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Potential yield and yield gap analysis of rice (*Oryza Sativa* L) in eastern and north eastern regions of India using CERES-rice model

P.K.SINGH, K.K.SINGH, S.C.BHAN, A.K.BAXLA, AKHILESH GUPTA[1], R. BALASUBRAMANIAN[2] and L.S.RATHORE

Agromet Service Cell, India Meteorological Department, New Delhi-110003

[1]Department of Science & Technology, New Delhi-110016

[2] Agrimet, IMD, Pune-411005.

Email: pksingh66@gmail.com

ABSTRACT

Crop simulation models have been used to determine potential yield in a given environment. The twenty one years (1990-10) weather data and reported rice yield of Bhagalpur, Ranchi, Kalyani and Jorhat districts of eastern and north eastern region of India were used to simulate the yield under the various management conditions and compared with the reported yield of the districts. The management option included dates of sowing, irrigations and fertilizers application. The potential yield, attainable yield, yield gap etc were computed over the period. The results revealed that the rice yield of Kalyani and Ranchi districts showed increasing trend (30 to 65 kg $ha^{-1}yr^{-1}$) while decreasing trend was observed in Bhagalpur and Jorhat districts (6 to 9 kg $ha^{-1}yr^{-1}$). The potential yield simulated by model in different districts varied between 2864 to 4742 kg ha^{-1}, while reported yield varied between 1159 to 2224 kg ha^{-1}. The delay in sowing by 15 days caused reduction in rice yield by 31 to 74 kg $ha^{-1}day^{-1}$ at different locations. The management yield gap was between 1495 to 3216 kg ha^{-1} while sowing yield gap was between 467.4 to 1114.0 kg ha^{-1} in different districts under study.

Key words: CERES-Rice, yield gap, potential yield

In India, rice is grown in extremely diverse hydrological environments such as irrigated, rain-fed uplands, lowlands, as well as under deep-water conditions. Most of the rice producing areas of Punjab, Haryana, Andhra Pradesh and Tamil Nadu are irrigated. Rain-fed rice is grown in several states such as West Bengal, Uttar Pradesh, Orissa, Bihar, Assam, Karnataka, Maharashtra, Madhya Pradesh and Jharkhand. West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab and Orissa altogether account for 60% of the total rice production and almost 50% of the total rice cultivated area in India. Since rice is mostly rain-fed in most of the states, the production is strongly dependent on distribution of rainfall. The transplanting is largely dependent upon the date of onset of monsoon. In some eastern states, erratic rainfall leads to drought during the vegetative period, and later on, the crop may be damaged by submergence due to high rainfall. Other constraints are soil acidity in southern and eastern India, salinity and alkalinity in northern India (Aggarwal *et al,* 2008).

Crop simulation models have been used to determine potential yield of any crop with which, the yield gap in a given environmental situation can be determined and possibilities for the yield improvement can be assessed. Patel *et. al* (2006) and Patel *et.al* (2008) analysed the yield gap in different districts of Gujarat and suggested the subsequent adjustment of appropriate sowing window to provide possibilities for obtaining potential yields. Aggarwal and Kalra (1994) studied the climatically potential grain yield of wheat and yield gaps in India. Estimation of yield gap in any crop helps to have target–oriented approach in achieving regional food security. The yield targets serve as a reference for calculating the required agronomic inputs and for assessing their environmental effects. In this paper an attempt has been made to study the potential yield and yield gap analysis of rice in different districts eastern and north eastern parts of India.

