70	-31.18	-19.84	**2.17**	-45.94	-21.88	**-10.58**	**-6.83**	-56.02	-33.58	-30.38	-15.12
99-00	-36.53	-19.78	-15.87	**3.93**	-46.52	-19.82	-20.05	**-1.09**	-44.33	-33.17	-25.53	**-4.58**
00-01	**-5.53**	**-6.12**	**0.16**	**-1.51**	-26.86	-30.89	**0.97**	**2.23**	-26.01	-27.75	**2.94**	16.46
01-02	25.07	20.67	**-12.52**	-18.38	**-1.03**	**-4.94**	**-12.87**	-22.37	19.74	**4.90**	**0.31**	**-3.63**
02-03	15.69	**-5.81**	-34.13	-31.07	**2.26**	**-2.46**	-24.91	-20.68	21.00	27.01	**-0.72**	**6.50**
03-04	-18.79	46.64	-16.08	**-14.35**	-32.68	**-8.69**	**-6.04**	**2.46**	-34.50	**-12.95**	**-5.63**	**13.55**
04-05	**7.82**	32.14	**6.15**	**-0.62**	-21.57	**11.42**	**0.77**	**0.07**	-19.38	**-11.20**	22.72	23.83
05-06	-17.28	**-12.26**	**-0.20**	**-0.35**	-33.27	-16.50	**-13.07**	**0.47**	-43.73	-18.60	**-11.04**	**1.18**
06-07	42.67	27.31	**-7.60**	**8.36**	16.77	**7.16**	**0.04**	28.62	-26.38	**-5.54**	**8.59**	34.82
07-08	**-11.01**	**4.04**	-16.06	-16.05	-19.28	**0.48**	**-10.91**	**-9.86**	**-11.56**	**-1.15**	**-2.96**	**4.94**
Av.	**-3.90**	**8.91**	**-4.52**	**2.54**	-22.31	**-9.08**	**-11.21**	**0.58**	**-14.54**	**-7.20**	**-3.86**	**9.48**

Recommendation for the scientific community

- Minimum temperature is found most effective and influencing weather parameter in wheat seed yield.
- It is evident from the regression model (Y=12014.11(827.317)-432.373(65.451)Tmin(Jan)-206.133(52.674)Tmin(Dec) R2 :0.90) that the increase in the minimum temperature during January by 1.0 ^{0}C, there is reduction in yield by 432 kg/ha, while increase in minimum temperature by 1.0 ^{0}C during December (>12.5 ^{0}C) reduces the yield by 206 kg/ha in D2 sown crop. Thus, higher minimum temperature (>11.0 ^{0}C) during January is not desirable for the wheat crop.

- Growing degree days (GDD) requirement for wheat crop were found to be 1815 ± 57.

- CERES-wheat model of DSSAT family validate wheat (cv. GW-496) yield satisfactory under optimum sowing with optimum irrigation as compared to early/late sowing and stress treatments. So it is recommended to use CERES-wheat model for growth and yield simulation of wheat cv. GW-496 under optimum condition.


THANK YOU