



## Assessing the impact of temperature and rainfall on mustard yield through detrended production index

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सार — वर्तमान अध्ययन का उद्देश्य 18 वर्षों के आधार पर पश्चिम बंगाल के पांच जिलों अर्थात् हुगली, नादिया, बर्दवान, मुर्शिदाबाद और दक्षिण 24 परगना के लिए डीपीआई के माध्यम से सरसों की उपज पर तापमान और वर्षा के अलग-अलग और संयुक्त प्रभाव का मूल्यांकन करना है। चयनित अध्ययन क्षेत्र राज्य के विभिन्न कृषि-जलवायु क्षेत्रों, अर्थात् पुराने जलोढ़ क्षेत्र, नए जलोढ़ क्षेत्र और तटीय लवणीय क्षेत्र से संबंधित हैं। इन जिलों में सरसों की खेती का मौसम अक्टूबर के मध्य से शुरू होता है और जनवरी के मध्य (रबी सीज़न) तक जारी रहता है। डिट्रेंडेड प्रोडक्शन इंडेक्स (डीपीआई) की गणना अध्ययन अवधि में वास्तविक वार्षिक उपज और अभिकलित प्रवृत्ति मान के आधार पर की गई है। इस मामले में अधिकतम और न्यूनतम तापमान के साथ-साथ वर्षा के आंकड़ों को मुख्य रूप से महत्व दिया गया। संभावित डीपीआई के माध्यम से तापमान और वर्षा के प्रभाव के साथ-साथ उनकी परस्पर क्रिया को स्पष्ट किया जाता है। इस प्रक्रिया द्वारा पश्चिम बंगाल के पांच जिलों में प्रमुख मौसम प्राचलों के कारण सरसों की उपज में भिन्नता दिखाई गई है। इस अध्ययन से दो समीकरण प्राप्त हुए हैं, एक अधिकतम और न्यूनतम तापमान पर आधारित तथा दूसरा तापमान और वर्षा के संयुक्त प्रभाव को सम्मिलित करता है। इनका उपयोग उपज पूर्वानुमान के मॉडल बनाने में आसानी से किया जा सकता है। बढ़े हुए तापमान के कारण उपज में कमी के स्पष्ट संकेत निर्णय लेने की प्रक्रिया में मार्गदर्शन करेंगे। यदि भविष्य में तापमान में वृद्धि जारी रहती है तो अध्ययन क्षेत्र में सरसों की खेती के लिए बुआई के समय में संशोधन एक महत्वपूर्ण समाधान है। इस शोध कार्य के परिणाम फसल उत्पादन पर प्रमुख मौसम प्राचलों के प्रभावों का मूल्यांकन करने और उसके आधार पर उपज पूर्वानुमान मॉडल तैयार करने के लिए डीपीआई को शामिल करने के विचार का दृढ़ता से समर्थन करते हैं।

**ABSTRACT.** The present study aims to evaluate the individual and combined impact of temperature and rainfall on mustard yield through DPI for five districts, viz., Hooghly, Nadia, Burdwan, Mursidabad and South 24 Parganas of West Bengal based on 18 years. The selected study areas belong to different agro-climatic zones of the state, namely the old alluvial zone, new alluvial zone and coastal saline zone. The mustard growing season in these districts starts from the middle of October and continues upto the middle of January (Rabi season). The Detrended Production Index (DPI) was calculated based on the actual annual yield of the study period and the computed trend value. Maximum and minimum temperatures along with rainfall data were given prime importance in this case. The effect of temperature and rainfall as well as their interaction is clarified through the generated DPI. The yield variation of mustard in the five districts of West Bengal due to prime weather parameters are shown by this process. Two equations, one based on max and min temperature and another incorporating the combined effect of temperature and rainfall, are the outcomes of the study. They can be easily utilized to form models of yield forecast. The clear indication towards yield reduction due to enhanced temperature will guide in decision making process. Modification of the sowing window is an important solution for mustard cultivation in the study region if the temperature continues to increase in the future. The results of this work strongly support the idea of engaging DPI to evaluate the impacts of prime weather parameters on crop production and generate the yield forecasting models based on that.

