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Forecasting impact of climate change on potato productivity in West Bengal and adaptation strategies

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ABSTRACT

The WOFOST crop growth simulation model was used to study the impact of climate change on potential potato productivity in West Bengal and also to devise management strategy to minimize the impact of climate change through selection of suitable variety and shifting the date of planting. The study was carried out at 13 locations in West Bengal. The simulation was done for baseline scenario and future climate scenario of 2020 and 2055 for three potato cultivars, *viz.*, Kufri Badshah (long duration), Kufri Jyoti (medium duration) and Kufri Pukhraj (short duration), for A1FI high emission scenario of temperature and CO_2. Simulation revealed that although the increase in temperature is likely to reduce the yield by 8.8 to 10.1% in 2020 and 23.7 to 28.8% in 2055, a corresponding increase in CO_2 may increase the yields by 4.5 to 4.7% in 2020 and 19.2 to 20.5% in 2055. However, under the combined effect of CO_2 and temperature, the highest decline of 6.1% in productivity of Kufri Pukhraj is expected followed by 5.9% in Kufri Jyoti and 5.1% Kufri Badshah in 2020, with corresponding figures of 12.0, 10.5 and 8.8% in 2055. Results further revealed that the negative effect of climate change on potato productivity can be counter-balanced to some extent through change in date of planting and/ or selection of suitable varieties, as it may bring down the reduction in yield from 5.7 to 1.5% in 2020 and 9.7 to 7.1% in 2055.

Key words: Adaptation, climate change, potato, West Bengal, yield.

INTRODUCTION

In India, potato is largely grown during winter season and is mainly confined to Indo-Gangetic plains. The autumn/winter planted crop in northern plains of India comprising the states of Uttar Pradesh, West Bengal, Bihar, Punjab and Haryana contributes 90% to total potato production in India. However, in the future changing climates, the productivity of potato in this region is likely to decrease as the availability of its suitable growing period is likely to be impacted seriously. As per the IPCC 4th Assessment Report, an increase in temperature ranging from 0.78ºC during September, October, November to 1.17ºC during December, January, February is expected under A1FI scenario by 2020, in South Asia. These changes are expected to aggravate and range from 1.71ºC during June, July, August to 3.16ºC during December, January, February, *i.e.* the main potato growing season in 2055. Thus, in 2020 the potato season is likely to be warmer by 0.78º to 1.18ºC and in 2055, by 2.41º to 3.16ºC under A1FI scenario. During the same period, the CO_2 calculation is likely to increase from present 400 to 415 ppm in 2020 and 590 ppm in 2055 (IPCC, 7). The increase in CO_2 is expected to bring on increase in productivity of potato as reported by many workers. However, Increase in temperature and atmospheric CO_2, both are interlinked and occur simultaneously and the CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on tuber yield. Thus, here is an urgent need to study the impact of likely changes in temperature and CO_2 on regional vulnerability of potato productivity in future, in order to direct our research efforts to meet the challenges and devise adaptation strategy to minimize the likely impact of climate change. For this purpose, crop growth models are very useful and are used widely to simulate crop growth and yield of annual and perennial crops under diverse situations. Keeping this in view a study was undertaken to study the impact of climate change on potential potato productivity West Bengal, which is the second largest producer of potato in India and to select the suitable variety and date of planting to minimize the impact of climate change.

MATERIALS AND METHODS

WOFOST (WOrld FOod STudies), a mechanistic model developed at Wageningen University, the Netherlands, simulates the growth of a crop based upon eco-physiological processes. This model was used in the present study for impact assessment of climate change on potato productivity and scheduling planting date and selection of suitable cultivar to minimize climatic impact in West Bengal. The model is widely used to assess the effect of climate change

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on the growth and yield of many crops including potato throughout the world (Wolf *et al*., 15) and is one of the three most widely used crop growth models for climate change studies (Tubiello and Ewert, 14). The major processes in this model are phenological development, CO_2 assimilation, transpiration, respiration, partitioning of assimilates to the various organs, and dry matter production (Boogaard *et al*., 2).

