International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 157-160
© 2018 IJCS
Received: 25-09-2018
Accepted: 30-10-2018

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Zone wise yield forecast for rice crop of using simulation model

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Abstract

Rice is one of the important staple cereal crops of the world with an area of 147.3 million ha and production of 518.4 million tonnes. In Asia, 90% of world's rice is grown and consumed rice contributes around 45% of India's cereal production and is the main staple food for over 60% of the population in the country. In C.G., Rice is cultivated in an area of 3.5 million ha with a total production of 5.9 million tonnes and productivity of 1646 Kg per ha. The data related to the productivity, area and production were collected from Department of Agriculture and Bio-technology, Chhattisgarh. Meteorological data were collected from different Agromet observatories located in the different station of IGKV, Raipur. The results showed that the values of coefficient of determination (R^2) was 0.98, 0.99,0.98 and 0.99 in the zones 1, 2, 3 and 4, respectively. However all the values were found significant at 5%probability level during the period 1998-2007. Deviations in simulated yields showed positive correlation (r) values 0.51, 0.41, 0.27 and 0.22 in zones 1,2, 3 and 4 respectively. Average yield was found 1353 Kg ha^{-1} for zone 1, 1223 Kg ha^{-1} for zone 2, 1133 Kg ha^{-1} for zone 3 and 1288 Kg ha^{-1} for zone 4, respectively. It was concluded that CERES-rice can be utilized to predict development (phonological stages), growth, yield and yield attributes.

Keywords: rice crop, yield forecast, simulation model, statistical model, zonewise

Introduction

Rice is one of the important staple cereal crops of the world with an area of 147.3 million ha and production of 518.4 million tonnes. In Asia, 90% of world's rice is grown and consumed and about 2.8 million people derive 35-39% of the total calorie intake from Rice (Anonymous, 1996) [1]. Rice contributes around 45% of India's cereal production and is the main staple food for over 60% of the population in the country. Presently, Rice is cultivated in an area of 43 million ha with a total production of 86.30 million tonnes (Singh *et al.*, 2001) [7]. In C.G., Rice is cultivated in an area of 3.5 million ha with a total production of 5.9 million tonnes and productivity of 1646 Kg per ha. With the current trends of population growth and agricultural production, the demand for food in most parts of world will grow nearly double by the 2025 and nearly triple by 2050. In the increasing food demand scenario the forecasting of rice production well in advance would be of immense value for policy makers.

Crop production involves a complex interaction between crop genotype, the soil, the aerial environment and crop management practices. Weather plays an important role in the growth and development of the rice and decides the year to year variability in rice yield. Fluctuations in the total seasonal rainfall and its intra-seasonal distribution have strong influence on rice productivity. Moisture stress due to prolonged dry spells and thermal stress due to heat wave conditions significantly affect the rice productivity when they occur in critical life stages of the crop.

CERES-Rice (Crop Environment Resources synthesis) is a dynamic crop simulation model developed by Godwin *et al.* (1992) [2] to simulate plant physiological processes, such as photosynthesis, transportation, nutrient and water uptake, respiration, morphogenesis and biomass partitioning to predict growth, development and yield in daily time steps in a manner similar to the processes as they are visualized (Uehara G., 1985) [8]. Thus CERES-Rice model could be used to predict the productivity of crop on experimental as well as regional level.

Empirical statistical model are developed on the basis of long term relationship between crop yield and several variables (representing weather, soil characteristic, technology trend, etc.) The independent variables are either measured meteorological parameters such as temperature, rainfall, solar radiation or estimates such as potential evapo-transpiration, simulated soil

Moisture regime etc. The weighting coefficients in these equations are by necessity obtained in an empirical manner using standard statistical procedure such as multiple regression analysis. This approach does not easily lead to an explanation of cause and effect relationships. Advantages of these methods are ease in formulation and analysis, simplicity and good performance inspite of their obvious limitations.

Keeping these points in view, a study was carried out to forecast the rice yield for different Zone of Chhattisgarh through simulation Model.

Materials and Methods

The study was carried out in the Department of Agrometeorology, COA, IGKV, Raipur, while the data related to the productivity, area and production were collected from Department of Agriculture and Bio-technology, Chhattisgarh. Meteorological data were collected from different Agromet observatories located in the different station of IGKV, Raipur.

Description of CERES-rice model

The CERES-Rice model of the DSSAT modeling system is an advanced physiologically based rice crop growth simulation model and has been widely applied to understanding the relationship between rice and its environment. The model estimates yield of irrigated and non-irrigated rice, determine duration of growth stages, dry matter production and portioning, root system dynamics, effect of soil water and soil nitrogen contents on photosynthesis, carbon balance and water balance. Ritchie *et al*. (1987) [5] and Hoogenboom *et al*. (2003) [3] have provided a detailed description of the model.

