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# Evaluation of Model CERES-Wheat (Ver. 4.0) under Temperate conditions of Kashmir Valley

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**Abstract:** Yield forecasting under variable growth conditions of temperate Kashmir using mechanistic crop growth models is required for decision making at different topography and altitude. Data from fields experiment carried out during winter months of 2003-04 and 2004-05 at Shalimar (34°-05′N 74°-89′E) 1587 m above mean sea level was used to calibrate and validate CERES-wheat (ver.4). Field experiment comprised of six wheat varieties, sown on 1, 15 and 30 October. Model performance was satisfactory with regard to parameters, phenological events (days to anthesis and maturity), seed yield and N-uptake (RMSE of 6.2 days, 6.9 days, 0.17 t fed$^{-1}$ and 6.8 kg fed$^{-1}$, repectively. Predicted biomass yield was under estimated, However partitioning study suggest that baring stem weight and total biomass, leaf and ear weight pattern provided good estimate of all tested varieties at different sowing dates. Optimum period for higher wheat yield was predicted from 25 to 30th September. Nitrogen level of 80 kg fed$^{-1}$ with 1 October sowing date simulated highest wheat yield under temperate Kashmir.

**Key words:** CERES-wheat . validation . varieties . sowing date . simulation . nitrogen

## INTRODUCTION

Productivity of wheat depends on the prevailing environmental conditions during the crop growth which cannot be modified to a great extent under field conditions. However, with the adoption of agronomic management, favourable environment can be created. Tewari and Singh [1, 2] revealed that temperature cannot be manipulated but seeding time can be adjusted to meet the specific requirements. According to Watson [3] different crop species and varieties within a crop species show marked variation in their optimum temperature range that minimised adverse effect of delayed or early sowing. Kashmir valley is blessed with most suitable climatic condition for winter cereals. Singh *et al.* [4] suggested that identification of variety for greater stability in growth and yield attributes would be certainly of great significance in order to stabilise and sustain the productivity of wheat in the country. Simulation models can be used as a research tool; they provide scientists with unambiguous mathematical communication about perceptions, hypothesis, interpretations, important processes of crop and its ecosystem that help in decision making on location specific agro-techniques. Jamieson and Munro [5] emphasised that crop growth models save time, energy, additional experimentation and less labour intensive methods.

## MATERIALS AND METHODS

A field experiment was conducted during winter seasons of 2003-04 and 2004-05 on Hapladulfs, silty clay loam soil at the Shalimar campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (34°-05′ N 74°-89′ E; 1587 elevation). Soil contained 1.15% organic carbon and N, P and K, 125, 8.52 and 120.5 ppm, respectively. Field experiment was laid out in split plot design which comprised of three sowing dates (1 October, 15 October and 30 October) assign to main plots and six cultivars (HS 240, HS 365, HS 295 SKW 191, SKW 193, Shalimar wheat-1) in sub-plots, replicated thrice.

**Crop establishment:** Each plot in the field was levelled separately and sown with the six varieties at 20 cm row spacing on 1, 15 and 30 October as per treatment with a seeding rate of 50 kg fed$^{-1}$. Crop was irrigated at heading and dough stage only as more than 80% precipitation is received during crop growth period and less evapo-transpiration rate due to low temperature. One half of N as urea and full dose of P&K as single super phosphate and muriate of potash, respectively was applied prior to sowing and N was applies in two splits each during early spring (ending February) and at heading stage.

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Table 1: Genetic coefficients of cultivars

| | Cultivars | | | | | |
|---|---|---|---|---|---|---|
| Parameter | HS 240 | HS 295 | HS 365 | SKW 191 | SKW 193 | Shalimar wheat-1 |
| Vernilaization coefficient (P1V) | 46 | 44 | 44 | 44 | 47 | 44 |
| Photoperiodism coefficient (P1D) | 35 | 25 | 30 | 25 | 35 | 29 |
| Grain filling period coefficient (P5) | 690 | 680 | 670 | 670 | 680 | 680 |
| Kernel number coefficient (G1) | 19 | 21 | 18 | 20 | 20 | 21 |
| Kernel weight coefficient (G2) | 47 | 46 | 46 | 46 | 46 | 46 |
| Tiller weight coefficient (G3) | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Phyllochron interval (PHINT) | 92 | 90 | 87 | 92 | 79 | 80 |

All plots received 40 Kg N $fed^{-1}$, 10 Kg P $fed^{-1}$ and 14 Kg K $fed^{-1}$.