Further, WOFOST model has been calibrated for Indian potato cultivars using the time course data on potato growth and development for Indo-Gangetic region. The potato cultivars for which the model has been calibrated are Kufri Badshah, Kufri Jyoti, Kufri Bahar and Kufri Pukhraj (Dua *et al*., 3). Comparison of actual and simulated values revealed a difference of two days in emergence of Kufri Pukhraj, while no difference in case of Kufri Badshah and Kufri Pukhraj (Table 1). The difference in time taken for initiation of tubers from planting varied from + 1 (Kufri Badshah) to + 7 (Kufri Pukhraj) days for the three (Dua *et al.*, 3). The simulated total dry matter yield ranged from 0.5 to 5.6% and the simulated total tuber dry matter yield varied from 0.6 to 7.5%, thus the calibration was satisfactory (Table 1). Fortnightly mean minimum and maximum temperatures (ºC) of some locations under study in West Bengal during baseline scenario (2000) are given in Table 2. For the present study, the model was run for 13 locations spread across the state (Table 3).

Three potato cultivars, belonging to late (Kufri Badshah), medium (Kufri Bahar) and early (Kufri Pukhraj) maturity group were selected for simulation studies. The latter two cultivars alone account for about 88% of total potato acreage in West Bengal (Annual Report, CPRI, 1). Since the normal date of planting in West Bengal is second week of October, the model was run for 10th of October. The simulation study was carried out to estimate potential yields of potato cultivars for baseline and both the future scenarios.

Indian Meteorological Department (IMD) district normal of 1971-2000 of 13 districts of West Bengal (Table 2) were used for baseline scenario (year

Table 1. Comparison of measured (actual) and simulated values of some important parameters of potato cultivars.

Parameter	Kufri Badshah			Kufri Jyoti			Kufri Pukhraj		
	Mea.	Sim.	Diff.	Mea.	Sim.	Diff.	Mea.	Sim.	Diff.
Emergence (days)	17	15	2	15	15	0	15	15	0
Tuber initiation (days)	37	36	1	32	35	3	29	36	7
Total DM yield (t/ha)	14.6	15.5	5.6%	12.3	12.6	2.5%	13.1	13.1	0.5%
Tuber DM yield (t/ha)	8.7	8.9	2.1%	7.3	7.9	7.5%	8.3	8.3	0.6%

Mea. = measured; sim. = simulated; diff. = difference

Table 2. Fortnightly mean minimum and maximum temperatures (ºC) of some locations under study in West Bengal during baseline scenario (2000).

Month	Fortnight	Bankura		Hoogly		Jalpaiguri		Malda		Medinipur	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
October	I	23.7	32.9	24.4	32.9	21.4	31.7	24.5	32.3	24.6	33.9
	II	21.7	32.1	22.2	32.2	18.4	31.2	22.3	31.8	22.5	33.7
November	I	19.2	30.5	19.5	31.1	16.0	30.0	19.8	30.5	20.1	32.9
	II	16.7	29.3	16.7	29.8	13.9	28.6	17.1	29.1	17.4	31.5
December	I	13.5	26.9	13.5	27.8	11.5	27.0	14.6	27.3	14.8	29.7
	II	11.6	25.9	12.3	26.7	9.7	25.5	12.9	25.7	13.7	28.4
January	I	11.3	25.6	11.9	25.6	9.0	24.8	12.0	24.4	13.3	28.0
	II	12.5	26.8	12.6	26.5	9.6	24.8	12.3	25.2	14.2	28.2
February	I	14.0	27.6	14.4	27.8	10.5	25.4	13.6	26.9	16.5	29.2
	II	16.3	30.3	16.3	30.0	12.1	27.5	15.5	29.5	18.4	31.7
March	I	17.9	32.2	18.6	32.0	14.1	29.2	17.3	32.1	20.5	33.7
	II	20.9	36.0	21.3	34.4	16.7	31.4	19.9	34.9	22.9	35.8

Table 3. Geographical area of West Bengal (%) under different yield classes in 2000 (baseline scenario).