Inputs files

Weather data

The input data required to run the DSSAT shell include daily weather information (maximum as well as minimum temperature, rainfall and solar radiation). Daily weather data from 1998 to 2007 were collected from the Department of Agricultural Meteorology, Indira Gandhi Agricultural University, Raipur (C.G.). S.G.CARS. Jagdalpur, COA Bilaspur and COA Ambikapur. Daily weather data as stated above includes parameters of temperature (maximum and minimum), rainfall, and bright sunshine hours.

Soil data

The model also requires horizon-wise data such as; number of horizons, thickness of a horizon (cm), field capacity (fraction), wilting point (fraction), air dry level (fraction), lower limit drained (cm^3 cm^{-3}). Upper drained limit (cm^3 cm^{-3}), saturated hydraulic conductivity (cm hr^{-1}), bulk density moist (g cm^{-3}), organic carbon (%), clay (<0.002 mm) (%), silt (0.05 to 0.002 mm) (%), coarse fraction (> 2mm) (%), total nitrogen (%), pH in water, pH in buffer, cation exchange capacity (cmol kg^{-1}), root growth factor (0.0 to 1.0). This all information was obtained from published literature. The values of soil parameters, which could not be obtained from literature were taken as normal. The initial water status of the soil in each year was assumed at drained upper limit (0.03 Mpa) in a fallow field.

Genetic coefficient

The CERES-Rice model uses eight genetic coefficients viz., P1, P20, P2R, P5, G1, G2, G3 and G4. The first four coefficients are describes below:

P1	Time period (expressed as growing degree days [GDD] in °C above a base temperature of 9°C) from seedling emergence during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant.
P20	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P20 developmental rate is slowed, hence there is delay due to longer day lengths.
P2R	Extent to which phasic development leading to panicle initiation is delayed (expressed in GDD in °C) for each hour increase in photoperiod above P20.
P5	Time period in GDD (°C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9°C.
G1	Potential spikelet number coefficient as estimated from the number of spikelets per gram of main culm dry weight (less leaf blades and sheaths plus spikes) at anthesis (a typical value is 55).
G2	Single grain weight (gram) under ideal growing conditions, i.e. non-limiting light, water, nutrients and absence of pests and diseases.
G3	Tillering coefficient (scalar value) relative to IR64 cultivar under ideal conditions (a high tillering cultivar would have coefficient greater than 1.0).
G4	Temperature tolerance coefficient (using 1.0) for varieties grown in normal environments. G4 for japonica type rice growing in warmer environment would be 1.0 or greater. Likewise, the G4 value for indica type rice in very cool environments or season would be less than 1.0.

These genetic coefficients were derived iteratively following Hunt's method (Hunt *et al.*, 1993) [4].

Result and Discussion

District/ zone level prediction of rice yields

The identified sixteen districts were divided in four zones by merging different districts with their neighboring major coherent rice yield variability districts, resulting overall four zones in Chhattisgarh. Rice yields were for the period from 1998-2007 and their comparison was made with the actual observed rice yield.

Zone -1 (Raipur, Mahasamund, Durg, Kavardha and Koria)

Predicted yield for Raipur district (Table 1) ranged from 504 kg ha^{-1} to 2013 kg ha^{-1} with a mean yield of 1352kg ha^{-1}. The yield forecasts for the years 1998-2007 were 1438, 1464, 504, 1211, 687, 2013, 1332, 1705, 1511 and 1660 kg ha^{-1}.The value of coefficient of determination R^2 was 0.16. Correlation coefficient between deviations of observed and simulated yield was 0.51 for the Zone -1. The rice yields were predicted using relationship between observed and simulation model predicted yields, which varied from average 9 kg ha^{-1} (1998-2007).

