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ORIGINAL ARTICLE **OPEN ACCESS**

Validation of CERES-Maize model for growth, yield attributes and yield of *kharif* maize for Southern Rajasthan

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ABSTRACT
The present study was conducted by using data from the experiment carried out at Instructional Farm, RCA, Udaipur (Rajasthan) during kharif 2013 and 2014. The experiment was conducted with two sowing dates with four cultivar (Pratap HQPM – 1, Bio – 9637, Pratap Makka – 3 and Pratap Makka – 5) and three foliar spray (2 % urea, 4 % urea and water spray). Sowing dates of experimental crop were 25thJune and 15thJuly. Genetic coefficients required for the CERES-Maize V 4.5 model for simulation of the growth, yield and yield attributes of maize crop have been derived for all for maize cultivars for this agroclimatic zone. Simulated values obtained were validated against observed values of field experiment during kharif2013 and 2014. Results revealed that the CERES V 4.5 model performed well for simulating phenological stages, test weight, grain and stover yield and the per cent error was always less than 15 per cent.
Key words: CERES-Maize model, genetic coefficient, validation

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INTRODUCTION

Maize or corn (*Zea mays*) is one of the most important cereal crops cultivated globally. Maize is also known as 'Queen' of cereals because it has the highest genetic yield potential among the cereals. Maize occupies an important place in India due to its high potential for yield and greater demand for food, feed and industrial utilization. In India maize is grown over an area of 9.4 million hectares with the production of 24.4 million tonnes in year 2013-14 and ranks as the third in food grain production [1]. Average productivity of maize in India is 2676 kg ha^{-1} and share of maize in total *kharif* food grain production is 16.62 per cent. Maize is cultivated in almost all the states of India, but its extensive cultivation is confined to Karnataka, Andhra Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Bihar, Uttar Pradesh, Madhya Pradesh, and Gujarat. Rajasthan occupies an area of 8.91 lakh hectares with a production of 15.51 lakh tones and productivity of 1740 kg ha^{-1} [2]. Rajasthan ranks 4th in maize with 7.74 per cent share in overall production in India.

Successful prediction of plant growth and yield require appropriate crop growth model and this model was found to be able to predict the phenological occurrence of the crop in advance to decision making for farmers in respect to crop management operations as well planning point of view for betteroutputs, timely harvesting of crop.

The CERES-Maize model has been tested and evaluated extensively by many researchers across location with good agreements between observed and simulated values for a wide range of experimental practices against field data and environmental conditions around the world. Whereas, very few studies have been undertaken in India especially in Rajasthan to evaluate the CERES-Maize model. Therefore, the main objective of this study was to validate the performance of CERES-maize model in simulating the effect of date of sowing and cultivars on growth and yield of maize (*Zea mays* L.) in southern Rajasthan.

MATERIAL AND METHODS

The experiment was conducted during *kharif* season of 2013 and 2014 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur. The experimental site is situated in the step foot of Aravali Hills at 24^{0}35' N latitude and 72^{0}42' E longitude and at an elevation of 582.17 m above mean sea level. This region falls under agro-climatic zone IV- a (Sub-humid Southern Plains and Aravali Hills) of Rajasthan. The soil of experimental field was clay loam in texture, slightly alkaline in reaction and calcareous in nature. It was medium in nitrogen and phosphorus and rich in available potassium. The experiment was laid out in split plot design with three replications, assigning 24 treatments consisting of two date of sowing (25th June and 15th July), four varieties (Pratap HQPM – 1, Bio – 9637, Pratap Makka – 3 and Pratap Makka – 5) as main plot treatments and three foliar spray (2 % urea, 4 % urea and water spray) as sub plot treatment.Data with respect to growth, yield and yield attributes were carefully recorded from randomly selected plants. The CERES-Maize V 4.5 model was validated during *kharif* 2013 and 2014 with the genetic coefficients derived (Table 1) from data sets.

Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from its use should be performed. Model validation, in its simplest form is a comparison between simulated and observed values. Model validation, in its simplest form is a comparison between simulated and observed values.Beyond comparisons, there are several statistical measures available to evaluate the association between predicted and observed values.