Potential productivity (t/ha)	Kufri Badshah	Kufri Jyoti	Kufri Pukhraj
24.0-30.0	0.0	8.0	4.6
30.1-36.0	29.0	27.8	23.5
36.1-42.0	50.1	48.6	42.3
42.1-48.0	20.9	15.6	29.7

2000). Hargreaves-Samani equation, which uses the maximum and minimum temperature to estimate solar radiation was employed for working out total solar radiation and is reported to be the best suited for Indian conditions (Samani, 11). After converting weather data into WOFOST weather file format the simulation studies were carried out for A1FI high emission scenario. For generation of scenario for 2020 and 2055, projected changes in surface air temperature for sub-regions of the Asia under SRES A1FI pathway based on the Fourth Assessment Report (AR4) Atmosphere-Ocean General Circulation Models (AOGCMs) were added to the baseline data (IPCC, 8). Based on the Bern-CC model for A1FI scenario projected atmospheric CO_2 concentration was used for incorporating the effect of change in CO_2 concentration in WOFOST model (IPCC, 8). For atmospheric CO_2 concentration 367 ppm (for baseline), 415 ppm (for 2020) and 590 ppm (for 2055) were used in the present study.

A 25-40% (mean 32.5%) increase in yield in C_3 plants due to doubling of CO_2 from 355-710 ppm has been reported (Wolf *et al.*, 15) hence for incorporating the impact of CO_2, the changes were made in the WOFOST model for parameters, *viz.* light-use efficiency of single leaf and maximum leaf CO_2 assimilation rate. In the earlier studies, changes have been made in initial angle (+11%) and in maximum of the CO_2 assimilation light response curve and response curve (+60%) parameters of WOFOST model for doubling CO_2 concentration from 355 to 710 ppm. Under the experimental conditions with non-limiting supply of water and nutrients, and where temperatures are kept near the optimum for crop growth, the yield increase for C_3 crops with a doubling of CO_2 has been estimated at 30% by various workers (Fuhrer, 6). Therefore, assuming linear relationship between the CO_2 increase and the growth processes we have taken these figures for yield as +10% (30/32.5 × 11) and + 55% (30/32.5 × 60) for doubling CO_2 concentration for potato. Accordingly, these parameters were changed for 2020 and 2055 for A1FI scenario as follows:

Change	2020	2055
Light-use efficiency of single leaf	+10% × (415-367)/ 355 = +1.4%	+10% × (590-367)/ 355 = + 6.28%
Maximum leaf CO_2 assimilation rate	+55% × (415-367)/ 355 = +7.4%	+55% × (590-367)/ 355 = +34.5%

An image of 500 m pixel size of West Bengal was used for generation of GIS maps using 'Geomatica' software for creation of maps of the base line productivity and change in productivity of different potato cultivars under future climate scenarios. Surface layers of the attributes data of each district containing productivity and change in productivity under different future climate scenarios were geo-statistically interpolated using kriging technique were produced. For estimation of the area falling under different class of attributes and modeling for % change in productivity was done in EASIPACE.

RESULTS AND DISCUSSION

The potato productivity varied largely within the state under baseline scenario ranging from 31.2 to 46.9, 29.0 to 45.4 and 29.6 to 48.2, for Kufri Badshah, Kufri Jyoti and Kufri Pukhraj, respectively. The mean productivity for respective cultivars was 38.9, 37.2 and 39.2 t/ha (Table 3) when the point data of 13 locations was extrapolated over entire state using kriging. In general a decline in average productivity was observed on moving from northern to southern part of the state to coastal parts. The northern districts, namely, Jalpaiguri, Dinajpur and Bardhaman had the higher baseline productivities, whereas the

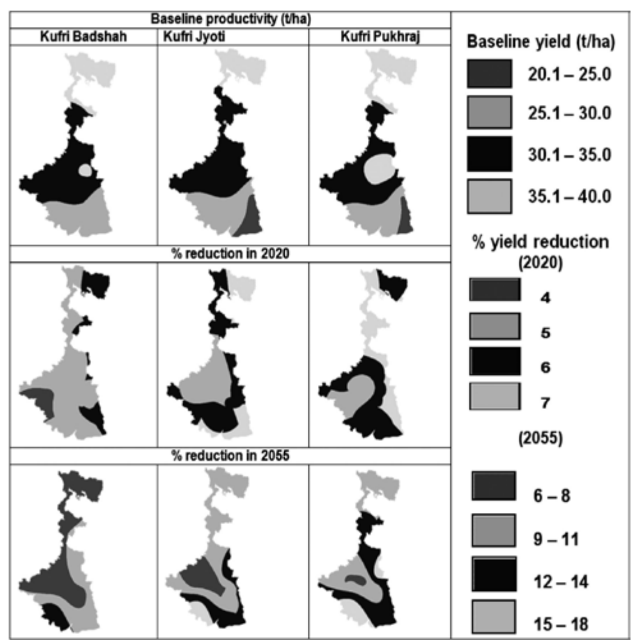

Fig. 1. Productivity decline in different potato growing areas of West Bengal.

southern districts Medinipur, North Parganas and South Parganas had lowest productivity for all the three potato cultivars for which the model was run (Fig. 1).

