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ADAPTATION STRATEGIES FOR OPTIMUM SOWING OF WHEAT VARIETIES AND VALIDATION THROUGH CERES-WHEAT MODEL IN CHANGING CLIMATIC CONDITIONS UNDER SHIVALIK RANGE OF N-W HIMALAYAS

VIKAS GUPTA[1]* AND MEENAKSHI GUPTA

Division of Agronomy, SKUAST-Jammu, Chatha, J&K UT 180009, India

Keywords: Sowing environments, Varieties, Nitrogen levels, Wheat, Temperature, CERES-Wheat Model

Abstract

Experiments were conducted at Research Farm of Agromet Research Centre, SKUAST-Jammu, during *rabi* 2015-16 and 2016-17, and comprised of 3 varieties, 3 sowing environments and 3 N-levels laid out in split-split plot design. The growth and development of wheat crop was also validated through CERES-Wheat model. Earlier sown wheat took more days for physiological maturity as compared to normal and late sown crop. WH-1105 variety took maximum days for physiological maturity and followed by HD-2967 and RSP-561. Higher dose of nitrogen took more calendar days for physiological maturity as compared to lower doses of nitrogen. WH 1105 variety recorded significantly superior grain and biological yield as compared to HD 2967 and RSP 561. The coefficient of determination (R^2) between validation of observed and simulated days to anthesis and maturity was 0.79 and 0.76, respectively. The values obtained for R^2 during validation of CERES-wheat model for grain yield of wheat was 0.78. Maximum temperature during reproductive stage showed distinct effect on grain yield of crop.

Introduction

India is one of the main wheat producing countries of the world after China. It is the second staple food crop of India, cultivated on about 30.60 million hectare with the production of 98.38 MTs and productivity of 32.16 q/ha (Anon. 2017). In J&K UT, it is grown on about 0.32 mha with production and productivity of 0.50 MTs and 1550 kg/ha, respectively (Anonymous 2016). Several agronomic and climatic factors prevent the full intrinsic yield potential of wheat varieties from being realized in a particular region. Various adverse climatic effects like terminal heat stress and excessive rainfall during reproductive stage reduce the yield to a great extent. The fluctuations in climatic conditions enhanced the vulnerability of the crop to vagaries of various weather factors. Delay in sowing by each day causes a remarkable yield loss in wheat according to various field experiments (Ortiz-Monasterio *et al.* 1994) which was largely due to terminal heat stress. Adequate growth and augmentation of crop could be obtained by adjusting the sowing environments which leads to better yield; as perfect sowing environment exploits the full genetic potential of a particular variety by providing optimum growth conditions such as temperature, light, humidity and rainfall (Gupta *et al.* 2020). The unfavourable environments created by high temperature mostly during reproductive stages especially grain filling stage could be minimized by adjusting the sowing time to an optimum time for different varieties, which are suitable for early, normal and late sown environmental conditions for assured higher yield (Gupta *et al*. 2020a). The accumulated temperature is considered as the principal factor affecting year-to-year variation in phenology (Gupta *et al*. 2021).

*Author for correspondence: <vikasadr@gmail.com>. [1]Present address: Advanced Centre for Rainfed Agriculture (ACRA), SKUAST-J, Rakh Dhiansar, Samba, J&K UT 181133, India.

Temperature is the main and important environmental factor which influences the phenology and yield of wheat crop. In a recent study under Coupled Model Inter-Comparison Project 5(CMIP5), projected under the business-as-usual scenario, mean warming in India is likely to be in the range of 1.7-2.0^{0}C by 2030s and 3.3-4.8^{0}C by 2080s relative to pre-industrial times, and precipitation may increase from 4-5% by 2030s and from 6-14% by 2080s as compared to 1961-1990 balime (Chaturvedi *et al.* 2012). In the present study, the CERES wheat (DSSAT) crop simulation model is chosen. Crop Environment Resource Synthesis (CERES)-Wheat model is a process based management-oriented model that can simulate the growth and development of wheat crop (Ritchie *et al.* 1998). CERES-Wheat has been successfully used worldwide for a variety of purposes: as an aid to fertilizer N management (Zalud *et al.* 2001) and climate change (Iglesias *et al.* 2000). Therefore, efforts have to be made and to minimize the effect of extreme weather events like temperature and other weather parametres by alteration in sowing dates, choosing appropriate varieties and N-levels and their validation using CERES-Wheat Model.