**Simulation modelling:** The Cropping System Model (CSM) CERES wheat released with DSSAT v4 was used in this study as a maiden attempt under existing agro-climatic conditions. The DSSAT-CSM simulates growth, development and yield of a crop growing on a uniform area of land under prescribed or simulated management as well as changes in soil water, carbon and nitrogen that take place under the cropping system over time Jones *et al.* [6]. The CERES-wheat model simulates the input of the main environmental factors, such as weather, soil and major soil characteristics and crop management on wheat growth, development and yield Ritchi *et al.* [7].

**Genetic coefficients:** Cultivar specific genotypic coefficients of each wheat cultivar was derived (Table 1) from the experimental data by using data set of one treatment (1, October sowing). The coefficients were estimated by adjusting coefficients until close match were achieved between simulated and observed phenology and yield.

## RESULTS AND DISCUSSION

**Climate and weather conditions:** The Kashmir valley has humid temperate climate characterised by hot summers and severe cold winters. The annual precipitation ranges from 676 to 1193 mm with an average of 944.6 mm. Owing to western disturbances most of the precipitation is received from December to April. Winters are cold and cloudy followed by clear sunny summer months. The minimum and maximum temperature range between –8.0 to 33°C, exhibit considerable fluctuation both in summer and winter (Met. observatory, Division of Agronomy, SKUAST-K, Shalimar).

**Model validation:** To assess the accuracy of the CMS-CERES-wheat model simulation results were validated against observed data generated from all treatments (six cultivars of wheat sown on 1, 15 and 30 October). Prediction capabilities of the model were tested by judging the performance of the crop in terms of grain yield, phenology (days to anthesis and maturity), N uptake, canopy weight (biological weight) and leaf area index. Observed periodic partitioning of biomass into stem weight, leaf weight and ear weight from field experimentation was also used to compare with predicted values to evaluate the performance of the model, as biomass was under estimated through out crop growth. Jamieson *et al.* [8] and Bannayan *et al.* [9] also reported similar results.

For crop growth models, the accurate simulation of phenological development under different growth conditions is the major requirement for accurate prediction of crop growth and yield. Simulated phenology (days to anthesis and maturity) for different cultivars under varied sowing dates matched well with the observed values with RMSE value of 6.2 and 6.9 ($R^2$=0.79 and 0.94) days respectively, across varieties and planting dates (Fig. 1). Days to anthesis ranged between 179 to 203 days and 170 to 208 days for observed and simulated data, respectively. Duration to maturity ranged between 217 to 256 days and 224 to 263 days for observed and predicted values, respectively. Cultivars HS 295, SKW 191 and Shalimar wheat-1 sown on 30$^{th}$ October recorded least number of days to mature for both predicted and observed values where as cultivar HS 240 sown on 1 October took maximum number of days to mature for both simulated and observed values.

Validation of model revealed that the grain yield could be predicted fairly well under temperate conditions of Kashmir. The observed values of all treatments ranged from 1.29 to 2.69 t $fed^{-1}$, compared to simulated data ranging from 1.18 to 2.73t $fed^{-1}$.

Measured leaf area index was higher than simulated LAI (Fig. 1) with respect to all treatments except cultivar HS 295 sown on 15 October and HS 240 sown on 30 October. Predicted LAI ranged from 0.78 to 50.92 percent as higher values of RMSE (1.2) was