With the combined effect of temperature and CO_2, it is likely that mean productivity of Kufri Pukhraj will experience greatest decline (6.1%) followed by Kufri Jyoti (5.9%) and Kufri Badshah (5.1%) under 2020 climatic scenario. The similar trends are expected in 2055 with the corresponding figures of 12.0, 10.5 and 8.8%. In 2020, the maximum area of West Bengal (73%) is likely to experience about 5% yield reduction under Kufri Badshah; while about 88.7% geographical area is likely to experience 5 to 6% reduction under Kufri Jyoti. However, >80% area under Kufri Pukhraj is likely to experience 6-7% reduction in yield. The overall reduction under these varieties in 2020 is likely to range from 5.1% (Kufri Badshah) to 6.1% (Kufri Pukhraj) in 2020, when the whole state is taken under consideration.

The mean decline in productivity in 2055, when the temperature is likely to be 3.16ºC higher over baseline and the CO_2 concentration to be 590 ppm, is expected to 8.8% for Kufri Badshah, 10.5% of Kufri Jyoti and the maximum 12.0% for Kufri Pukhraj. About 92% of geographical area under Kufri Badshah is likely to experience 6 to 11% decline in 2055, while about 94% area is expected to show a decline ranging to 6-14% in Kufri Jyoti yield. However, in case of Kufri Pukhraj, much higher yield reduction is expected, *i.e.* 9-18% in about 97% area of West Bengal (Table 5).

In general, in 2020, the much reduction in Kufri Badshah productivity is expected in southern (coastal) parts of West Bengal under the future climate scenario. With the rise in temperature alone, model results have shown an average decline in the productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj to the tune of 8.8, 9.8 and 10.1% in 2020 and 23.7, 26.8 and 28.8%, respectively in 2055, averaged over 13 locations over baseline scenario. Increase in temperature has adverse effects on potato growth. High temperature is reported to reduce tuber number and size. Tuberization as well as gross photosynthetic rate is inhibited by even moderately high temperatures, ultimately affecting the total biomass production and tuber yield and these losses will be compensated to a greater extent by increase in CO_2 content. The corresponding expected increase in productivity of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj due to rise in CO_2 is likely to be 4.5, 4.7, and 4.6% in 2020 and 19.2, 20.5 and 20.1% in 2055. The CO_2 concentration and assimilation are positively correlated and a 10% increase in tuber yield is estimated for every 100 ppm increase in CO_2 concentration (Miglietta *et al.,* 10). These positive effects are attributed to increased photosynthesis by 10 to 40% (Schapendonk *et al*., 12; Katny *et al*., 9). However, the increase in temperature and CO_2 go hand in hand and the increase in CO_2 does not seem to compensate the yield losses caused by increase in temperature at any location and under any scenario (Singh *et al*., 13). However, it offsets the losses to some extent. Thus, the net decline in the productivities of Kufri Badshah, Kufri Jyoti and Kufri Pukhraj as result of combined effect of rise in temperature and CO_2 will be 4.6, 5.4 and 5.9% in 2020, respectively. However, in 2055 more yield declines are predicted. The corresponding figures of productivity decline for the same cultivars are 8.1, 9.8 and 11.3%. Amongst three cultivars the highest yield loss (6.9%) will be in Malda district in case of Kufri Pukhraj followed by Kufri Jyoti (6.4%) in North Nadia South Parganas district and 5.3% in Kufri Badshah in Malda district under 2020 scenario. Amongst three cultivars, the highest yield loss (18.4%) will be in case of Kufri Pukhraj followed by Kufri Jyoti (17.15) and Kufri Badshah (13.9%) In case of Kufri Pukhraj highest loss of yield (18.4%) under 2055 scenario. However, for the same cultivar Nadia district will have more yield decline (5.2%) in 2020. In case of Kufri Jyoti again the highest loss of yield (17.1%) is predicted in 2055 and for the same cultivar Nadia district will have more yield decline (5.2%) in 2020.