Materials and Methods

Experiments were conducted during *rabi* 2015-16 and 2016-17 at Research Farm of Agromet Research Centre, SKUAST-Jammu (Latitude 32^{0}39$^/$ N, longitude 74^{0}58$^/$ E and altitude 332 m amsl). The soil of the experimental site was sandy clay loam having available nitrogen 236.20 kg/ha, phosphorus 13.10 kg/ha and potash 120.10 kg/ha with pH 7.8 and organic carbon 0.38%. The meteorological data for the crop season during *rabi* 2015-16 and 2016-17 used in the present study was obtained from Meterological Observatory of SKUAST-J, Chatha. The rainfall data of the crop growing periods revealed that a total of 148.8 mm and 238.0 mm of rainfall was received during *rabi* 2015-16 and 2016-17, respectively. The treatments comprised of 3 varieties (HD 2967, RSP 561 and WH 1105), 3 sowing environments (25th October-early, 14th November-normal and 4th December-late) with 3 N-levels (100, 125 and 150 kg/ha) replicated thrice in split-split plot design.

Model calibration is a process of adjusting some model parameters to the local conditions. Observed weather data and soil parameters of Chatha, SKUAST-Jammu for *rabi* season 2015-16 was used for calibrating the coefficients of wheat varieties. The genetic coefficients of wheat varieties were estimated from field experiment by adjusting the coefficients until a close match was achieved between simulated and observed phenology and yield. The available data included planting date, emergence date, anthesis date, maturity date and grain yield of wheat. To assess the accuracy of the model simulations, observations and data generated from 3 varieties, sowing environments and N-levels each, the data of *rabi* 2016-17 was used for validating the performance of CERES-Wheat Model. Prediction capabilities of the model were tested by judging the performance of the crop in terms of phenology, days taken to anthesis and maturity and grain yield.

Results and Discussion

Days to achieve various phenophases were much affected due to different sowing environments of wheat ranging from 25th October to 4th December. Higher number of days to achieve phenophases like CRI, tillering, jointing (vegetative stages) recorded in late sowing (4th December) followed by normal and early sowing. However, days to anthesis, milking, hard dough and physiological maturity were higher in the crop sown on 25th October followed by normal and late sowings. The earlier sown crop had more number of days for grain filling period. Anthesis, milking, dough stage started earlier with the delay in sowing and late sown crop took significantly less number of days to complete these stages (Figs 1 & 2). More days taken by normal and late sown wheat for CRI, tillering and jointing stages was due to the fact that the maximum and minimum temperatures were very low at that time as compared to the same phenophases during early sowing of wheat. The other phenological stages like anthesis, milking, dough and physiological maturity were accomplished earlier in normal and late sown wheat crop because of higher maximum, minimum and mean temperatures during these phenological stages. Shorter phenophasic duration under late sown crop was because of the fact that later stages of growth coincides with the abrupt rise in air temperature and thereby causing the shortening of late growth stages resulting in early maturity of the crop. Similar findings were also reported by Kaur *et al*. 2016. Fisher (1985) confirmed that high temperature during grain filling period reduced the grain filling duration and also imposes major limitation on kernel weight and grain yield.

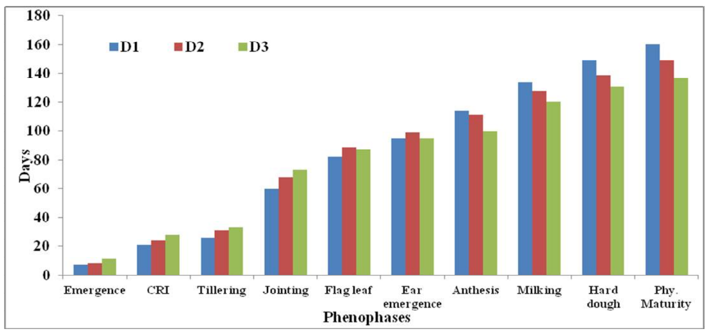

Fig. 1. Effect of sowing environments on occurrence of various phenophases in wheat during *rabi* 2015-16.

