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Sensitivity of CERES-Rice model to different environmental parameters on the productivity of aromatic rice in middle Gujarat

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ABSTRACT

The present investigation was carried out during *kharif* season of 2007 and 2008 to develop genetic coefficients of four different genotypes of aromatic rice (cv. Pankhali, Narmada, GR-104 and Pusa Basmati-1) transplanted on three different dates viz., D_1 (8th July), D_2 (22nd July) and D_3 (8th August). The sensitivity analysis of CERES-Rice model with respect to different scenarios of duration of photoperiods, solar radiation, CO_2 concentration, maximum and minimum temperatures were carried out. The simulated grain yield increased linearly with incremental unit increase in day length, solar radiation, reduction of maximum temperature and vice *versa.* Simulated grain yields increased up to 27.9% under elevated scenarios of CO_2 from 380 to 410 ppm by the model. Large yield reductions were observed on decreasing plant population. However, model did not show any significant change due to increase in the plant population. The model was found enough sensitive to account for the effects of transplant age of seedlings on simulated grain yield in comparison with the base yield.

Key words: CERES-Rice, genetic coefficient, aromatic rice genotypes, transplanting dates, sensitivity analysis.

Crop growth simulation models are useful tools for considering the complex interactions between a range of factors that affect crop performance, including weather, soil properties and management. Sensitivity test of the crop simulation model is the process by which various input parameters are evaluated with regards to their importance relative to simulation relations. The increase in maximum temperature decreased grain yield significantly in sensitive analysis of the CERES-Rice model (Karim *et al.* (1994). Lal *et al*. (1998) observed that a 3.0 °C rise in temperature (under elevated CO_2 concentration) nearly cancelled out positive effect of elevated CO_2 on the wheat and rice yields as studied through use of CERES-Wheat and rice models for North West India. The simulated grain yields of paddy decreased with increased transplant age of seedlings (Hundal and Kaur 1999).

MATERIALS AND METHODS

In the present investigation the Crop Environment Resource Synthesis (CERES)-Rice model (Ritchie and Otter, 1985) was used to calibrate pertinent genetic coefficients using experimental data collected at Navagam Research Station of middle Gujarat Agro-climatic region during *kharif* season of 2007 and 2008. The sensitivity of the CERES-Rice model to different environmental parameters was studied in terms of grain yield of various cultivars of aromatic rice. The simulated yields under optimum conditions were considered as reference or base yield. The climatic parameters selected for this purpose were photoperiod, solar radiation and ambient (maximum and minimum) temperature with their respective incremental units ranging between ± 0.5 to ±2. 5 (h), ± 1 to ± 5 MJ m^{-2} day^{-1}, and ± 1 to ± 3°C. In addition to these, two elevated levels of carbon dioxide (380 and 410 ppm) were also included in the studies. Under non-climatic parameters, plant population (75 to 200 m^{-2}) and transplant age of seedlings (30 to 40 days) were evaluated for their role and influences on yield.

RESULTS AND DISCUSSIONS

Effects of photoperiod

The sensitivity of CERES-Rice simulated grain yield under altered photoperiod indicated that with incremental unit increase in day length, the simulated yield increased linearly and *vice versa* (Table 1). The percentage change over base yield was recorded highest in the case cv. Gr-104 and lowest in cv. Pankhali.

Since, rice crop is a short day plant, any increase in photoperiod delay the flowering. Hence, longer vegetative phase resulted in to higher dry matter production converted in to higher grain yield.

Effects of solar radiation

The results of varying solar radiation on grain yield showed that with increase of solar radiation from 1 to 5 MJm^{-2} day^{-1}, the yield increased gradually in comparison with base

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Table 1 : Sensitivity of CERES-Rice model to different environmental parameters for four different cultivars of rice.