The baseline productivity of all the three cultivars studied was highest in Jalpaiguri district. Rise in temperature is likely to decrease the productivity of Kufri Jyoti by 8 to 10.7%, while increased CO_2 will increase the productivity ranging from 4.6 to 5.2%. However, under combined effect of increase in temperature and CO_2, it is likely to decline productivity by 4.4 to 6.4% with an average reduction of 5.4% across the locations in 2020 scenario. However, in 2055 scenario, rise in temperature on Kufri Badshah is likely to decrease the productivity by 22.9 to 38.3%, and increased CO_2 will increase the productivity ranging from 19.5 to 22.9%. However, combined effect of increase in temperature and CO_2 would reduce the productivity by 6.1 to 17.1% with an average reduction of 9.8% across the locations in 2055. The reduction will be highest in Medinipur (17.1%) followed by Nadia (12.6%) district.

Increase in temperature by 1.18°C in Kufri Pukhraj (early) is likely to decrease the productivity by 8.7 to 10.8%, while increased CO_2 has shown to increase the productivity ranging from 4.4 (in Malda, Dinajpur and South Parganas districts) to 5.2% in Nadia district. However, combined effect of increase in temperature and CO_2 will reduce the productivity by 4.4 (Bardhaman district) to 6.9% in Malda district with an average reduction of 5.9% across the locations in 2020 scenario. However, in 2050 scenario rise in temperature in Kufri Badshah (late) is likely to decrease the productivity by 23.5 in Bardhaman to 43.8% in Medinipur district, and increased CO_2 will increase the productivity ranging from 19.1 (Malda) to 22.7% (Nadia). However, combined effect of increase in temperature and CO_2 will reduce the productivity by 7.3 to 18.4% with an average reduction of 11.3% across the locations in 2050 scenario. The reduction will be highest in Medinipur (18.4%) followed by Nadia (16.0%) district. Under 2020 scenario productivity of the three cultivars will be decreased most in Medinipur followed Nadia by the combined effect of increased temperature and CO_2, whereas in Bardhaman and Bankura districts productivity of all the three cultivars will be least affected. Amongst three cultivars, Kufri Pukhraj on an average will experience maximum reduction in yield (5.9%) followed by Kufri Jyoti (5.4%) and Kufri Badshah (4.6%) across the districts. Under 2055 scenario also the similar trend was observed. Productivity of the three cultivars will be decreased most in Medinipur followed Nadia under the combined effect of increased temperature and CO_2, whereas in Bardhaman and Bankura districts productivity of all the three cultivars will be least affected. Amongst three cultivars, Kufri Pukhraj on an average will experience maximum reduction in yield (11.3%) followed by Kufri Jyoti (9.8%) and Kufri Badshah (8.1%) across the districts. Similar effects on potato productivity were observed in Punjab and Uttar Pradesh by Dua *et al*. (5, 6).

WOFOST model was run for nine dates at ten days interval starting from 11 October for adaptation strategies for all the three varieties under study. The model was run for five locations, *viz*. Bankura, Hoogly, Jalpaiguri, Malda and Medinipur, which are the representative of different potato growing areas spread across the state. The model results for three different cultivars and for three different climate scenario, one present and two future, are presented in Fig. 2. The productivity of all the three cultivars declined in the future climate scenarios, irrespective of date of planting. However, degree of decline varied at different locations. At Medinipur, Bankura and Malda, greater decline was simulated in Kufri Pukhraj and Kufri Jyoti at earlier planting dates, whereas, at Jalpaiguri, the decline in the yield of all the three cultivars was more at earliest planting and the gap reduced with delay in planting. The result further revealed that after reaching the peak in terms of productivity, during 31st October to 10th November period, a less decline in the productivity of Kufri Pukhraj was observed compared to remaining two cultivars, as a result, Kufri Pukhraj was found to be much suitable for late planting as compared to Kufri Badshah and Kufri Jyoti (Fig. 2 and Table 6). The analysis of change in planting date has revealed that shifting the date of planting to 10 days later at all the locations gave the highest yield of Kufri Badshah in 2020 scenario. This could result in a mean reduction of only 1.5% averaged over 5 districts compared to 5.1% under normal date of planting. Similarly, a zero to 10 day delay in planting may bring down the yield reduction in the same variety from 8.8 to 7.6% in 2055. However, change in date of planting was not found to be a suitable option for Kufri Badshah in 2055 for northern districts of Malda and Medinipur as advancing or delaying planting, both, resulted in decline in productivity of Kufri Badshah there, whereas in Bankura, Hoogly and Jalpaiguri, advancing planting by 10 days from the normal 10th November, gave the highest productivity as simulated by WOFOST for 2055.