Table 1: Zone I (Raipur) rice yield predicted for Simulation model

Raipur						
Year	**Obs-Yield**	**Trend-Yield**	**DevIation**	**Sim-Yld**	**Sim_dev**	**Pre-Yield**
1998	1091	1035	5.4	5162	39.0	1438
1999	1471	1107	32.9	4911	32.2	1464
2000	550	1180	-53.4	1586	-57.3	504
2001	1485	1252	18.6	3593	-3.3	1211
2002	781	1324	-41.0	1927	-48.1	687
2003	1806	1397	29.3	5352	44.1	2013
2004	1531	1469	4.2	3366	-9.4	1332
2005	1836	1542	19.1	4108	10.6	1705
2006	1513	1614	-6.3	3477	-6.4	1511
2007	1543	1687	-8.5	3656	-1.6	1660
Ave-Yield	1361			3714		1353

Zone - 2 (Dhamtari, Rajnandgaon, Kanker, Jagdalpur and Dantewada)

Deviations in observed yields were regressed with deviations in simulated yields, it showed highly positive correlation (r = 0.41,). Predicted yield for Jagdalpur district (Table 2) ranged from 998 kg ha^{-1} to 1668 kg ha^{-} with a mean yield of 1223 kg ha^{-1}. The yield forecasts for the years 1998-2007 were 1668, 1438, 988, 1350, 367, 1482, 1092, 1510, 1080 and 1252 kg ha^{-1}. The value of coefficient of determination (Fig 2) R^2 was 0.17.

The Correlation coefficient between deviations of observed and simulated yield was 0.41 for the Zone -2. The rice yields were predicted using relationship between observed and simulation model predicted yields, which varied from average 12 kg ha^{-1} (1998-2007).

Table 2: Zone II (Jagdalpur) rice yield predicted for Simulation model.

Jagdalpur						
Year	**Obs-Yield**	**Trend-Yield**	**Dev**	**Sim-Yld**	**Sim_dev**	**Pre-Yield**
1998	1035	1091	-5.1	3306	52.9	1668
1999	1152	1123	2.6	2770	28.1	1438
2000	1145	1155	-0.8	1849	-14.5	988
2001	1398	1187	17.8	2459	13.8	1350
2002	962	1219	-21.1	651	-69.9	367
2003	1636	1251	30.8	2561	18.5	1482
2004	933	1283	-27.3	1840	-14.9	1092
2005	1260	1315	-4.1	2483	14.9	1510
2006	1305	1347	-3.1	1734	-19.8	1080
2007	1519	1379	10.2	1963	-9.2	1252
Ave-Yield	1235			2162		1223

Zone - 3 (Jashpur and Surguja)

Predicted yield for Ambikapur district (Table 3) ranged from 689 kg ha^{-1} to 1333 kg ha^{-} with a mean yield of 1133 kg ha^{-1}. The yield forecasts for the years 1998-2007 were 1333, 1304, 689, 1180, 1170, 1480, 1327, 892, 648 and 1310 kg ha^{-1}. The value of cofficient of determination (Fig 3) R^2 was 0.073.

Correlation coefficient between deviations of observed and simulated yield was 0.27 for the Zone -3. The rice yields were predicted using relationship between observed and simulation model predicted yields average value is same. Sharma and Kumar (2006) [6] parameterized and validated CERES-Rice model for Rice crop in H.P. using experimental results.

Table 3: Zone III (Ambikapur) rice yield predicted for Simulation model

Ambikapur						
Year	**Obs-Yield**	**Trend-Yield**	**Dev**	**Sim-Yld**	**Sim_dev**	**Pre-Yield**
1998	1018	1214	-16.2	2595	9.8	1333
1999	1168	1196	-2.4	2578	9.0	1304
2000	1147	1178	-2.6	1382	-41.5	689
2001	1555	1160	34.0	2404	1.7	1180
2002	1256	1142	10.0	2422	2.4	1170
2003	1233	1124	9.7	3113	31.7	1480
2004	792	1106	-28.4	2836	20.0	1327
2005	962	1088	-11.6	1938	-18.0	892
2006	1101	1070	2.9	1431	-39.5	648
2007	1100	1052	4.5	2944	24.5	1310
Ave-Yield	1133			2364		1133

Zone - 4 (Janjgir, Bilaspur, Korba and Raigarh)

Simulation model Predicted yield for Bilaspur district (Table 4) ranged from 527 kg ha^{-1} to 1747 kg ha^{-} with a mean yield of 1288 kg ha^{-1}. The yield forecasts for the years 1998-2007 were 1553, 1451, 746, 1281, 527, 1747, 1212, 1608, 1296and 1456 kg ha^{-1}. The value of coefficient of determination (Fig 4) R^2 was 0.048.

Correlation coefficient between deviations of observed and simulated yield was 0.22 for the Zone - 4. The rice yields were predicted using relationship between observed and simulation model predicted yields, which varied from average 72 kg ha^{-1} (1998-2007). Sharma and Kumar (2006) parameterized and validated CERES-Rice model for Rice crop in H.P. using experimental results.