Parameters	Cultivars							
	Pankhali		Narmada		Gr-104		Pusa-Basmati-1	
Base yield	3793 kg ha^{-1}		4243 kg ha^{-1}		4887 kg ha^{-1}		4177 kg ha^{-1}	
Environmental Parameters	Simulated grain yield (kg ha^{-1})	% Change	Simulated grain yied (kg ha^{-1})	% Change	Simulated grain yied (kg ha^{-1})	% Change	Simulated grain yied (kg ha^{-1})	% Change
a. Day length (h)								
0.5	3866	1.9	4550	7.2	5129	5.0	4426	6.0
1.0	4049	6.7	4642	9.4	5228	7.0	4508	7.9
1.5	4094	7.9	4755	12.1	5697	16.6	4584	9.7
2.0	4284	12.9	4881	15.0	5761	17.9	4892	17.1
2.5	4292	13.2	4850	14.3	5432	11.2	5004	19.8
-0.5	3549	-6.4	3928	-7.4	3877	-20.7	4145	-0.8
-1.0	3542	-6.6	3796	-10.5	3769	-22.9	3790	-9.3
-1.5	3472	-8.5	3721	-12.3	3599	-26.4	3698	-11.5
-2.0	3472	-8.5	3721	-12.3	3551	-27.3	3414	-18.3
-2.5	3472	-8.5	3721	-12.3	3551	-27.3	3414	-18.3
b. Solar radiation (MJm^{-2} day^{-1})								
1	3961	4.4	4445	4.8	5280	8.0	4388	5.1
2	4149	9.4	4599	8.4	5452	11.6	4526	8.4
3	4337	14.3	4665	9.9	5729	17.2	4630	10.8
4	4511	18.9	4576	7.8	5828	19.3	4849	16.1
5	4656	22.8	4470	5.3	5871	20.1	4831	15.7
-1	3582	-5.6	4040	-4.8	4614	-5.6	4026	-3.6
-2	3391	-10.6	3834	-9.6	3731	-23.7	3804	-8.9
-3	3198	-15.7	3625	-14.6	3904	-20.1	3595	-13.9
-4	2970	-21.7	3413	-19.6	3631	-25.7	3407	-18.4
-5	2772	-26.9	3194	-24.7	2846	-41.8	3161	-24.3
c. Max. temperature(°C)								
1	3487	-8.1	3962	-6.6	4593	-6.0	4134	-1.0
2	3432	-9.5	3910	-7.8	3914	-19.9	3801	-9.0
3	3399	-10.4	3870	-8.8	3856	-21.1	3686	-11.8
-1	3994	5.3	4380	3.2	5150	5.4	4580	9.6
-2	4287	13.0	4722	11.3	5689	16.4	4764	14.1
-3	4501	18.7	5050	19.0	5457	11.7	5057	21.1
d. Min. temperature(°C)								
1	3468	-8.6	3936	-7.2	4625	-5.4	3974	-4.9
2	3220	-15.1	3711	-12.5	3738	-23.5	3780	-9.5
3	3118	-17.8	3500	-17.5	3475	-28.9	3488	-16.5
-1	3964	4.5	4383	3.3	5166	5.7	4477	7.2
-2	4215	11.1	4683	10.4	5312	8.7	4686	12.2
-3	4498	18.6	5053	19.1	5504	12.6	4832	15.7
e. CO2 Concentration								
	4589	21	5241	23.5	6250	27.9	5247	25.6

yield in all the cultivars. The gradual reduction in solar radiation, the gradual decrease in yield in terms of per cent change from base yield was noted in all the four genotypes (Table 1).

Effects of maximum air temperature

Sensitivity of CERES-Rice model to incremental units of maximum air temperature showed a gradual decrease in yield while the down scaled maximum temperature increased

Table 2 : Sensitivity of CERES-Rice model to transplant age (Days) of seedlings and plant population for four different cultivars of rice

Parameters	Cultivars							
	Pankhali		Narmada		Gr-104		Pusa-Basmati-1	
	Simulated grain yield (kg ha^{-1})	% Change	Simulated grain yield (kg ha^{-1})	% Change	Simulated grain yield (kg ha^{-1})	% Change	Simulated grain yield (kg ha^{-1})	% Change
a. Age of seedlings (Days)								
30	3525	-7.1	3902	-8.0	4324	-11.5	4053	-3.0
35	3267	-13.9	3784	-10.8	4104	-16.0	3797	-9.1
40	3185	-16.0	3452	-18.6	3811	-22.0	3580	-14.3
b. Plant population (plant m^{-2})								
75	3802	0.2	4340	2.3	5092	4.2	4387	5.0
100	3862	1.8	4376	3.1	5125	4.9	4495	7.6
125	3919	3.3	4455	5.0	5151	5.4	4457	6.7
150	3862	1.8	4325	1.9	5212	6.7	4471	7.0
175	3902	2.9	4382	3.3	5291	8.3	4485	7.4
200	3942	3.9	4408	3.9	5321	8.9	4495	7.6

the yield in all four genotypes of rice (Table 1). Maximum reduction in yield was recorded in GR-104 genotype whereas cv. Pankhali recorded least reduction for corresponding temperature level. The highest positive percentage change in yield over base yield due to reduction of maximum temperature was recorded in cv. Pusa Basmati-1 and least in genotype GR-104.

Effects of minimum air temperature

The result of simulated yield indicated decrease in yields with increase in minimum temperature above that corresponding to potential conditions in all four genotypes of rice (Table 1). This might be due to higher rate of respiration during night time caused by higher minimum temperature that resulted in to comparatively higher loss of photosynthates. The reduction was however, less for the heat tolerant cultivar (Pankhali). Paradoxically, the low minimum temperature increased the yield in the all four genotypes of rice, but not in the same magnitude as that of reduction in yield with increase in minimum temperature and decrease in maximum temperature.

Effect of elevated carbon dioxide

The simulated grain yields increased under elevated level (410 ppm concentration over the base value 380 ppm) of CO_2 by 21.0, 23, 27.9 and 25.6 (Table 1) in cv. Pankhali, Narmada, GR-104 and Pusa Basmati-1 respectively when compared with base yield. This clearly showed that elevated concentration of CO_2 had a significant and positive impact on the grain yield of various genotypes of rice, but GR-104 could be performed better under elevated concentration of rice than that of other genotypes.

Effect of transplant age of seedling

The striking features observed while studying the sensitivity analysis of CERES-Rice model to transplant age of seedling was that the magnitude of percentage change ranged between -3.0 to -22.0 (Table 2) from base grain yield when transplant age was increased 5 to15 days from optimum age (25 days old). However, the magnitude of percentage change from base yield was more or less same among the various cultivars of aromatic rice.

Effect of plant population

Model showed little increase (up to 8.9 %) in yield over the base yield by increasing the plant population from 75 to 200 per sq. meter. This showed the insensitivity of the model to varying plant population level (Table 2).

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