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Assessment of Weather Impact on Biomass, Yield and Harvest Index

RANI SAXENA[1], V. BHARADWAJ[2] AND NAVEEN KALRA[3]

[1] *Department of Agricultural Meteorology, G.B. Pant Univ. of Agric. and Technology, Pantnagar* [2] *Division of Environmental Sciences and* [3] *Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi-110 012*

ABSTRACT

Weather is one of the key components influencing agricultural production and productivity. To assess the impact of weather variables on wheat crop, two varieties (PBW 343 and UP 2382) were sown as early (28th October), timely (17th November) and late (10th December) during *rabi* (winter) seasons of 2002-03 and 2003-04. The model, Wheat Growth Simulator (WTGROWS), is a dynamic model to predict above ground biomass, yield and harvest index under different conditions to relate climatic dependence on early, timely and late sowing conditions. The model was calibrated by using the genetic constants evaluated from first sowing. Using the genetic constants evaluated for two varieties, validation of the model was carried out using second sowing by judging the performance in terms of above ground biomass, grain yield and harvest index. After validation, the model was used for computing the climatic variability in terms of above ground biomass, yield and harvest index. Observed grain yield were recorded higher in case of timely sowing (54 q/ha) followed by early sowing (48 q/ha) and late sowing (43 q/ha) with coefficient of variation 18.86 at 1% level of significance. Higher harvest index were recorded in case of timely sowing (38.6 %) followed by early sowing (37.1 %) and late sowing (36.9 %). Higher above ground biomass accumulation were recorded in case of timely sowing (1464.68 g/m^2) followed by early sowing (1358.41 g/m^2) and late sowing (1248.79 g/m^2). Similar results were also simulated by WTGROWS model for Pantnagar region.

Key words: Wheat, weather, biomass, harvest index, WTGROWS.

Introduction

Wheat (*Triticum aestivum L*) is the second most important cereal crop after rice and its main crop areas are situated in the temperate to sub tropical climatic regions. Weather is the dynamic feature of our physical environment. Crop production depends on the climate to a greater extent than any other single factor of the environment. The main reason for low average wheat yields in India are the short growing season, unfavorable weather conditions, low fertility and moisture status of the soil. The limits imposed by low levels of fertility and moisture can be overcome by the use of fertilizers and irrigation. Not withstanding the advantages, which may be gained in these ways, yield will still be limited by the shortness of the growing season, which is conditioned by high temperature during later part of life cycle of the crop. The time of sowing plays an important role in modifying the length of vegetative and reproductive phases in this crop (Mall and Gupta, 2000). In this paper, an attempt have been made to establish crop weather relationship to simulate above ground biomass, yield and harvest index using WTGROWS for early, timely and late sown conditions. WTGROWS model was sensitive to weather and soil of different locations and it simulates the effects of weather, soils, environment and agronomic management on crop growth and yield. Simulation models integrate the effects of different factors on productivity. These have been used for determining the production potential of a location knowing its resources, optimism agronomy, quantification of yield gaps, and to study the consequences of weather variability and change on agriculture. Model was validated using data sets collected from different locations including years, soil types (Table 1), dates of sowing (Table 2) and genotypes (Table 3) for irrigated conditions.

Table 1. Soil properties (profile range) of Haldi loam and Beni silty clay loam series

Physical constants	Haldi loam	Beni silty clay loam
Bulk density (Mg m^{-3})	1.39 - 1.69	1.33 - 1.58
Moisture (FC-WP, %)	28.6 - 8.2	34.6 - 8.4
Hydraulic conductivity (cm hr^{-1})	1.63 - 2.34	0.52 - 1.48
Organic carbon (%)	0.2 - 0.7	0.6 - 0.9
pH (1:2.5 soil water suspension)	5.7 - 8.0	5.9 - 8.2

Table 2. Schedule of sowing and cultural operations (Julian days) for two growing seasons of wheat i.e., 2002-03 and 2003-04

Operations	Julian day for two years		
	Early	Timely	Late
Presowing irrigation	292	312	336
Ploughing 298	349	342	
Harrowing 299	320	343	
N fertilizer applied at sowing	302	322	345
Sowing date	302	322	345
Irrigation schedule	318,348,13,54	343,10,43,54	1,32,54
Top dressing of N fertilizer	357,6	11,42	36,69
Weeding application	306,338,15	353,20,61	13,43,92
Harvesting and threshing	106,111	106,111	106,111

