Journal of Agrometeorology 10(2) : 165- 169 (Dec. 2008)

Assessment of production potential of rice with and without moisture stress in clayey soil using CERES-Rice model

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ABSTRACT

CERES-Rice model incorporated in DSSAT ver 3.5 was used to simulate the rice (var: IR 36) yields for the period 1973-2002. The input data required for running the model viz., soil and weather data were collected from the Departments of Soil Science and Agrometeorology of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, respectively.

The results revealed that the potential yields of rice varied from 81.97 to 105.50 q ha^{-1} and 39.74 to 89.49 q ha^{-1} under irrigated and rainfed conditions respectively during the study period. If years of different rainfall situations were considered the yield reduction due to water stress under rainfed conditions ranged from 3.87 to 61.44 q ha^{-1} as compared to irrigated conditions indicating that under good rainfall conditions the rainfed rice yields are as good as irrigated rice yields.

Key Words: CERES-Rice model, yield potential, water stress

Rice is grown under the diverse environmental conditions of a wide range of latitudes and altitudes. The major climatic factors affecting growth and yield include solar radiation, temperature and rainfall (the later is particularly important in rainfed rice culture). In Chhattisgarh State rice is grown mostly under rainfed conditions and the productivity is very low as compared to national average. The average national productivity of rice is currently about 2 t ha^{-1} in contrast to the yield of about 6 t ha^{-1} which has been achieved in some parts of Uttar Pradesh, Punjab and Haryana due to favourable environmental conditions and better management techniques. In Chhattisgarh, only 25 per cent of the total rice cultivated area is under irrigation, the productivity being 1.6 to 1.9 t ha^{-1}, under irrigated condition and 1.0 to 1.1 t ha^{-1} under rainfed condition.

Crop simulation models not only help to extrapolate production technologies from one growing environment to the other but also to develop contingent plans at a given location under different stress conditions. DSSAT is a dynamic crop simulation model and within this the models for rice, maize, wheat etc are embedded. Various researchers (Kovacs *et al*., 1995 and Prasada Rao *et al*., 1994) tried to validated the DSSAT model for different crops under different situations. In the present study an attempt was made to assess the effect of moisture stress in different rainfall situations on the productivity of rice under rainfed conditions of Raipur in clayey soil.

MATERIALS AND METHODS:

In the study the CERES-Rice model embedded in DSSAT was used to assess the potential yields of rice during a period of 30 years (1973-2002) and attemepts were made to work out quantitatively the effect of water stress on rice yields as compared to irrigated conditions under different growing environments and the biomass productivity was also examined.

Weather data

Daily weather data from 1973 to 2002 were collected from the Department of Agricultural Meteorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh).

Preparation of weather files for model

Simulation model requires weather data to be stored in the format, which is compatible to the model. Weather data pertaining to this location were arranged in specific format of DSSAT 3.5 and were given the file extension of WTH.

S. No.		Particulars	Values
A.		**Physical Properties**	
	1.	Mechanical Compositions	
		Sand (%)	21.48
		Silt (%)	35.46
		Clay (%)	43.06
		Textural Class	Clayey
	2.	Field Capacity (%) (0-20 cm soil depth)	30.4
	3.	Permanent Wilting Point (%)	13.50
	4.	Maximum water holding capacity (%)	38.04
	5.	Bulk Density (Mg m^{-3})	1.42
B.		**Chemical Composition**	
	1.	Available N (kg ha^{-1})	206.03
	2.	Available P (kg ha^{-1})	13.75
	3.	Available K (kg ha^{-1})	365.35
	4.	pH (1:2.5, soil:water)	6.9
	5.	EC (dsm^{-1} at 25°C)	0.13

Year wise weather files in DSSAT were prepared for the study period (1973-2002). As DSSAT3.5 uses weather parameters in a sequence of Julian day, all the data like solar radiation, maximum temperature, minimum temperature and rainfall were compiled in the required manner.

Soil data

Soil data includes soil texture, soil local classification, soil family SCS system, soil depth (m), colour (moist), Albedo (fraction), evaporation limit (cm), drainage rate (fraction day^{-1}), runoff curve number, mineralization factor (0 to 1 scale), photosynthesis factor (0 to 1 scale) pH in buffer determination method, amount (%) and determination method of nitrogen, phosphorus and potassium were collected from the Department of Soil Science, IGKV, Raipur.

The initial water status of the soil in each year was assumed at drained upper limit (0.03 Mpa) in a fallow field.

The soil data used in the soil are as follows:

RESULTS AND DISCUSSION

The yield potential during different years of the study period both under irrigated and rainffed conditions simulated through CERES-Rice model are shown in Table 1. It can be seen that the potential yields even under irrigated conditions varied from 104.84 q ha^{-1} to 81.97 q ha^{-1}. These variations in potential yields during the study period were due to variations in thermal and radiation regimes. But under rainfed conditions the potential yield variations are due to variations in all the three regimes viz, thermal, radiation as well as moisture regime. The yield potential under rainfed conditions varied from 39.74 q ha^{-1} in 2002 to 87.99 q ha^{-1} in 1973. The year 2002 happened to be severe drought year in Raipur with an amount of 725 mm of rainfall as against the average of 1027.9 mm.