**Key words** – Temperature, rainfall, DPI, Mustard.

### 1. Introduction

India is one of the largest rapeseed-mustard growing countries in the world, occupying the first position in area

and second position in production after China (Khavse *et al.*, 2014). In India, it is the second most important edible oilseed crop after groundnut and accounts for nearly 30 percent of the total oilseed produced in the

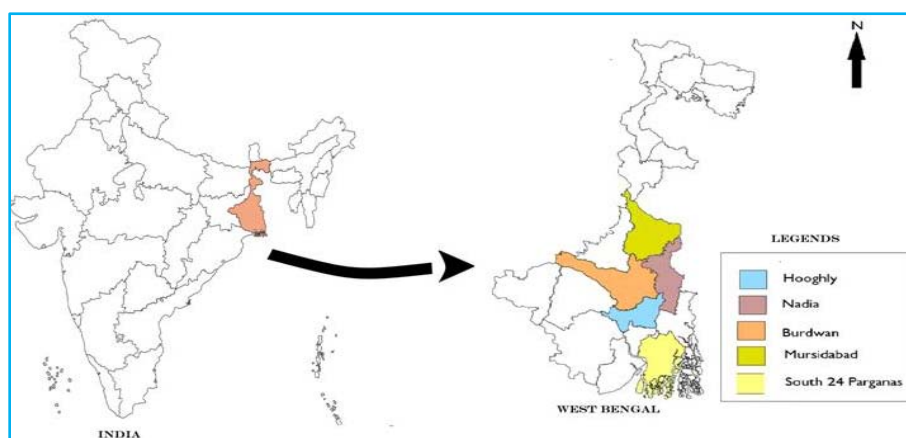


Fig. 1. Study area of the work comprising five districts of West Bengal

country. The rapeseed-mustard growing areas of India have witnessed a “yellow revolution” through the Technology Mission on Oilseeds during the last two decades of the 20<sup>th</sup> century (IKisan, 2019). But mustard productivity of West Bengal is not satisfactory. West Bengal holds 5<sup>th</sup> position in mustard production with 8.64% share in India (APEDA, 2018). As per ICAR, the area, production and the productivity of Mustard in West Bengal are 4.2 lakh ha, 3.8 lakh tonnes and 909 kg ha<sup>-1</sup> respectively. Mustard alone contributes 53% of total oilseed production of the state (Dutta, 2016). The low productivity of mustard in this state is a result of several factors. Adjustments to sowing time may be the only non-monetary solution to this problem. Doing so, a suitable growing period with optimum weather conditions may be provided. Weather parameters play the most important role in determining the mustard growth, development and yield because weather strongly influences the physical expression of genetic potential of the crop (Robertson *et al.*, 2002; Kar and Chakravarty, 2001). Any significant deviation of temperature, moisture supply and radiation from the optimum value becomes detrimental to crop productivity. Therefore, it is important to understand the meteorological aspects affecting plant growth and to maximize the production of any crop, understanding the effects of those factors on plant growth and development must be worked out (Singh *et al.*, 2016). As the physio-chemical and biological activities of rapeseed-mustard are governed by the weather variables prevailing in a particular area, their yield also varies from region to region. The temperature plays the most important role in influencing the duration and yield of mustard (Khushu *et al.*, 2008, Prasad *et al.*, 2018, Gupta *et al.*, 2017, Islam *et al.*, 2019). Thus, response of different genotypes to one environment, or a single genotype to different environments, can be quite different (Rao *et al.*, 1998). Hence, evaluation of the influences of weather conditions on the yield of mustard is necessary, which can show the