Table 3. Genotypic characterization and a list of parameters required in WTGROWS for UP 2382 and PBW 343 wheat varieties

Genotypic constants	**Units**	**UP 2382**	**PBW 343**
Base temperature	°C	3.6	3.8
Thermal time for germination	°C -d	70	70
Germination to 50% flowering	°C -d	800	800
50% flowering to maturity	°C -d	373	375
Relative growth rate of leaves	d	0.005	0.0060
Specific leaf area	dm^2/mg	0.0020	0.002
Radiation use efficiency	g/MJ	2.75	2.8
Extinction coefficient of leaf at flowering		0.60	0.75
Root growth rate	mm/day	25	27
Potential storage organ weight	mg/grain	42	45
Nitrogen content (storage organ)	Fraction	0.02	0.021

Materials and Methods

A field experiment was conducted at Crop Research center of G.B.P.U.A & T., Pantnagar, situated at latitude 29^0 N' longitude 79^0 3' E and at a altitude of 243.84 meters above mean sea level during the *rabi* (winter) seasons of 2002-03 and 2003-04. This area enjoys humid sub-tropical type of climate with hot dry summers and cold winters. It has a dry season from October to mid of June and a wet season from mid June to October. During the year, temperature are the highest in May-June and the lowest in December-January. The soils of this region (tarai) have been developed from calcareous, medium to moderately coarse textured materials under the pre-dominant influence of tall grass vegetation and moderately well to well drained conditions. The area under study is fertile, having rich organic matter. The soil of experimental field belongs to Haldi loam series and Beni silty clay loam series (Table 1). Two varieties were sown as early (28th October), timely (17th November) and late (10th December) and different cultural operations were performed (Table 2) to expose same variety to different weather conditions at different phenological stages.

The harvest index (HI) was computed using relationship: HI = Grain yield / Biological yield

Results and Discussion

The model wheat growth simulator (WTGROWS) developed by Aggarwal and Kalra (1994) at IARI, New Delhi is used to simulate above ground biomass, yield and harvest index for early, timely and late sown wheat. Temporal variation of weather variables during early, timely and late sown wheat is given in Fig.1. Higher maximum and minimum temperatures were observed during all growth stages of early sowing (Table 4), which caused reduction in yield. Optimum weather prevailed during timely sowing of wheat (Table 4), hence yields were higher. The seasonal average variation for early, timely and late sown wheat of maximum temperature are 22.9 to 25.8^{0}C, 22.63 to 25.15^{0}C and 21.96 to 25.21^{0}C with coefficient of variation 2.3, 2.5 and 5.2 %, minimum temperature are 9.92 to 10.93, 9.74 to 10.81 and 9.88 to 11.31^{0}C with coefficient of variation 9.5, 9.3 and 9.6 %. The seasonal average variation for early, timely and late sown wheat of bright sunshine hours are 6.94 to 6.98, 6.79 to 6.78 and 6.46 to 6.73 hrs with coefficient of variation 5.3, 6.5 and 9.6 %. The seasonal average variation for early, timely and late sown wheat of wind speed are 2.73 to 3.48, 2.81 to 3.36 and 3.21 to 3.82 km / hr with coefficient of variation 20.5, 21.7 and 24.4 %. The seasonal average variation for early, timely and late sown wheat of rainfall are 123, 122.8 and 117.4 mm with coefficient of variation 31.3, 30.5 and 34.3 %.

Observed and simulated above ground biomass

The values of simulated above ground biomass were higher than the observed values (Fig. 2). Also the above ground biomass was higher in case of PBW 343 than UP 2382. The percent variation in simulated results when compared with the observed is higher. The comparatively larger variations in the simulated results might be due to the inter varietal differences in carbohydrate partitioning and specific leaf weight, which presently in the study have not been accounted for calibration of WTGROWS. In the beginning of the crop growth, the simulated values were relatively higher when compared with the observed for both the varieties. Subsequently, the difference between observed and simulated values for these varieties got narrowed down at the time of harvest.