Willmott [3] calculate an index of agreement (D), MAE and RMSE as follows.

$$D = 1 - \left[\sum_{i=1}^{n} (P_i - O_i)^2 \Big/ \sum_{i=1}^{n} \left(I P_i^{'} I + I O_i^{'} I \right)^2 \right]$$

$$MAE = \sum_{i=1}^{n} \left[1 P_i - O_i 1 \right] / n$$

$$RMSE = \left[\sum_{i=1}^{n} (P_i - O_i)^2 / n \right]^{1/2}$$

Where,

O = Observed value

P = Predicted value

$P^{'}_{i}$ = Pi – P and $O^{'}_{i}$ = Oi – O.

Varshneya [4] gave a simple indication of error in prediction defined the Percent Error (PE). PE is defined as ratio of RMSE to mean observed value expressed as percentage.

$$PE = \frac{RMSE}{\bar{O}} \times 100$$

To assess the accuracy of the model simulation compared with the observations, data generated from two date of sowing and four cultivars of maize over 2 years (2013 and 2014) were used for validating the performance of CMS-CERES-Maize model. Prediction capabilities of the model were tested by judging the performance of the crop in terms of grain yield, phenology (days to emergence and maturity), straw yield and test weight.

Model calibration or parameterization is the adjustment of parameters so that simulated values compare well with observed values. Six genetic coefficients (Table 4.1) that influence the occurrence of growth and stages in the CERES 4.5 maize model for all four genotypes were derived iteratively, by manipulating the relevant coefficients to achieve the best possible match between the simulated and one set of observed field data. The calibrated genetic coefficients i.e. P_1, p_2, p_5, g_2, g_3 and PHINT for different maize cultivars were 375, 0.400, 750, 810, 8.30 and 38 for Pratap HQPM – 1, 355, 0.400, 770, 840, 7.30 and 36 for Bio – 9637, 310, 0.000, 730, 726, 7.00 and 30 for Pratap Makka – 3 and 285, 0.300, 730, 750, 7.30 and 30 for Pratap Makka – 5, respectively.

RESULTS AND DISCUSSION

Days to emergence

The observed duration of days to emergence varied between 3.95 (D_1V_4) to 5.19 days (D_2V_2), 3.96 (D_2V_3) to 5.30 days (D_2V_2) during 2013 and 2014, respectively. Similarly, the corresponding values as simulated by the model ranged between 4 to 5 days during both the years. Days to emergence as simulated by the model were found almost same as observed days to emergence during both the years (Table 4.2).

The range of magnitude of deviation between simulated and observed days to emergence varied less than one day in various treatments during the years 2013 and 2014. The highest magnitude of error percent of deviation between simulated and observed days to emergence was recorded as 6.98 and 9.50 per cent in 15th July sown Pratap Makka – 5 during the years 2013 and 2014, respectively. However, during both the years, 25th June sown Pratap Makka – 3 recorded near perfect agreement between simulated and observed days to emergence. The trend of MAE, RMSE and degree of agreement were recorded almost same as observed for days to emergence. The performance of CERES 4.5 model in terms of simulated days to emergence was found superior in the year 2013 to that in 2014. Soler *et al.* [5] also reported Close prediction of days to emergence in maize by using CERES-maize model in different environments.

Days to physiological maturity

An effort was made to predict the days to maturity for different treatments and the results of predictions were evaluated with respect to the observed duration in days. Data presented in Table 4.3 reveal that the observed duration of days to maturity varied between 79.11 (D_2V_3) to 98.74 (D_1V_1) days and that simulated by model ranged between 98 (D_2V_3) and 105 (D_1V_1) days during the crop-growing season of the year 2013. Similarly, the observed variation in days to maturity ranged between 79.21 (D_2V_2) to 99.40 (D_1V_1) days and that simulated values from 97 (D_2V_3 and D_2V_4) to 108 (D_2V_1) for the year 2014.

The values of error percent in the model simulated days to maturity from their correspondingly observed values in different cultivars of maize varied between - 6.34 to - 23.87 days during 2013 and -1.87 to -22.46 days during 2014. The highest magnitude of error percent of deviation between simulated and observed days to maturity recorded was -23.87 and 22.46 per cent in D_2V_3 during 2013 and 2014, respectively.