MATERIAL AND METHODS

The CERES-rice model embedded in DSSATv4.5 was used to evaluate the potential yields of rice for 21 years (1990-2010) periods in Bhagalpur, Ranchi, Kalyani and Jorhat districts of Bihar, Jharkhand, West Bengal and Assam

Table 1: Input data used in the model

Parameters	Bhagalpur	Ranchi	Kalyani	Jorhat
Latitude	25.23	23.36	23.4	26.75
Longitude	86.95	85.33	88.48	94.22
Altitude	40	635	11	89
Soil	Sandy clay loam	Loamy sand	Sandy loam	Sandy loam
Depth	60 cm	60 cm	50 cm	40 cm
Wilting point	0.15 to 0.20	0.05 to 0.11	0.066 to 0.137	0. 069 to 0.146
Field Capacity	0.212 to 0. 304	0.137 to 0.185	0.164 to 0.243	0.134 to 0.248
Saturations	0.360 to 0.417	0.355 to 0.415	0.348 to 0.489	0.349 to 0.491
Bulk density (g/cc)	1.48 to 1.52	1.35 to 1.70	1.40 to1.50	1.45 to 1.59
pH	7.30 to 7.50	6.6 to 7.3	6.0 to 7.0	4.5 to 5.0
Crop variety	Rajender mansuri	Vandana	Shatabadi	Ranjeet
Weather and Reported yield	1990-2010	1990-2010	1990-2010	1990-2010
Optimum sowing window	15th July	10th July	15th July	1st July

states of India. The corresponding the daily weather data (Tmax & Tmin, Rainfall and Bright Sunshine) for each station was collected from IMD, New Delhi. The districts wise rice yield data for same period was obtained from DAC, GOI and New Delhi. The soil information needed for model was obtained from the research stations. The details input data required to run the model are presented in Table 1.

The crop genetic input data, which explains how the life cycle of a rice cultivars respond to its environment; have been developed for cultivars i.e**.** Rmansuri (Bhagalpur), Vandana (Ranchi), Shatabadi (Kalyani) and Ranjeet (Jorhat) using Research Farm data of different locations (Singh, et al. 2010). The calibrated model was used to simulate the potential yield defined as the maximum yield of variety restricted without limitation of water and nutrients and optimum cultural management. The attainable yield is defined as the yield that farmer can achieve using the best management practices like optimum sowing date, irrigation, fertilizers etc. However, attainable yield are obtained by delayed sowing by 15 days as farmer cannot manage sowing in time in one day.

Yield gap analysis

The total yield gap was calculated using difference between the actual and potential yield of rice crop, while the management gap was calculated as the difference between attainable yield and actual yield, and the sowing gap was calculated as the difference between potential yield and attainable yield.

RESULTS AND DISCUSSIONS

The CERES-rice model simulated the rice yield under three transplanting dates viz. 1st, 15th and 30th July at Bhagalpur; 25th June, 10th and 25th July at Ranchi; 1st, 15th and 30th July at Kalyani and 25th June, 1st and 25th July at Jorhat. The maximum yield was obtained on different sowing dates at different locations viz. 15 July in Bhagalpur, 10th July in Ranchi, 15th July in Kalyani and 1st July in Jorhat district which are the optimum sowing dates in these districts.

Actual yield

Fig. 1 shows the variability and trends in rice yield over 21 year periods in all the four districts (Bhagalpur, Ranchi, Kalyani and Jorhat) of eastern and north eastern of India. In Kalyani district the rice yield was highest among all the four districts and it ranged from 1834 to 2596 kg ha^{-1} with mean of 2224 kg ha^{-1} and increasing trend of 29.6 kg ha^{-1} yr^{-1}. In Bhagalpur district the rice yield ranged from 607 to 1740 kg ha^{-1} with the mean of 1159 kg ha^{-1} and decreasing trend of 5.95 kg ha^{-1}. In Ranchi district the rice yield increased significantly over the period of time and ranged from 628 to 2830 kg ha^{-1} with mean of 1368 kg ha^{-1} and increasing trend of 65 kg ha^{-1} yr^{-1}. In Jorhat district the rice yield ranged from 1198 to 2120 kg ha^{-1} with mean of 1719.9 kg ha^{-1}and decreasing trend of 8.7 kg ha^{-1} yr^{-1}. Thus rice yield in two districts (Kalyani and Ranchi) was found to have increasing trend while in Bhagalpur and Jorhat districts, it had decreasing trend.