Observed and simulated yield

The results of simulated and observed grain yield were presented (Fig 3). There is a linear decrease in grain yield with delay in sowing, as delay in sowing reduces the length of growing period and results in early maturity of the crop as reported by Singh *et al.* (1997). Sankaran *et al.* (2000) used WTGROWS simulation model and suggested that the rate of improvement in the wheat yield might vary strongly depending upon the cultivars under study.

Observed and simulated harvest index

Simulated harvest index was higher than the observed values for early, timely and late sown for both the varieties (Fig. 4). The RMSE values for PBW 343 are 0.0083, 0.0080 and 0.0071 and for UP 2382 are 0.38, 0.51 and 0.33 for early, timely and late sown conditions, respectively. The larger variations in the simulated and observed harvest index might be due to the fact that inter varietal differences in carbohydrate partitioning and specific

Table 4. Variation of maximum and minimum temperature, sunshine hours, wind velocity and rainfall during different growth stages of early, timely and late sown wheat.

Growth stages	Period (DAS)	Maximum temperature (°C)			Minimum temperature (°C)			Sunshine hours (hrs)			Wind velocity (m/s)			Rainfall (mm)		
		Early	Timely	Late	Early	Timely	Late	Early	Timely	Late	Early	Timely	Late	Early	Timely	Late
Crown root initiation (CRI)	0-21	28.41	25.18	20.07	13.05	8.46	9.05	7.69	7.40	4.01	1.87	1.74	3.52	0.07	0.01	0.00
CRI - early jointing	21-42	24.91	20.96	16.99	8.22	9.29	7.40	7.13	3.84	3.55	1.65	3.25	2.67	0.00	0.27	0.20
Early jointing - late jointing	42-63	20.69	16.48	18.21	9.17	7.31	7.36	4.12	3.58	4.33	3.44	2.75	3.32	0.27	0.00	1.30
Late jointing - flowering	63-84	16.68	17.94	25.54	7.31	7.39	9.65	3.48	3.93	8.71	2.67	3.42	2.78	0.00	1.30	0.00
Flowering - milking	84-105	17.91	25.47	30.74	7.46	9.77	13.70	3.98	8.47	9.05	3.36	2.62	4.18	1.30	0.00	0.00
Milking - maturity	105-135	26.72	31.81	36.54	10.63	13.84	16.72	8.89	9.24	9.76	3.26	4.17	4.82	0.00	0.00	0.00