The results of various test criteria used for evaluation of model with respect to days to maturity for 2013 and 2014 were calculated and are presented in Table 3 and results showed the values of errors as computed in terms of MAE, RMSE and percent errors showed that model performed better in 2014 than in 2013. The index of agreement (0.93 and 0.94) during 2013 and 2014, respectively shows reasonable agreement between simulated and observed days to maturity. Days to maturity as simulated by the model were found to have been underestimated on comparison with correspondingly by observed during both the years. The performance of the model in simulating days to maturity was good as magnitudes of error percent remain less than 15.0 per cent in most of the cases. The results are in tune with those of Ritchie and Alagarswamy [6].

Leaf area Index

The results depicted in Table 4 show that the highest LAI 3.00 (2013) and 3.11 (2014) was recorded in cultivar Pratap Makka - 3 under 25th June sowing than other treatment combinations. Simulated LAI in D_1 sown maize were 2.49, 3.34, 3.40 and 3.40 for cultivars Pratap HQPM – 1, Bio – 9637, Pratap Makka – 3 and Pratap Makka – 5, respectively while, the corresponding values of observed LAI was 2.67, 2.71, 3.00 and 2.97 in 2013. A slight higher LAI was simulated than observed except Pratap HQPM – 1 during the year 2013. The observed values of LAI in case of D_2 sowing were 2.55, 2.51, 2.89 and 2.74 for Pratap HQPM – 1, Bio – 9637, Pratap Makka – 3 and Pratap Makka – 5, respectively in 2013, while the simulated LAI were 2.57, 3.43, 3.26 and 3.26, respectively for corresponding cultivars. LAI as simulated by the model were found to have been overestimated on comparison with correspondingly by observed under 15th July sowing date in the year 2013. Similarly, during 2014, the model overestimated the LAI in all four cultivars and dates of sowing except at few points *i.e.* D_1V_1, D_2V_1 and D_2V_2.

The error percentage between simulated leaf area index by the model and the corresponding observed ones during both the years are presented in Table 4. The range of error percent between simulated and observed LAI varied between -23.16 to 6.90 % during 2013. The corresponding values in 2014 were -24.83 to 24.29 %. The performance of the model in simulating the LAI was good as magnitudes of error remain less than 15.0 per cent in most of the cases except D_1V_2 and D_2V_4 in 2013 and D_1V_2 and D_2V_2 in 2014. However, there was no definite trend of error per cent found among the treatment consisting of two different dates of sowing and four different cultivars. The results of various test criteria used for evaluation of model with respect to leaf area index for both the years were calculated and are presented in Table 4. The values of RMSE for observed and simulated maximum LAI were 0.40 and 0.38 for 2013 and 2014, respectively. The per cent error during 2013 and 2014 was also less than 15 per cent i.e. 14.45 and 13.30 per cent, respectively.The findings of present investigation are in close agreement with the finding of Chisanga *et al.* [7].

Test weight

An effort was made to predict the test weight for different treatments and the results of predictions were evaluated with respect to the observed test weight. As per data presented in Table 5, the observed test weight varied between 158.56 g (D_2V_3) to 206.56 g (D_1V_1) and that simulated by model ranged between 172.50 g (D_2V_3) and 206.80 g (D_1V_4) during the year 2013. Similarly, the observed variation in test weight ranged between 169.47 g (D_2V_3) to 218.32 g (D_1V_1) and that simulated values from 173.4 g (D_1V_2) to 216.60 g (D_2V_1) for the year 2014.

The highest magnitude of error percent of deviation between simulated and observed test weight was - 8.79 in D_2V_3 followed by - 8.51 in D_1V_4 during 2013. Similarly, during 2014, the error per cent of deviation was -19.83 in D_2V_1 followed by 17.27 in D_1V_2. The results of various test criteria used for evaluation of model with respect to test weight for 2013 and 2014 showed that the values of errors as computed in terms of MAE, RMSE and percent errors showed that model performed better in 2013 than in 2014. The close agreement between the observed and simulated values for test weight were also reported by Lobell and Burke [8].