Table 4: Zone IV (Bilaspur) rice yield predicted for Simulation model

BILASPUR						
Year	**Obs-Yield**	**Trend-Yield**	**Dev**	**Sim-Yld**	**Sim_dev**	**Pre-Yield**
1998	1059	1249	-15.2	4234	46.0	1553
1999	1585	1274	24.4	3841	30.2	1451
2000	1111	1299	-14.4	1718	-35.9	746
2001	1799	1323	36.0	3026	5.3	1281
2002	783	1348	-41.9	1289	-59.0	527
2003	1687	1372	22.9	3957	31.3	1747
2004	1024	1397	-26.7	2603	-12.1	1212
2005	1604	1422	12.8	3296	12.7	1608
2006	1452	1446	0.4	2606	-13.1	1296
2007	1497	1471	1.8	2810	-5.4	1456
Ave-Yield	1360			2938		1288

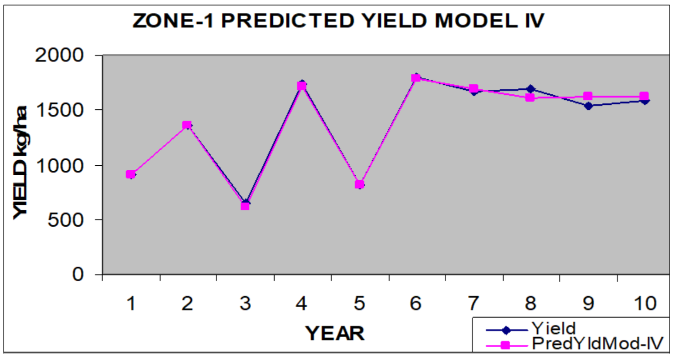

Fig 1: Zone wise predicted yield model, Raipur

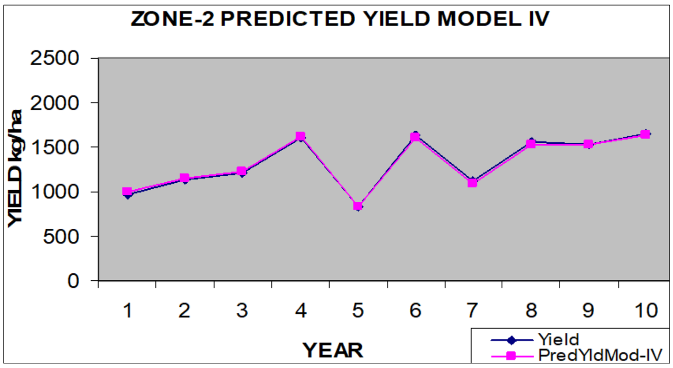

Fig 2: Zone wise predicted yield model, Jagdalpur

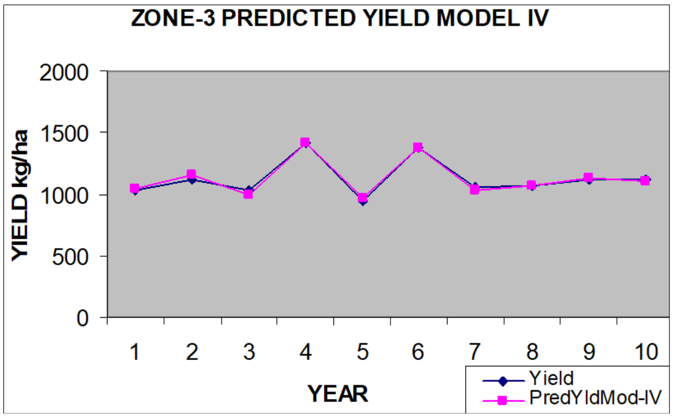

Fig 3: Zone wise predicted yield model, Ambikapur

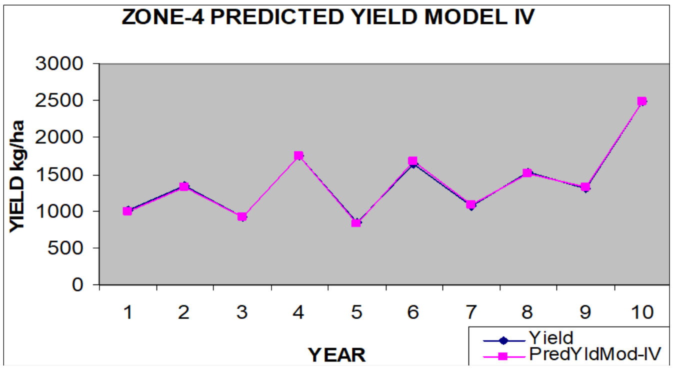

Fig 4: Zone wise predicted yield model, Bilaspur

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