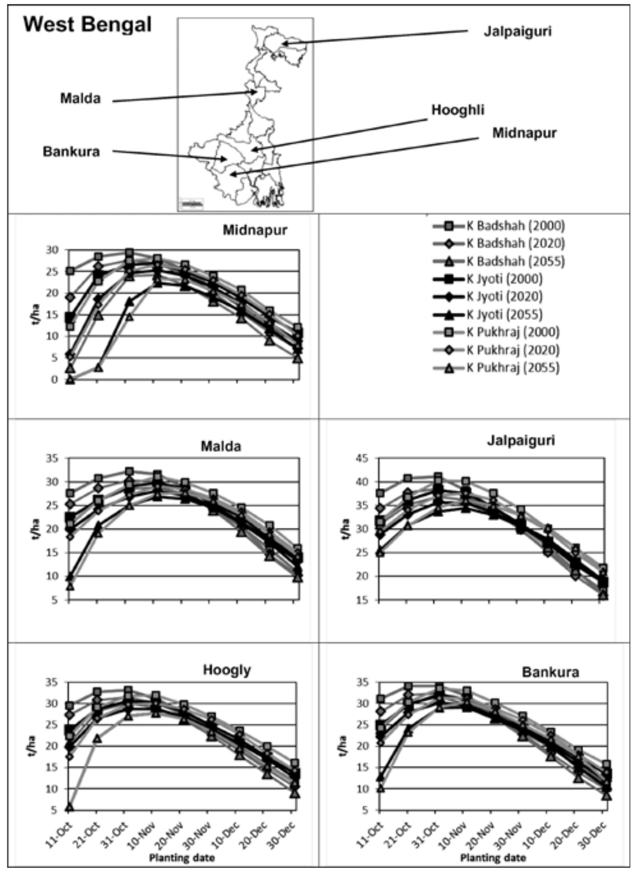

Fig. 2. Simulated productivity of different potato cultivars in different parts of West Bengal as affected by date of planting under baseline and future climate scenario.

Table 4. Productivity of potato cultivars in baseline year and changes thereof in future climates (interpolated results for total geographical area of West Bengal).

Particulars	Kufri Badshah	Kufri Jyoti	Kufri Pukhraj
Baseline yield (t/ha)	38.9	37.2	39.2
Overall reduction In yield (%)			
2020	5.1	5.9	6.1
2055	8.8	10.5	12.0
Yield reduction classes (%) in 2020	% geographical area of W. Bengal		
4	8.9	0.0	0.0
5	73.0	33.8	19.6
6	18.2	44.9	50.4
7	0.0	21.3	30.0
Yield reduction (%) classes in 2055			
6-8	54.6	17.2	2.8
9-11	37.0	56.3	44.1
12-14	8.4	20.1	40.4
15-18	0.0	6.4	12.7

A perusal of dates presented in Table 6 showed that in case of Kufri Badshah, advancing potato planting by 10 days from normal date of planting *i.e.* 10th of November, is likely to give the best yield at all the five locations in the future climate of 2020 and this could result in the lesser decline (-1.5%) in potential productivity as compared to productivity at normal dates of planting (-5.1%) (Table 4). It shows that just by manipulating the date of planting, the decline in the productivity of Kufri Badshah can be reduced by around 70%. In the year 2055, the change in date of planting is recommended for northern districts of Malda and Medinipur as advancing or delaying planting, both, resulted in decline in productivity of Kufri Badshah there, whereas in Bankura, Hoogly and Jalpaiguri, advancing planting by 10 days from the normal 10th November, gave the highest productivity as simulated by WOFOST for 2055. Planting Kufri Jyoti 10 days earlier than the normal date of planting (10th November) resulted in maximum simulated yield at Bankura, Hoogly and Jalpaiguri only in future climate scenario of 2020. However, the change in date of planting is not a suitable option for Kufri Jyoti under scenario of 2055. The model has shown that for Kufri Jyoti (2055 scenario) and for Kufri Pukhraj (both 2020 and 2055 scenarios) 10th November would be the best planting date.