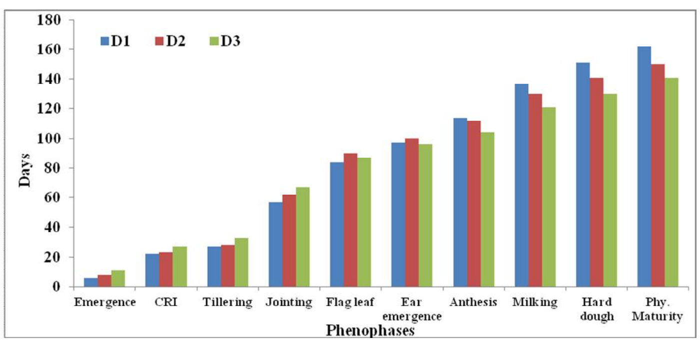

Fig. 2. Effect of sowing environments on occurrence of various phenophases in wheat during *rabi* 2016-17.

There was a significant difference between grain and biological yield of wheat crop due to varieties, sowing environments and nitrogen levels. Statistically superior grain yield of variety WH 1105 (45.73 & 46.17 q/ha) was recorded in comparison to HD 2967 (41.60 & 43.95 q/ha) and RSP 561 (39.75 & 42.55 q/ha) varieties during first and second year of experimentation, respectively. However, varieties HD 2967 and RSP 561 were statistically similar (Table 1).

The higher grain and biological yields might be due the greater genetic potential and better utilization of radiation thereby leading to production of maximum leaf area and dry matter which in turn resulted into higher grain and biological yields. Similar results were also reported by Kumar *et al*. (2015) and Kaur *et al*. (2016). Variety WH 1105 performed significantly better than HD 2967 at various locations as reported in the progress report of AICWBIP (Tiwari *et al*. 2015-16).

There was an unfavourable effect on grain and biological yields of wheat due to delay in sowing. There was a marked difference in grain yield of wheat crop due to sowing environments. Early sown (25th October) wheat crop recorded significantly higher grain and biological yield as compared to normal and late sowings. Normal and late sown wheat recorded about 9.1 and 27.6% less grain yield than early sown crop in *rabi* 2015-16 (Table 1). Lower grain and biological yield of wheat crop in sowing environments later than 25th October was mainly due to higher temperature during reproductive periods of the crop. During milking stage, in normal sown wheat crop (14th November), maximum and minimum temperature was also higher by about 2 and 1.5^{0}C than their respective normals in *rabi* 2015-16 which might have reduced the days taken for reproductive stage in comparison to earlier sown crop and ultimately reduced the yield. Sandhu *et al.* (2016) also reported reduction in productivity of wheat by 3^{0}C rise in temperature during this period, and adjudged to be the most critical stage. Gupta *et al*. (2017) also reported reduction in wheat yield due to higher minimum temperature during the reproductive stage at Jammu.

Table 1. Yield and harvest index of wheat varieties, under various sowing environments and N-levels.

Treatments	Grain yield		Biological yield		Harvest index	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Varieties						
V_1: HD 2967	41.60	43.95	100.17	107.73	41.5	40.8
V_2: RSP 561	39.75	42.55	98.98	107.43	40.2	39.6
V_3: WH 1105	45.73	46.17	108.44	113.65	42.1	40.5
CD (5%)	3.32	1.84	5.01	3.38	NS	NS
Sowing environments						
D_1: 25th October	47.07	48.57	113.21	121.30	41.5	40.0
D_2: 14th November	43.13	46.49	102.72	113.46	42.0	41.0
D_3: 4th December	36.87	37.59	91.66	94.05	40.3	40.0
CD (5%)	2.02	1.82	3.45	3.97	1.36	0.78
Nitrogen levels						
N_1: 100 kg N/ha	39.55	41.79	96.07	104.41	41.1	40.0
N_2: 125 kg N/ha	43.13	44.71	104.16	110.76	41.3	40.4
N_3: 150 kg N/ha	44.40	46.16	107.37	113.63	41.3	40.6
CD (5%)	1.35	1.41	5.97	6.88	NS	NS