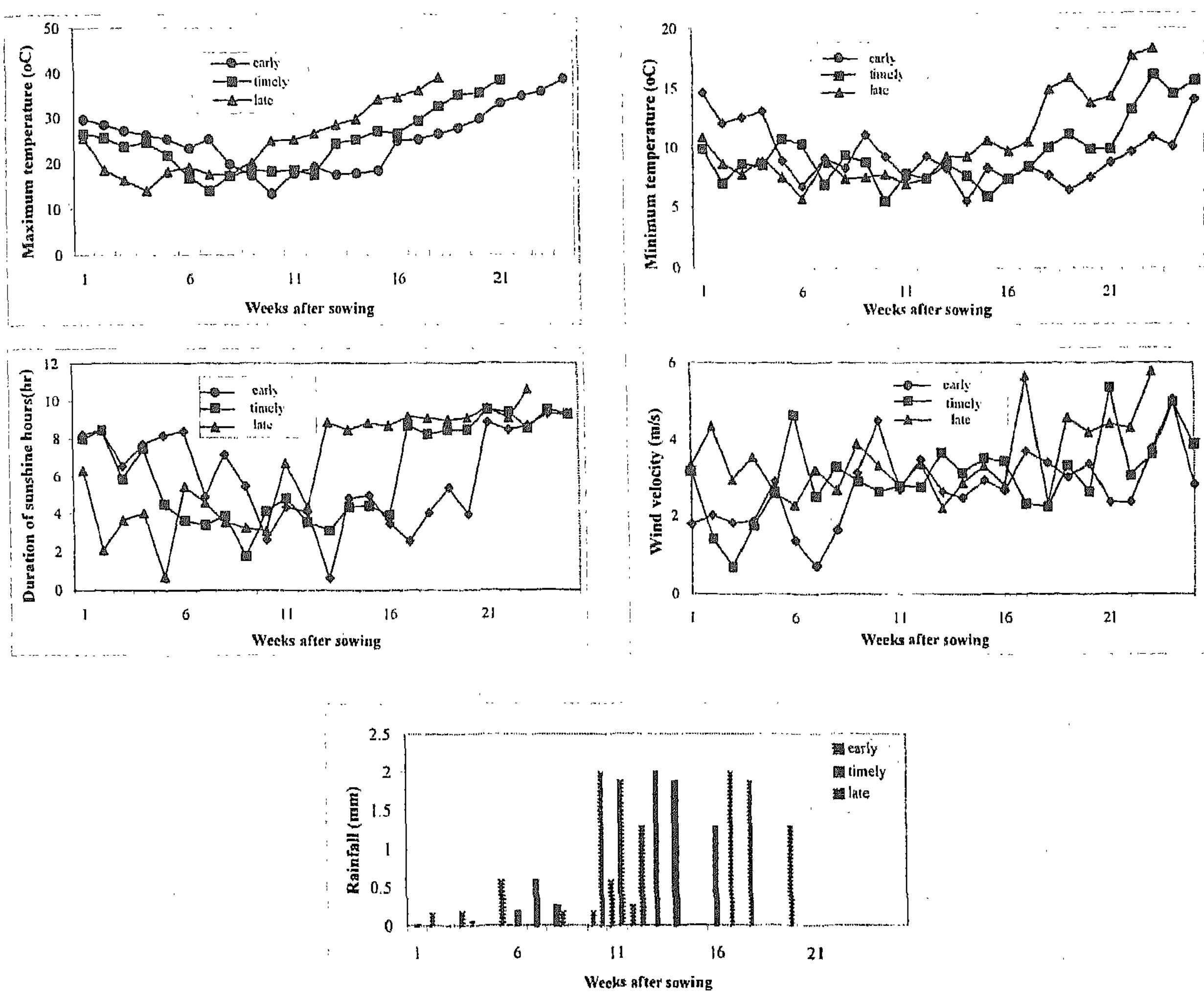

Fig. 1. Temporal variation in maximum and minimum temperature, sunshine hours, wind velocity and rainfall

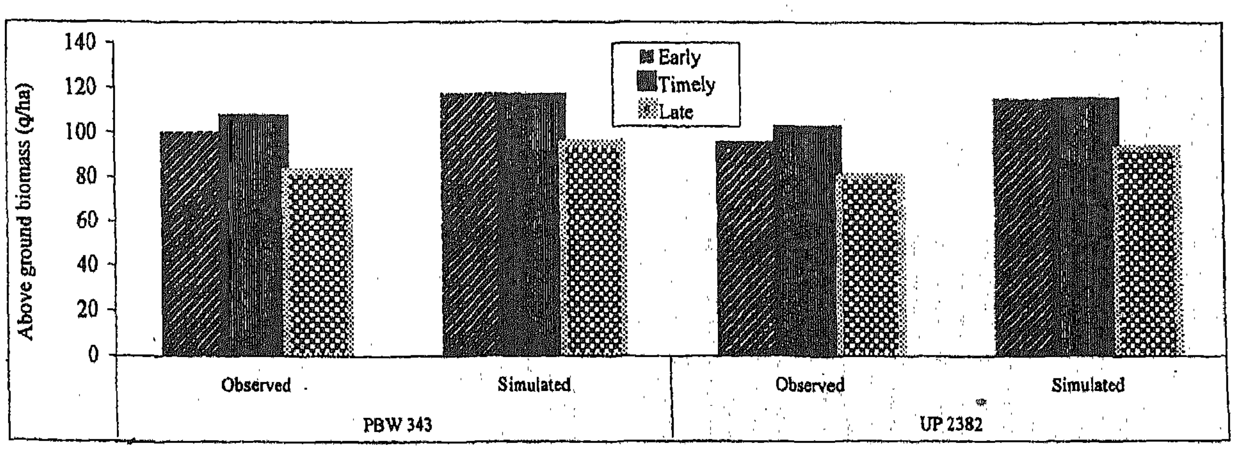

Fig. 2. Simulated and observed above ground biomass (q/ha) for early, timely and late sown conditions for PBW 343 and UP 2382