Grain yield

Measured grain yield of maize varied from 3625 (D_2V_3) to 5210 kg ha^{-1} (D_1V_1) among different cultivars and dates of sowing during 2013, while grain yield simulated by CERES 4.5 crop growth simulation model ranged between 4067 (D_2V_4) to 5243 kg ha^{-1} (D_1V_1). The model overestimated the grain yield in most of the treatment combinations except D_2V_1 and D_2V_4. Similarly, in the year 2014, measured grain yield of maize varied from 3565 (D_2V_3) to 5379 kg ha^{-1} (D_1V_1) among different cultivars and dates of sowing, while grain yield simulated by CERES 4.5 crop growth simulation model ranged between 3590 (D_2V_2) to 4948 kg ha^{-1} (D_1V_1).

Error percent of simulated grain yields of maize by CERES 4.5 from those corresponding observed ones during the crop seasons of 2013 and 2014 are presented in Table 6. Error per cent ranged between 1.93 (D_2V_4) to -18.26 (D_2V_3) during 2013 and 19.68 (D_2V_1) to -19.33 (D_2V_3) during 2014. Results for grain yields as simulated by the model under two different date of sowing and four different cultivars were found under acceptable limits.

The results also showed that the model overestimated the grain yield in most of the treatment combinations except D_2V_1 during 2013. Whereas, during 2014, model underestimated the grain yield in most of the treatment combinations except D_2V_3. Simulation performance of the model under all treatments was satisfactory and performed best under timely sowing on 25th June during both the years except D_1V_3 in the year 2014.

The averaged errors as computed by MAE (mean absolute error) were 284.50 and 542.75 kg ha^{-1}, while RMSE (Root mean square error) were 399.07 and 607.70 during 2013 and 2014, respectively. Lower MAE and RMSE were lower during the year 2013. Similarly, the lower PE (percent error) also followed the same trend like MAE and RMSE with 8.88 and 13.25 values during both the years. Index of agreement (D) for both the years was 0.97 and 0.93. The evaluation of the model on an overall basis revealed that the simulation performance of the model in respect of grain yield was found perfect. Although, simulated grain yields by the model were very close with the observed grain yield for different dates of sowing of various maize cultivars, but there was slight variations. Kumar et al. [9] also reported close prediction of grain yield by CERES-maize model in different environments.

Stover yield

Data presented in Table 7 reveal that measured stover yield of various maize cultivars ranged between 7222 (D_2V_2) to 9094 kg ha^{-1} (D_1V_4) among different date of sowing during year 2013, while model simulated stover yield ranged between 7164 (D_2V_3) to 8460 kg ha^{-1} (D_2V_4). The model overestimated the stover yield in the treatments of D_2V_1 and D_2V_4, while overestimation in rest of the treatments during 2013. In case of the second year crop season, measured stover yield ranged between 7343 (D_2V_2) to 9359 kg ha^{-1} (D_1V_4), while the simulated biomass varied from 7820 (D_1V_3) to 8927 kg ha^{-1} (D_2V_1). The model overestimated the stover yield in the treatments of D_1V_1, D_2V_1 and D_2V_2, while overestimation in rest of the treatments during 2014. The error percent for CERES 4.5 model simulated stover yield observed during the years 2013 and 2014 are presented in Table 7. Error percent ranged between –3.22 (D_2V_4) to 19.85 (D_1V_3) during 2013 and -16.89 to 15.97 during 2014. The lowest percent error recorded during 2013 and 2014 was 0.25 in D_2V_2 and 1.80 in D_2V_4, respectively.

The various test criteria for evaluation of model were computed for 2013 and 2014. Results showed that the average errors as computed by MAE were 821.25 and 831.78 kg ha^{-1}, while RMSE values were 1036.68 and 968.68 kg ha^{-1} during 2013 and 2014, respectively. The index of agreement (D) was 0.94 in both the years.The RMSE, MAE, PE and index of agreement values are under acceptable limits and results are in tune with those of Plantureux *et al.* [10].