The difference between the potential yields under irrigated and rainfed conditions is attributable to the effect of water stress under given set of the weather conditions. In this way the effect of water stress could be seen as reduced yields ranging from 58.67 q ha^{-1} in 1974 to only 3.81 q ha^{-1} in 1983. Thus, Raipur being a sub-humid climatic area, the rainfed rice yield levels are always equal to irrigated rice under given rainfall conditions.

If the years during the study period are categorized as drought, normal and excess rainfall years based on mean and standard deviation values, the effect of water stress can be clearly assessed (Table 2).

Considering the yields and area under rainfed and irrigated rice the weighted averages of actual

Table 1: Simulated potential yields of rice under irrigated and rainfed conditions in Raipur conditions

Year	Rainfall (mm)	Potential yield (q ha^{-1})			Actual yield (q ha^{-1})	
		Irrigated	Rainfed	Yield gap	Irrigated	Rainfed
1973	1271	92.39	87.99	4.4		
1974	798	92.29	33.67	58.62		
1975	1209	81.97	73.01	8.96		
1976	991	86.11	49.01	37.1		
1977	1138	87.35	73.44	13.91		
1978	996	88.44	68.82	19.62		
1979	623	82.92	42.22	40.7		
1980	1586	95.41	72.92	22.49		
1981	1132	97.52	84.04	13.48		
1982	821	95.99	44.29	51.7		
1983	1263	89.96	86.15	3.81	7.72	7.72
1984	1071	105.5	47.56	57.94	14.00	11.26
1985	1455	95.87	80.93	14.94	14.13	9.81
1986	1143	104.84	43.4	61.44	17.12	13.53
1987	715	96.82	89.49	7.33	13.89	7.37
1988	669	90.19	71.4	18.79	14.46	9.34
1989	1219	95.57	73.42	22.15	11.68	5.99
1990	1097	86.08	82.21	3.87	14.74	11.10
1991	786	98.83	59.64	39.19	16.57	11.41
1992	718	103.72	43.6	60.12	17.99	11.19
1993	1252	99.41	77.92	21.49	18.51	13.96
1994	1606	99.86	87.71	12.15	18.59	13.64
1995	1030	97.22	51.07	46.15	15.69	13.44
1996	1090	97.28	81.21	16.07	17.92	11.26
1997	1037	87.46	79.63	7.83	17.84	7.75
1998	894	87.21	80.31	6.9	15.68	6.87
1999	929	86.64	80.64	6.0		
2000	669	90.53	50.87	39.66		
2001	905	90.06	85.2	4.86		
2002	725	97.49	39.74	57.75		
Mean	1027.9	93.36	67.38		15.41	10.35
SD	259.2	6.32	17.78		2.87	2.61
CV	25.2	6.77	26.38		18.61	25.26

Table 2: Average potential yield reduction under drought, normal and excess rainfall years.

Rainfall category	Rainfall (mm)	Average potential yield reduction (q ha^{-1})		
		Irrigated	Rainfed	Reduction
Drought <(μ - σ)	686.5	93.61	56.22	37.39
Normal (μ ± σ)	1051.0	92.77	68.70	24.07
Excess >(<μ + σ)	1549.0	97.05	80.52	16.53

Table 3: Weighted average of actual and simulated rice yields

Year	Average rice yields (q ha^{-1})	
	Simulated	Actual
1983	87.67	07.72
1984	69.58	12.30
1985	87.06	11.58
1986	66.13	14.86
1987	92.72	10.24
1988	79.67	11.59
1989	82.28	08.27
1990	83.87	12.67
1991	76.49	13.63
1992	70.65	14.25
1993	88.02	16.10
1994	93.42	15.97
1995	72.76	14.50
1996	88.92	14.46
1997	83.23	12.39
1998	83.62	11.10

Table 4: Biomass production of different phenophases under excess, normal and drought conditions.

Phenophases	Rainfal	
	Excess	N
Start simulation	0.01	0.0
Transplanting	1.01	1.0
End Juvenile	1.68	1.8
Panicle Initiation	35.29	36
Heading	116.72	11
Beginning of grain filling	139.18	13
Milking to harvest	167.14	15

productivity of rice in Raipur district during the period 1983 to 2002 along with weighted average simulated potential yields are shown in Table 3. The weighted average of yields were obtained by multiplying the corresponding rice yields with irrigated and rainfed area ratios.

From the above table it is clear that there is a considerable gap between the productivity potential (weighted average) and actual yields. This suggests that there is a great scope for increasing the rice yields with suitable technological interventions like selection of suitable variety, quality seed, optimum sowing/planting time, optimum inputs by quantity and time of application etc.The biomass production and its partioning efficiency are important to assess the effect of drought or water stress. Infact under Raipur conditions, the water stress conditions occur only from heading to maturity stages. Therefore, attempts were made to workout the biomass production of rice crop of different phenophases as shown in Table 4.

It is seen that the biomass production gets affected only from the Panicle Initiation stage during drought years while under excess and normal rainfall conditions, there is no difference in biomass production till milking stage and the difference becomes considerably higher from milking to maturity stage.

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Received: June 2006; Accepted: August 2008