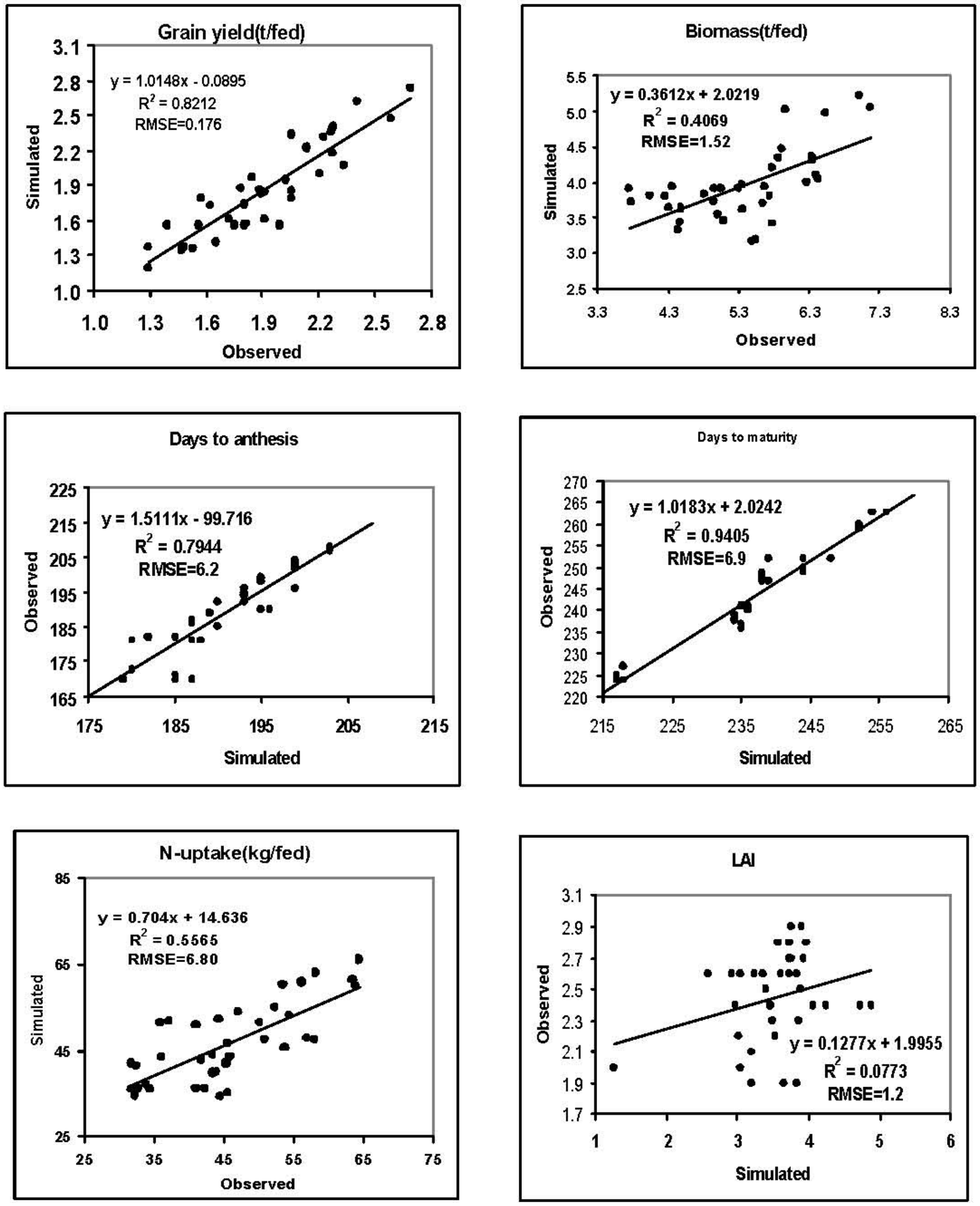


Fig. 1: Comparison of simulated and measured grain yield, phenology, LAI, biological yield and N-uptake

observed indicating under estimation. Predicted LAI ranged from 1.9 to 2.9 as compared to observed LAI from 1.25 to 4.89.

Model provided good estimate of nitrogen uptake compared with measured value (RMSE=6.8 kg fed$^{-1}$). The observed values of all treatments ranged from 31.7 to 64.3 kg fed$^{-1}$ where as corresponding value for simulated N uptake ranged from 34.5 to 66.3 kg fed$^{-1}$. Mean measured and simulated N uptake was 45.7 and 46.8 kg fed$^{-1}$, respectively.