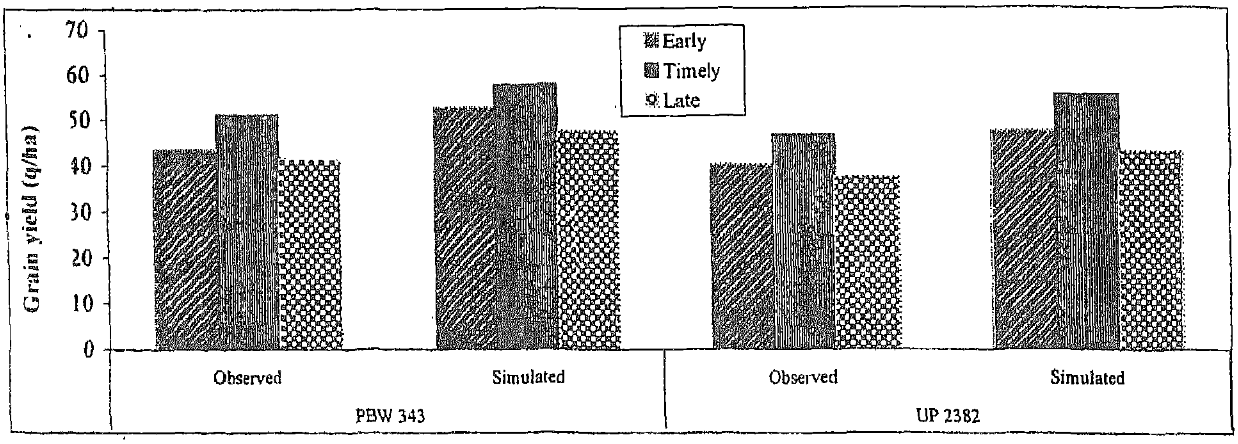

Fig. 3. Simulated and observed grain yields for early, timely and late sown conditions for PBW 343 and UP 2382

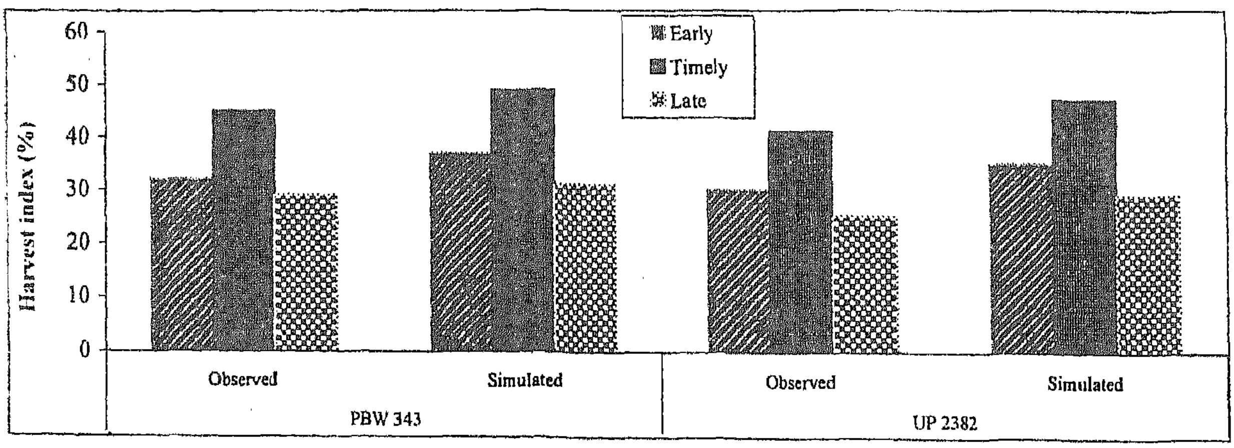

Fig. 4. Simulated and observed harvest index (HI) for early, timely and late sown conditions for PBW 343 and UP 2382

leaf weight, which presently in the study have not been accounted for calibration of WTGROWS.

Conclusions

The comparison of observed and simulated above ground biomass, yield and harvest index for early, timely and late sown wheat during 2002-03 and 2003-04 revealed that simulated values for above ground biomass, yield and harvest index for early, timely and late sown wheat were slightly higher than the observed values. The variation between simulated and observed yields in early, timely and late sown conditions for both PBW 343 and UP 2382 pointed out that yields were simulated satisfactorily by WTGROWS for Pantnagar region. The performance of the model for discriminating the inter varietal response was more satisfactory.

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