Potential yield

The potential yield simulated by the CERES-rice model was also found to be the highest yield in Kalyani district (4742 kg ha^{-1}) and it was 2.2 times higher than actual yield (2224 kg ha^{-1}). The potential yield in Ranchi (2864 kg

Table 2: Potential yield and yield gap of rice in different districts of eastern and northeastern region of India

Parameters	Yield (kgha^{-1})			Yield gap (kgha^{-1})		
	Actual	Potential	Attainable	Total	Management	Sowing
			Bhagalpur			
Mean	1159	4375.0	3261.0	3216.0	2102.0	1114.0
SD	294.5	427.5	276.0	356.7	324.7	418.5
CV (%)	25.4	9.8	8.5	11.1	23.7	37.6
			Ranchi			
Mean	1368.2	2864.0	2396.6	1495.8	1028.4	467.4
SD	515	390.3	364.5	335.5	285.9	139.7
CV (%)	37.6	13.6	15.2	22.4	27.8	29.9
			Kalyani			
Mean	2224	4742	3999	2518	1775.0	743
SD	247.3	269.0	225.6	284.4	225.1	221.8
CV (%)	11.1	5.7	5.6	11.3	11.3	29.9
			Jorhat			
Mean	1719.9	3582.8	3083.5	1862.9	1363.7	499.2
SD	204.5	237.9	206.8	319.9	248.7	170.9
CV (%)	12	7.0	7	17	18	34

ha^{-1}) was also twice the reported yield (1368 kg ha^{-1}) (Table 2). The potential yield in Bhagalpur district was found to be quite high (4374.9 kg ha^{-1}) and was about 4.0 times the actual yield (1159 kg ha^{-1}). The potential yield in Jorhat district (3582.8 kg ha^{-1}) was 2.1 times higher than actual yield (1719.9 kg ha^{-1}). It may be seen from the Table 2, that the potential yields were not only higher but also more stable over 21 years period as CV per cent was less (5.7 to 13.6) in comparison to higher CV per cent of reported yield (11.1 to 37.6 per cent). Bhandari *et al.,* (2002); Yadav *et al.* (2000) and Akula (2005) also reported higher potential yield of wheat crop. This may be due to the fact that the potential conditions were assured to be free from biotic and abiotic stress (Aggarwal, *et al.* 1994).Thus it may be seen from the Table 2, that the potential yields were not only higher but also more stable over 21 years period as CV per cent was less (5.7 to 13.6) in comparison to higher CV per cent of reported yield (11.1 to 37.6 per cent).

Attainable yield

The attainable yield was also highest in Kalyani district (3999 kg ha^{-1}) and the lowest yield in Ranchi district (2396.6 kg ha^{-1}). The attainable yield in Bhagalpur district was 3261 kg ha^{-1} while in Jorhat district it was 3582.8 kg ha^{-1}. The CV per cent of attainable yield was more or less and similar to that obtained for potential yield (Table 2).

Total yield gap

The total yield gap obtained as difference between potential yield and reported yield (Table 2) suggested that the highest yield gap (3215 kg ha^{-1}) was in Bhagalpur district and the lowest yield (1495 kg ha^{-1}) in Ranchi district. The total yield gap in Kalyani district was 2518kg ha^{-1} and in Jorhat district it was 1862.9 kg ha^{-1}. The coefficients of variation were between 11 to 22 per cent, suggesting higher uncertainly which is mainly attributed to higher variability in the reported yield.

Management yield gap

The management yield gap obtained as the difference between attainable yield and reported yield are presented in Table 2. The results show that the highest management yield gap (1999 kg ha^{-1}) was in Kalyani district and the lowest management yield gap (1028 kg ha^{-1}) in Ranchi district. The management yield gap in Bhagalpur district was 1368 kg ha^{-1} and the yield gap in Jorhat district was 1363.7 kg ha^{-1}. Thus there is large scope in increasing the yield through timely management of rice cultivation in these regious.