The predictability of biomass yield was comparatively poor as evident from high value of RMSE = 1.52 t fed$^{-1}$ as biomass was under predicted. Observed biomass yield ranged from 37.3 to 71.7 t fed$^{-1}$, compared to 31.7 to 52.4 t fed$^{-1}$ for simulated yield.

**Biomass partitioning:** As biomass was under predicted, therefore, components of biomass were further analysed to study which component was not

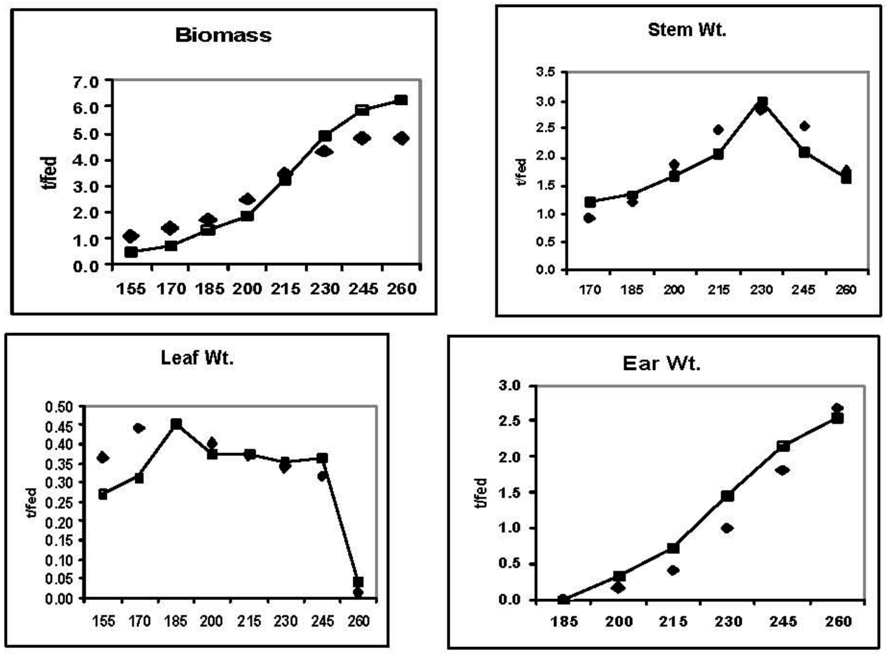


Fig. 2: Comparison of predicted and observed periodic dry matter partitioning (1 October sowing)

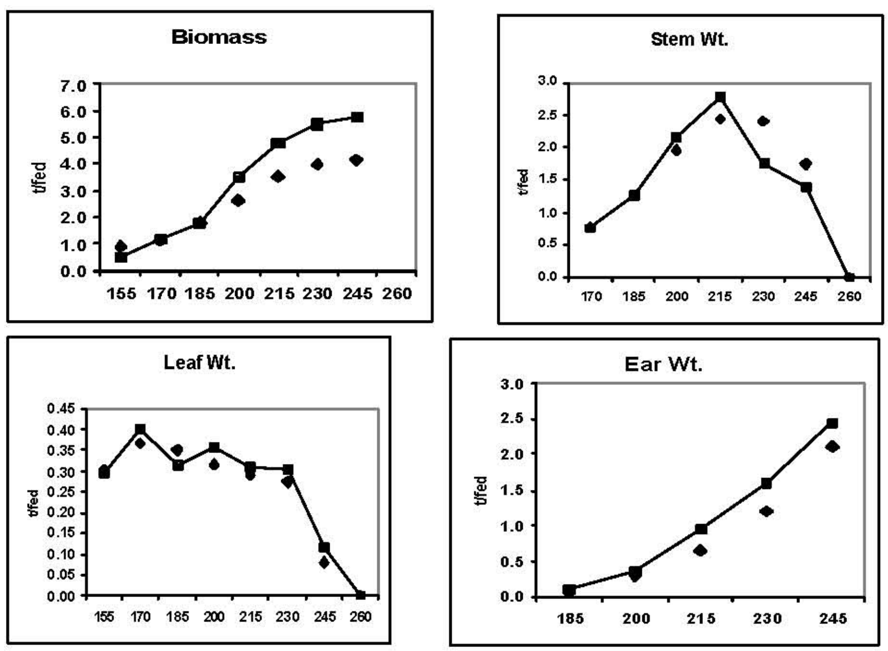


Fig. 3: Comparison of predicted and observed periodic dry matter partitioning (15 October owing)

simulated as expected. Partitioning studies revealed that predicted values of ear weight, leaf weight and pattern at different growth stages up to maturity provided good estimate for different cultivars and sowing dates but stem weight and total biomass was under estimated beyond 230 days after sowing. However, 15 October sowing also under estimated leaf weight pattern.