path towards overall yield improvement through adjustment of sowing window, variety and site selection, microclimatic modification, etc. So, it is necessary to evaluate the optimum weather conditions for a higher yield of rapeseed-mustard and the overall influence of the weather on mustard performance. Not only that, effect of weather parameters can be utilized for developing models for yield prediction. Accurate foretelling of yield can help to adopt appropriate policies and timely measurements regarding marketing, storage etc. A lot of research has taken place and much more are going on just to build up such models employing effects of the weather (Prasad and Dudhane, 1989; Pandey *et al.*, 2016). Several approaches have been evolved for this (Huda *et al.*, 1975; Shankar and Gupta, 1987; Laxmi and Kumar, 2011; Kumar *et al.*, 2014). The Detrended Production Index (DPI) is one of them. This index helps to eliminate the effects of all other yield improving factors except weather parameters. Thus, only the impact of weather on the yield can be studied. DPI seems to have immense potential as a model developing tool. But few works are available on DPI, especially for West Bengal. Biswas *et al.* (2017) depicted the efficiency of DPI in generating a favorable yield forecasting model for wet season rice in this state. Considering the background, the present study aims to evaluate the individual and combined impact of temperature and rainfall on mustard yield through DPI for five districts of West Bengal. The effect of enhanced temperature as a consequence of global warming on mustard yield is also studied in this work.

## 2. Materials and method

### 2.1. Study area

Five districts of West Bengal were chosen to conduct the experiment (Fig. 1). The crop data and weather information were collected from various stations of those

TABLE 1

## Coordinates and general climate of the study area

District	Coordinates	Climate
Hooghly	22.8963°N, 88.2461° E	Humid to sub-humid tropical climate with an oppressive hot summer, high humidity between April and September, short winter (December-February) and well distributed rainfall during the south-west monsoon season (June-September). Average daily winter temperature ranges from 11°C to 17°C. The climate of this region has a high potential for floods
Nadia	23.4710°N, 88.5565° E	Extreme climatic conditions due to the passage of the Tropics of Cancer passes through the centre of the district Average maximum temperature: 36°C Average minimum temperature: 8°C January is generally the coldest month In winter, prevailing winds are from the north and north west, with very heavy dew at night An average annual rainfall is 1455 mm
Burdwan	23.2324° N, 87.8615° E	Altitude : 98 feet Average annual temperature : 26.3 °C <b>Winter temperature</b> : Max : 24°C; Min: 10°C January is the coldest month with average temperature around 19.4°C <b>Average annual Rainfall</b> : 1313 mm December is the driest month with 2 mm of rain
Mursidabad	24.1759° N, 88.2802° E	The annual mean temperature is approximately 27 °C The average winter temperature : 9 °C to 11 °C January is the coldest month with the mean daily maximum temperature at 25.0 °C and the mean daily annual minimum temperature at 11.9 °C The district is sometimes affected by cold waves with passing western disturbances in the cold season and on such occasions the minimum temperature may go down to 4 or 5°C The average annual rainfall in the district is 1361.5mm Occasional fog occurs in the cold season
South 24 Parganas	22.1352° N, 88.4016° E	Hot and humid climate Average temperature in this district varies from a maximum of 38°C to a minimum around 13°C Average annual rainfall is 47 of around 1800 mm

five locations, *viz.*, Hooghly, Nadia, Burdwan, Mursidabad and South 24 Parganas. The selected study areas belong to different agroclimatic zones of the state, namely the old alluvial zone, new alluvial zone and coastal saline zone. The mustard growing season in these districts starts from the middle of October and continues upto the middle of January (*Rabi* season). The Coordinates and climatic conditions of the study areas are displayed in Table 1.