Sowing gap

The sowing gap is difference between potential and attainable yield due to delay sowing by 15 days. The sowing yield gap was highest (1114 kg ha^{-1}) in Bhagalpur district

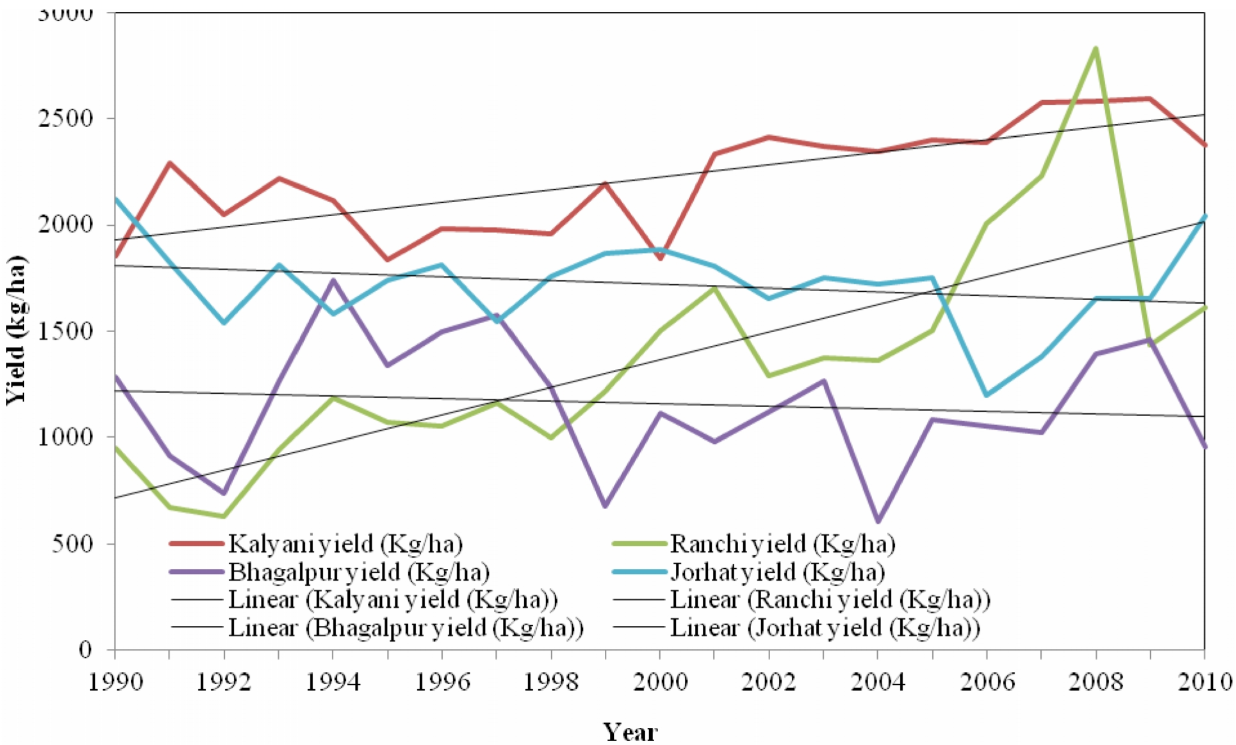

Fig.1 : Yield of rice trend line in different districts of eastern and northeastern region of India

and lowest (467 kg ha^{-1}) in Ranchi district (Table 2). The quantified analysis of sowing yield gap revealed that the delay in sowing caused reduction inyield at the rate ranging between 31 kg ha^{-1}day^{-1} in Ranchi to 74 kg ha^{-1}day^{-1} in Bhagalpur district. Patel *et al.* (2008) have also reported wheat sowing yield gap of 18 kg ha^{-1}day^{-1} in Gujarat and Aggarwal and Kalra (1994) have quantified wheat yield gap of 50 kg ha^{-1}day $^{-1}$ due to delay sowing.

CONCLUSIONS

The simulation analysis revealed that there is large yield gap exit in rice production in different districts of eastern and north eastern India. Rice yield could be increased by 11 to 22 per cent in different districts with better management practices. The delay is yield was found to cause reduction in rice yield at the rate of 31 to 74 kg ha^{-1}day^{-1}. Thus the CERES-Rice model can be used for such decision making for crop management and improving the resource use efficiency.

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