**Biomass yield:** Biomass accumulation observed periodically from 155 Days After Sowing (DAS) till harvest matched well with simulated biomass yield till 215 DAS at 1 October and 185 DAS at 15 October sowing. Beyond that simulation of cumulative biomass yield was much lower than the observed values. Where at 30 October sowing simulated biomass was under

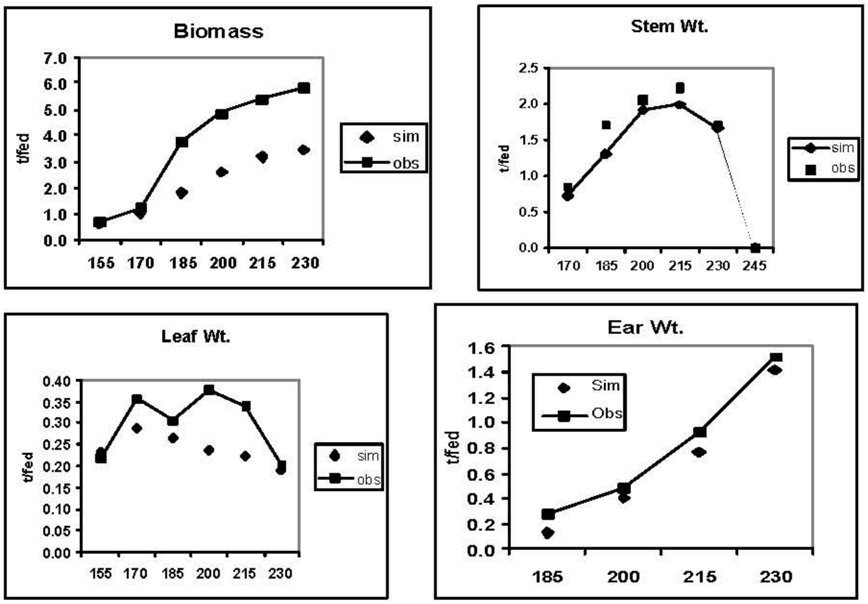


Fig. 4: Comparison of predicted and observed periodic dry matter partitioning (30 October sowing)

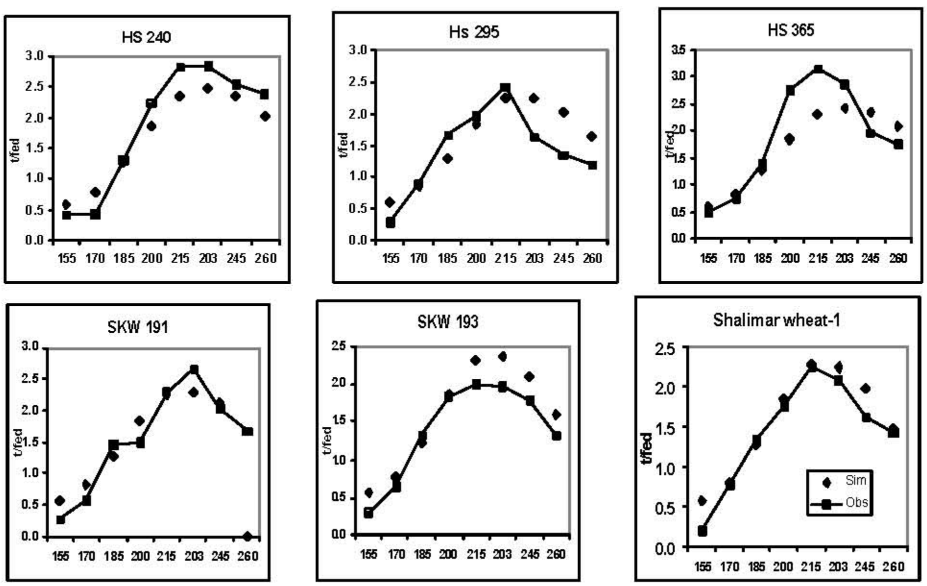


Fig. 5: Comparison of predicted and observed periodic stem weight of different wheat varieties