Table 1: Calibration of genetic coefficient of maize cultivars

Maize cultivars / Genetic coefficient	Pratap HQPM-1	Bio – 9637	Pratap Makka-3	Pratap Makka-5
P1 (Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days, °C day, above a base temperature) during which the plant is not responsive to changes in photoperiod**)**	**375**	**355**	**310**	**285**
P2 (Extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate)	**0.400**	**0.400**	**0.000**	**0.300**
P5 (Thermal time from silking to physiological maturity)	**750**	**770**	**730**	**730**
G2 (Maximum possible number of kernels per plant)	**810**	**840**	**726**	**750**
G3 (Kernel filling rate during the linear grain filling stage and under optimum conditions (mg day^{-1})	**8.30**	**7.30**	**7.00**	**7.30**
PHINT (Phyllochron interval; the interval in thermal time (degree days) between successive leaf tip appearances)	**38**	**36**	**30**	**30**

Table 2: Validation of CERES 4.5 Maize model simulated days to emergence of maize.

Treatment	**2013**				**2014**			
	Observed (days)	**Simulated (days)**	**Deviation (days)**	**Error %**	**Observed (days)**	**Simulated (days)**	**Deviation (days)**	**Error %**
D_1V_1	4.84	5	-0.16	3.31	4.85	5	-0.15	-3.09
D_1V_2	5.03	5	0.03	0.60	5.04	5	0.04	0.79
D_1V_3	4.01	4	0.01	0.25	4.02	4	0.02	0.50
D_1V_4	3.95	4	-0.05	-1.27	3.96	4	-0.04	-1.01
D_2V_1	5.16	5	0.16	3.10	5.27	5	0.27	5.12
D_2V_2	5.19	5	0.19	3.66	5.30	5	0.30	5.66
D_2V_3	4.19	4	0.19	4.53	4.30	4	0.30	6.98
D_2V_4	4.3	4	0.3	6.98	4.42	4	0.42	9.50
RMSE	0.16				0.24			
MAE	0.14				0.19			
PE	3.59				5.14			
Index of agreement (D)	0.98				0.98			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

Table 3: Validation of CERES 4.5 Maize model simulated days to physiological maturity of maize.

Treatment	**2013**				**2014**			
	Observed (days)	**Simulated (days)**	**Deviation (days)**	**Error %**	**Observed (days)**	**Simulated (days)**	**Deviation (days)**	**Error %**
D_1V_1	98.74	105	-6.26	-6.34	99.40	108	-8.60	-8.65
D_1V_2	94.86	102	-7.14	-7.52	95.63	107	-11.37	-11.89
D_1V_3	82.68	101	-18.32	-22.15	83.58	100	-16.42	-19.65
D_1V_4	89.43	101	-11.57	-12.94	90.20	100	-9.80	-10.87
D_2V_1	94.07	104	-9.93	-10.56	96.20	98	-1.80	-1.87
D_2V_2	92.20	102	-9.80	-10.63	92.33	98	-5.67	-6.15
D_2V_3	79.11	98	-18.89	-23.87	79.21	97	-17.79	-22.46
D_2V_4	85.32	99	-13.68	-16.03	86.42	97	-10.58	-12.24
RMSE	12.74				11.36			
MAE	11.95				10.25			
PE	14.22				12.57			
Index of agreement (D)	0.93				0.94			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

Table 4: Validation of CERES 4.5 Maize model simulated LAI of maize.

Treatment	2013				2014			
	Observed	Simulated	Deviation	Error %	Observed	Simulated	Deviation	Error %
D_1V_1	2.67	2.49	0.18	6.90	2.73	2.57	0.16	5.84
D_1V_2	2.71	3.34	-0.63	-23.16	2.81	3.50	-0.70	-24.83
D_1V_3	3.00	3.40	-0.40	-13.24	3.11	3.23	-0.13	-4.03
D_1V_4	2.97	3.40	-0.44	-14.73	2.96	3.23	-0.27	-9.29
D_2V_1	2.55	2.57	-0.02	-0.89	2.68	2.47	0.22	8.03
D_2V_2	2.51	2.78	-0.27	-10.78	2.70	2.04	0.65	24.29
D_2V_3	2.89	3.26	-0.37	-12.89	3.06	3.20	-0.14	-4.53
D_2V_4	2.74	3.26	-0.53	-19.23	2.91	3.20	-0.29	-10.02
RMSE	0.40				0.38			
MAE	0.35				0.32			
PE	14.45				13.40			
Index of agreement (D)	0.93				0.93			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

Table 5: Validation of CERES 4.5 Maize model simulated '000 grain weight (test weight) of maize.