Performance of wheat crop was excellent when supplied with 150 kg N/ha with respect to grain yields in *rabi* 2015-16 (44.40 q/ha) and 2016-17 (46.16 q/ha) but the values were statistically similar with that of 125 kg N/ha with the values of 43.13 and 44.71 q/ha, respectively (Table 1). Greater grain yield of wheat under higher N levels (125 kg/ha) could be traced to adequately N fertilized crop benefitted from higher rates of nitrogen nutrition that might have resulted into a more vigorous and extensive root system of crop leading to increased vegetative growth means for more sink formation and greater sink size, greater carbohydrate translocation from vegetative growth. Hameed *et al*. (2003) and Malve *et al.* (2017) also found the similar findings in wheat crop.

Under early and normal sowing environments WH 1105 variety proved to be better option as it recorded significantly higher grain yield values than HD 2967 and RSP 561 varieties (Table 2). Performance of all the varieties was statistically similar when the wheat crop was sown on 4th December (late). However, variety RSP 561 performed similarly during early and normal sowing environments. WH 1105 variety was found to be the best if sowing has to be done under early environment (25th October); whereas if sowing is to be done on 14th November (normal), varieties WH 1105, HD 2967 and RSP 561 can be taken into consideration. Hameed *et al*. (2003) concluded from his study that wheat variety Fakher-Sarhad performed better if it is sown on last week of October. Fayed *et al.* (2015) concluded from experiments on dates and varieties that Gemmeiza-9 variety of wheat is best suited under mediate sowing date (15th November) to maximize grain yield of wheat under N-Sinai environmental conditions.

Table 2. Interaction effect of varieties and sowing environments on grain yield (q/ha) of wheat.

Varieties	2015-16				2016-17			
	Sowing Environments				Sowing Environments			
	25th Oct.	14th Nov.	4th Dec.	Mean	25th Oct.	14th Nov.	4th Dec.	Mean
HD 2967	47.72	41.81	35.25	41.60	49.25	47.34	35.25	43.95
RSP 561	42.07	40.32	36.86	39.75	44.79	44.01	38.84	42.55
WH 1105	51.43	47.27	38.49	45.73	51.68	48.13	38.68	46.17
Mean	47.07	43.13	36.86		48.57	46.49	37.59	
CD (5%)	3.51				3.15			

Maximum temperature during reproductive stage of wheat showed a highly negative relationship with grain yield of the crop. A unit increase in maximum temperature during reproductive stage (anthesis to physiological maturity) of wheat crop reduced the grain yield by 2.16 q/ha (Fig. 3). Gupta *et al.* (2017) also found the similar results. Andarzian *et al.* (2015) concluded from his study that by delaying the sowing date beyond the optimum sowing date led to reduced grain weight because of the existence of high temperature during grain filling which decreased the length of grain filling period.

The CERES-Wheat model was calibrated for wheat crop for simulation of phenology and grain yield of wheat. The crop, weather and soil data was used to calibrate the CERES-Wheat model for the year 2015-16. The CERES-Wheat model calibrated with the data of the year 2015-16 was used to validate the crop data for the year 2016-17.