estimated beyond 215 DAS (Fig. 2-4). Biomass yield of different cultivars (mean of sowing dates) followed the similar trend. From 155 to 185 DAS predicted and observed biomass of all cultivars matched well, thereafter simulated biomass was underestimated up to maturity.

**Stem weight:** Stem dry matter observed periodically from 170 DAS up to maturity matched well with model predicted stem weight under 1 and 15 October, where under 30 October sowing stem weight was slightly under estimated throughout growth period (Fig. 4). Observed stem dry mater of different cultivars from 155 to 260 DAS matched well with simulated values of all cultivars. However, cultivar HS 365 underestimated simulated stem weight at 200 to 230 DAS where HS 295 over estimated values at 230 to 260 DAS (Fig. 5).

**Leaf weight:** At 1 October sowing leaf dry matter observed as compared to simulated leaf dry weight

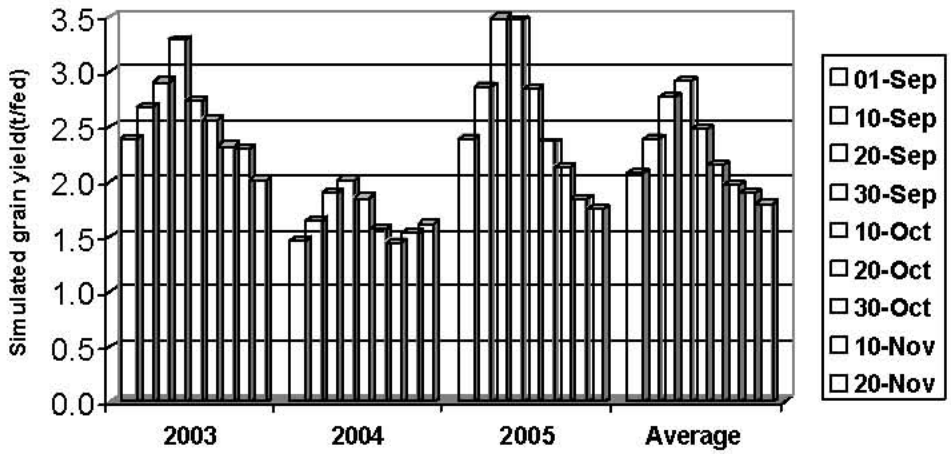


Fig. 8: Simulated grain yield of wheat as function of sowing

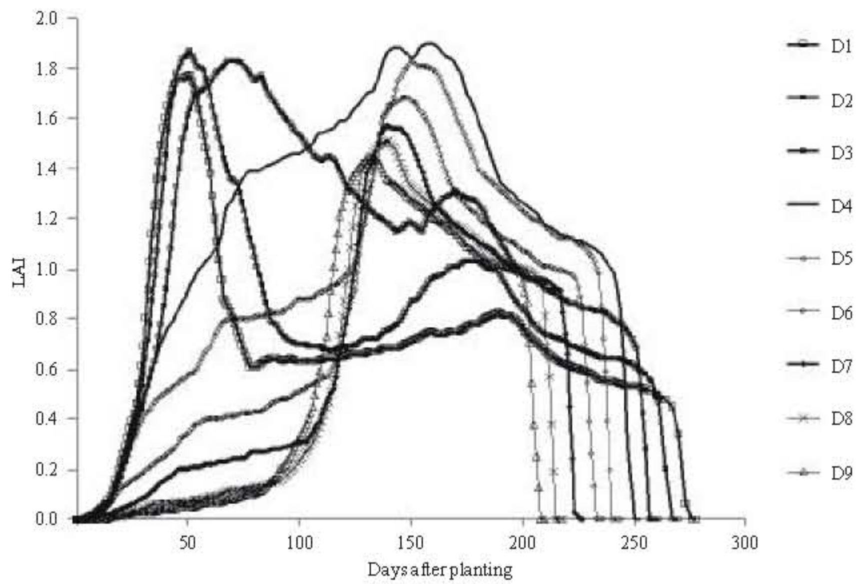


Fig. 9: Simulated LAI as function of dates of sowing

30 September (Fig. 8). Highest yield was recorded on 30 September sowing. This can be attributed to initial advantage of early sowing with respect to LAI, dry matter production and comparatively highest N uptake through out crop growth. However, sowing on 1 or 10 September recorded