From the simulation studies, it appears that Kufri Badshah has greater resilience against climate

Table 5. WOFOST simulated potential productivity of potato cultivars under baseline (2000) and future climate scenarios at different locations in West Bengal.

Station	Kufri Badshah							Kufri Jyoti							Kufri Pukhraj						
	Baseline yield (t/ha)	Change over baseline yield (%)						Base line yield (t/ha)	Change over baseline yield (%)						Base line yield (t/ha)	Change over baseline yield (%)					
		2020			2055				2020			2055				2020			2055		
		Due to temp.	Due to CO_2	Temp.+ CO_2	Due to temp.	Due to CO_2	Temp.+ CO_2		Due to temp.	Due to CO_2	Temp.+ CO_2	Due to temp.	Due to CO_2	Temp.+ CO_2		Due to temp.	Due to CO_2	Temp.+ CO_2	Due to temp.	Due to CO_2	Temp.+ CO_2
Bankura	38.4	-8.4	4.5	-4.2	-22.1	19.3	-6.4	37.3	-8.8	4.7	-4.4	-22.9	20.5	-6.1	39.7	-9.5	4.6	-5.3	-23.9	20	-7.8
Bardhaman	41.4	-7.8	4.5	-3.6	-21.5	19.3	-5.7	40.6	-9.1	4.7	-4.6	-23.3	20.5	-6.4	43.3	-8.7	4.6	-4.4	-23.5	20	-7.3
Dinajpur	42.5	-9	4.3	-4.9	-22.7	18.6	-7.6	40.7	-10.1	4.6	-5.9	-25.5	19.8	-9.4	42.7	-9.9	4.4	-5.7	-26.4	19.3	-11
Hawrah	36.5	-8.9	4.5	-4.8	-22.7	19.1	-7	34.8	-9.5	4.7	-5.2	-24.8	20.3	-8.3	36.6	-10.3	4.5	-6.2	-26	19.8	-9.9
Hoogly	37.9	-8.6	4.5	-4.5	-22.2	19.3	-6.4	36.2	-9.3	4.8	-5	-24.7	20.5	-8	38.3	-10.2	4.6	-6	-26	20.1	-9.5
Jalpaiguri	46.9	-8.8	4.4	-4.7	-22.7	18.8	-7.1	45.4	-9.9	4.7	-5.6	-25.1	20	-8.9	48.2	-10.5	4.5	-6.3	-26.1	19.6	-10.3
Kolkata	35.0	-9.1	4.4	-5	-22.7	19	-7.2	33.6	-10	4.6	-5.6	-25.6	20.3	-9.2	35.0	-10.6	4.5	-6.5	-26.9	19.9	-10
Malda	38.0	-9.2	4.3	-5.3	-23.2	18.5	-8.4	35.8	-9.7	4.5	-5.5	-25.7	19.5	-9.8	37.3	-10.9	4.4	-6.9	-28.2	19.1	-12.5
Medinipur	33.8	-8.5	4.6	-4.2	-29.9	20.1	-13.9	32.2	-10.2	5	-5.6	-38.3	21.7	-17.1	33.7	-9.7	4.8	-5.2	-43.8	21.3	-18.4
Nadia	42.7	-9.5	4.9	-5.1	-27.4	21.4	-10.6	40.7	-10	5.2	-5.3	-30.7	22.9	-12.6	43.8	-10.8	5.2	-6.1	-34.5	22.7	-16
North Parganas	31.2	-9.1	4.4	-5.1	-24.2	18.8	-9.2	29.0	-10.7	4.7	-6.4	-28.7	20.4	-11.4	29.6	-10.4	4.6	-6.2	-31.7	20	-12.4
South Parganas	31.6	-9.1	4.4	-5.1	-24.2	18.9	-9.1	29.4	-10.7	4.7	-6.4	-28.6	20.5	-11.4	30.0	-10.4	4.6	-6.2	-31.5	20	-12.2
Purulia	39.0	-8	4.4	-3.9	-22.3	18.8	-6.9	37.7	-9.6	4.6	-5.3	-24.6	19.9	-8.5	39.6	-9.4	4.4	-5.3	-25.4	19.3	-9.9
Mean	38.0	-8.8	4.5	-4.6	-23.7	19.2	-8.1	36.4	-9.8	4.7	-5.4	-26.8	20.5	-9.8	38.3	-10.1	4.6	-5.9	-28.8	20.1	-11.3