Treatment	2013				2014			
	Observed (g)	Simulated (g)	Deviation (g)	Error %	Observed (g)	Simulated (g)	Deviation (g)	Error %
D_1V_1	206.56	199.40	7.16	3.47	218.32	192.50	25.82	11.82
D_1V_2	194.80	197.20	-2.40	-1.23	209.60	173.40	36.20	17.27
D_1V_3	192.17	176.10	16.07	8.36	199.23	184.50	14.73	7.39
D_1V_4	190.59	206.80	-16.21	-8.51	198.88	212.00	-13.12	-6.60
D_2V_1	194.86	193.80	1.06	0.54	180.76	216.60	-35.84	-19.83
D_2V_2	189.40	199.80	-10.40	-5.49	186.55	195.60	-9.05	-4.85
D_2V_3	158.56	172.50	-13.94	-8.79	169.47	190.30	-20.83	-12.29
D_2V_4	175.06	189.60	-14.54	-8.30	176.16	198.50	-22.34	-12.68
RMSE	11.69				24.15			
MAE	10.22				22.24			
PE	6.23				12.55			
Index of agreement (D)	0.97				0.94			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

Table 6: Validation of CERES 4.5 Maize model simulated grain yield of maize.

Treatment	2013				2014			
	Observed (kg ha^{-1})	Simulated (kg ha^{-1})	Deviation (kg ha^{-1})	Error %	Observed (kg ha^{-1})	Simulated (kg ha^{-1})	Deviation (kg ha^{-1})	Error %
D_1V_1	5210	5243	-33.00	-0.63	5379	4948	431.00	8.01
D_1V_2	4893	4963	-70.00	-1.43	5081	4815	266.00	5.24
D_1V_3	4657	4850	-193.00	-4.14	4750	4082	668.00	14.06
D_1V_4	4301	4709	-408.00	-9.49	4279	3878	401.00	9.37
D_2V_1	4801	4757	44.00	0.92	5001	4017	984.00	19.68
D_2V_2	4315	5101	-786.00	-18.22	4388	3590	798.00	18.19
D_2V_3	3625	4287	-662.00	-18.26	3565	4254	-689.00	-19.33
D_2V_4	4147	4067	80.00	1.93	4235	4130	105.00	2.48
RMSE	399.07				607.70			
MAE	284.50				542.75			
PE	8.88				13.25			
Index of agreement (D)	0.97				0.93			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

Table 7: Validation of CERES 4.5 Maize model simulated Stover yield of maize.

Treatment	2013				2014			
	Observed (kg ha^{-1})	Simulated (kg ha^{-1})	Deviation (kg ha^{-1})	Error %	Observed (kg ha^{-1})	Simulated (kg ha^{-1})	Deviation (kg ha^{-1})	Error %
D_1V_1	7698	6949	749.00	9.73	7785	8070	-285.71	-3.67
D_1V_2	8652	7476	1176.00	13.59	8949	8520	428.75	4.79
D_1V_3	9023	7232	1791.00	19.85	9306	7820	1485.89	15.97
D_1V_4	9094	8254	840.00	9.24	9359	8397	962.64	10.29
D_2V_1	7671	7772	-101.00	-1.32	7637	8927	-1289.99	-16.89
D_2V_2	7222	7204	18.00	0.25	7343	8402	-1058.69	-14.42
D_2V_3	8795	7164	1631.00	18.54	8912	7915	996.89	11.19
D_2V_4	8196	8460	-264.00	-3.22	8074	7928	145.71	1.80
RMSE	1036.68				948.68			
MAE	821.25				831.78			
PE	12.50				11.27			
Index of agreement (D)	0.94				0.94			

D_1= 15th June, D_2=15th July, V_1= Pratap HQPM-1, V_2=Bio – 9637, V_3= Pratap Makka-3 and V_4= Pratap Makka-5

CONCLUSION

The present study is more helpful for planning and advising the farmers to optimize farm operations and marketing crops' produce. Simulated values obtained in respect to grain yield of maize would enable the policy makers to take economic decision.

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