abrupt increase in simulated LAI due to high temperature which could not sustain due to decrease in temperature during winter months (Fig. 9). For later sowing dates beyond 20 October sowing dates, days to maturity decreased compared to 20 and 30 September sowing. Late sown crop recorded low values of simulated LAI and biomass.

Simulated yield of three sowing dates (1, 15 and 30 October) in combination with nitrogen levels $N_0$, $N_{40}$ and $N_{80}$ kg fed$^{-1}$) revealed that all the three sowing dates, increasing levels of N increased yield (Fig. 10). Highest simulated yield was recorded at 1 October sowing and delayed sowing of 15 and 30 October recorded reduction in seed yield. Similar findings were reported by Saseendran *et al.* [10]. Response of nitrogen was more with delayed sowing than 1 October sowing though over all yield was more with early sowing date. It might be due to more congenial growth conditions prevailed at 1 October sowing and better prolonged utilisation of resources. Thus fertilizer response was comparatively less.

## CONCLUSION

Simulation studies show that wheat can be grown between 20 to 30 September with higher grain yield. Highest response of nitrogen fertilization (80 kg fed$^{-1}$)

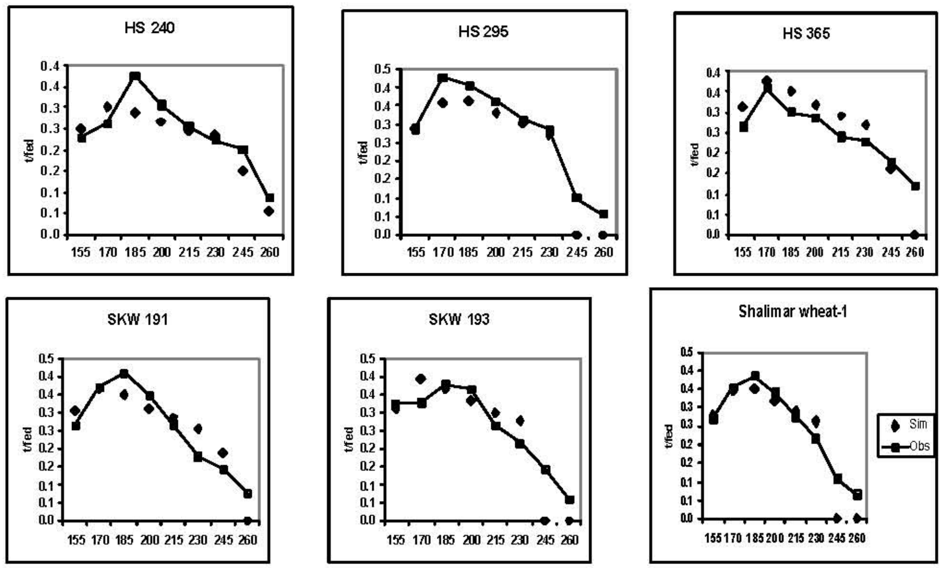


Fig. 6: Comparison of predicted and observed periodic leafweight of different wheat varieties