Accurate simulation of phenological events in a crop model under different growth conditions is important for a perfect prediction of crop growth and yield. CERES Wheat model was validated for days to anthesis and physiological maturity (Figs. 4 & 5). The model predicted dates of anthesis and maturity stages of wheat crop with coefficient of determination (R^2) between the simulated and observed days from sowing to anthesis and maturity stages to the tune of 0.79 and 0.76, respectively for *rabi* 2016-17. Kumari and Wadood (2016) also found the similar results regarding validation of days to anthesis and physiological maturity of wheat crop and the R^2 values were 0.61 and 0.74, respectively. Model showed a good relationship between predicted and observed grain yield of wheat values and coefficient of determination (R^2) was to the tune of 0.78 for validation (2016-17). The deviation between results of observed and simulated values of grain yield might be partly due to the error introduced in deriving the genetic coefficients for different varieties of wheat. The similar findings were also reported by Mall *et al*. (2016) during validation of CERES-Wheat model and observed R^2 value to the tune of 0.56 for grain yield of wheat.

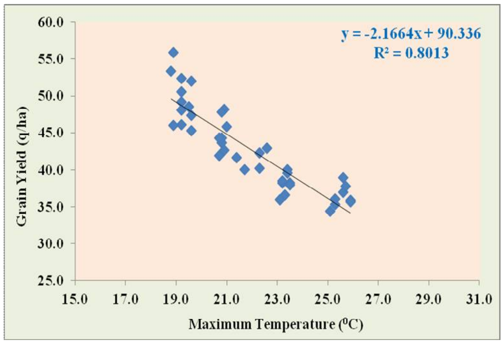

Fig. 3. Effect of maximum temperature at reproductive stage on grain yield of wheat .

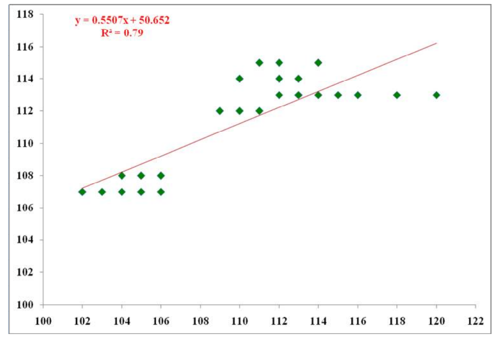

Fig. 4. Validation of days to anthesis of wheat through CERES-Wheat Model (*rabi* 2016-17).

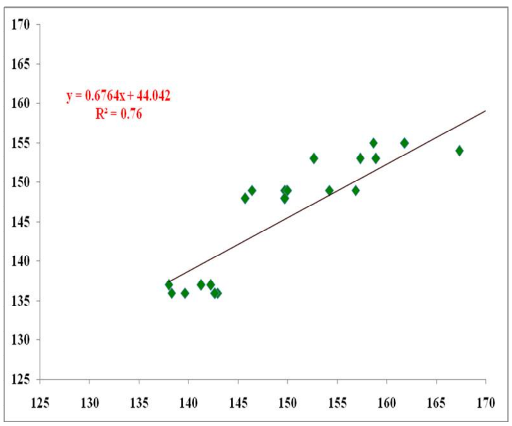

Fig. 5. Validation of days to maturity of wheat through CERES-Wheat Model (*rabi* 2016-17).

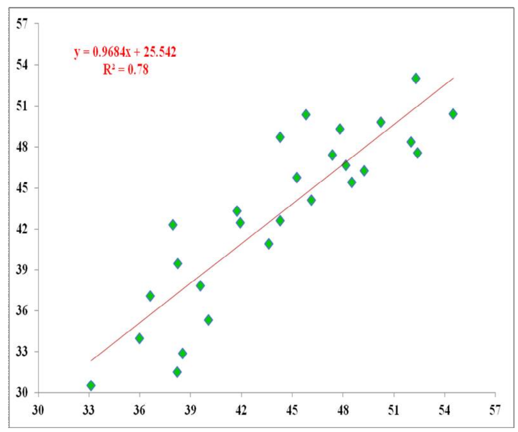

Fig. 6. Validation of grain yield of wheat through CERES-Wheat Model (2016-17).

The CERES-Wheat model provided rather reliable estimates of grain yield. The results might be useful for estimating the crop production and evaluate the effects of climate change on phenological events and grain yield of wheat under irrigated sub-tropical regions of N-W Himalayas.

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