Table 6. Potential productivity at normal date of planting in baseline year (2000) and change in date of planting in future climates.

Location	2000			2020				2055		
Change over baseline	Normal DOP*	Productivity (t/ha)	Best DOP	Productivity (t/ha)	Best DOP (days)	Productivity (%)	Best DOP	Productivity (t/ha)	Best DOP (days)	Productivity (%)
Kufri Badshah										
Bankura	10 Nov.	38.4	31-Oct	38.9	-10	1.3	31-Oct	37.8	-10	-1.6
Hoogly	10 Nov.	37.9	31-Oct	37.7	-10	-0.5	31-Oct	36	-10	-5.0
Jalpaiguri	10 Nov.	46.9	31-Oct	46.2	-10	-1.5	31-Oct	44.2	-10	-5.8
Malda	10 Nov.	38.0	31-Oct	36.3	-10	-4.5	10 Nov.	34.7	0	-8.7
Medinipur	10 Nov.	33.8	31-Oct	33.1	-10	-2.1	10 Nov.	28.1	0	-16.9
Mean		39.0		38.4		-1.5		36.2		-7.6
Kufri Jyoti										
Bankura	10 Nov.	37.3	31-Oct	36.1	-10	-3.2	10 Nov.	35	0	-6.2
Hoogly	10 Nov.	36.2	31-Oct	34.5	-10	-4.7	10 Nov.	33.3	0	-8.0
Jalpaiguri	10 Nov.	45.4	31-Oct	42.8	-10	-5.7	10 Nov.	41.3	0	-9.0
Malda	10 Nov.	35.8	10 Nov.	33.7	0	-5.9	10 Nov.	32.3	0	-9.8
Medinipur	10 Nov.	32.2	10 Nov.	30.3	0	-5.9	10 Nov.	30.3	0	-5.9
Mean		37.4		35.5		-5.1		34.4		-7.8
Kufri Pukhraj										
Bankura	10 Nov.	39.7	31 Oct and 10 Nov.	37.5	0 or -10	-5.5	10 Nov.	36.6	0	-7.8
Hoogly	10 Nov.	38.3	10 Nov.	36.0	0	-6.0	10 Nov.	34.7	0	-9.4
Jalpaiguri	10 Nov.	48.2	10 Nov.	45.2	0	-6.2	10 Nov.	43.3	0	-10.2
Malda	10 Nov.	37.3	10 Nov.	34.8	0	-6.7	10 Nov.	33.0	0	-11.5
Medinipur	10 Nov.	33.7	10 Nov.	32.0	0	-5.0	10 Nov.	27.9	0	-17.2
Mean		39.4		37.1		-5.9		35.1		-11.2

*DOP = Date of planting

change and could be more suitable cultivar in the future climates than Kufri Jyoti and Kufri Pukhraj at all the locations. The productivity of Kufri Badshah was 4.3% higher than Kufri Jyoti in the baseline scenario but in future scenario it increased to 5.2% (2055) and 8.2% (2020). Similarly, Kufri Badshah, which gave the lesser yield than Kufri Pukhraj in the baseline year (2000), is likely to yield more than 3% higher in future climates. Hence, with and advancement in 10 days in planting and by replacing the other two cultivars with Kufri Badshah at all the five locations representing the state can bring down the reduction in yield from 5.7% in 2020 (without adaptation) to +1.3 to 4.4% (mean -1.5%) and in 2055 from 10.4 to -7.1%.

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