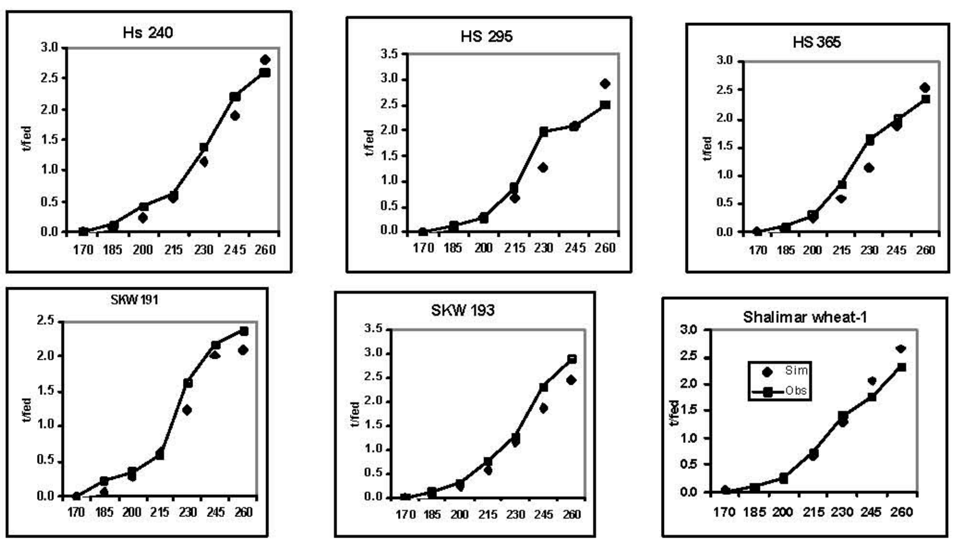


Fig.7: Comparison of predicted and observed periodic ear weight of different wheat varieties

match well beyond 200 DAS. Where as from 155 to 185 DAS simulated leaf weight was over estimated whereas at 15 October sowing simulated leaf weight was under estimated from 170 to 215 DAS. At 30 October, sowing observed and simulated leaf weight matched well through out growth period. Observed and model simulated leaf dry weight pattern from 155 to 260 DAS matched well with respect to all wheat cultivars. However, cultivars HS 365 and SKW 191 underestimated values at 260 DAS and cultivar HS 295, SKW 193 and Shalimar wheat-1 under estimated leaf dry weight at 245 and 260 DAS (Fig. 6).

**Ear weight:** At all three sowing dates observed and predicted ear weight pattern throughout growth period matched with slight under estimation of simulated ear weight at all three sowing dates. Observed mean ear dry weight over all dates of sowing for different cultivars matched well with predicted ear dry weight. Cultivars HS 295, HS 365 and SKW 193 slightly under estimated ear weight at 230 DAS (Fig. 7).

**Application:** Simulated yield of wheat at different sowing dates from 1 September to 20 November at 10 days interval suggest that most appropriate sowing date of wheat under temperate Kashmir was 20 September to

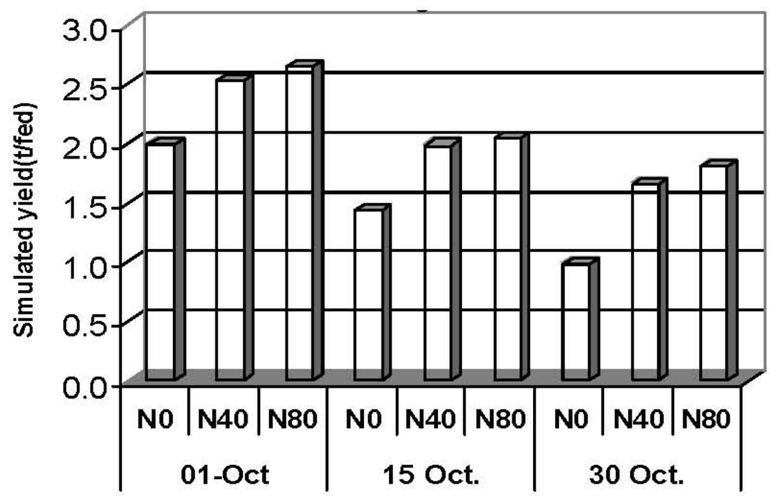


Fig. 10: Simulated grain yield as function of dates and nitrogen levels

at all sowing dates can be achieved, though highest yield can be obtained at 1 October sowing with 80 kg N fed$^{-1}$. Late sowing and no application of nitrogen recorded lowest simulated yield.

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