### 2.2. Collection of data

The present piece of study is based on 18 years' (1997 to 2014) dataset. Three to five stations were selected for each district and data were collected for those stations (Table 2). The detailed information on yield for 18 years was collected from the Government of West

TABLE 2

## Name of the weather stations representing different Districts

Name of the district	Name of the stations
Hooghly	Arambagh, Dhaniakhali, Singur
Nadia	Kalyani, Krishnanagar, Nakashipara, Ranaghat
Burdwan	Burdwan, Kalna, Kanska
Mursidabad	Behrampore, Chandipur, Kandi, Suti2
South 24 Parganas	Canning, Diamond Harbour, Kakdwip

Bengal for carrying out the study (Govt. of West Bengal, 2015). The weather data were collected from the India Meteorological Department (IMD) for the same period of

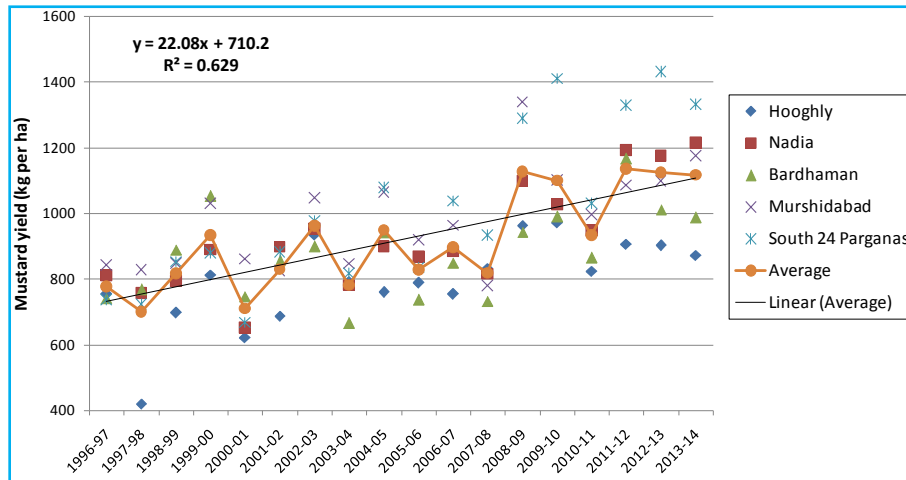


Fig. 2. Variation of mustard yield over years in the study region

time. Maximum and minimum temperatures along with rainfall data were given prime importance in this case. The entire growing season of mustard was divided into vegetative and reproductive stages for convenience of the study. Thus,  $T_{max}V$ ,  $T_{min}V$  and  $RFV$  refer to the maximum temperature, minimum temperature and rainfall in vegetative stage respectively. Likewise,  $T_{max}R$ ,  $T_{min}R$  and  $RF R$  indicate the maximum temperature, minimum temperature and rainfall in reproductive stage respectively.

2.3. Data analysis

The below mentioned steps were followed to analyze the data for assessing the impact of temperature and rainfall on mustard yield.

2.3.1. Formation of trend equations

While working with data over long period, trend components should be eradicated. It is done so that effects of all other parameters like increase of land, better management and technology etc. can be removed and only the effect of weather parameters can be observed. The trend equations can be produced through curve fitting.

2.3.2. Detrended Production Index (DPI)

The Detrended Production Index (DPI) was calculated based on the actual annual yield of the study period and the computed trend value. The percentage of the ratio of these two is known as DPI.

$$DPI = \frac{P}{T} * 100$$

where,

P = Actual annual yield of mustard from 1997 to 2014

T = Computed trend component

DPI value was worked out separately for each of the five districts as well as the average yield of those five districts in the time span of 18 years.

2.3.3. Evaluating the impact of temperature and rainfall on mustard yield

This was one of the most important steps of the entire study as it fulfilled the aim of the present work. A multiple linear regression model was used to perform this. At first, effect of temperature, including both maximum and minimum temperature was worked out. Then the same procedure was carried out for assessing the combined effect of temperature and rainfall on mustard yield.

2.3.4. Assessing the effect of enhanced temperature on mustard yield through developed equation

Climate change and global warming are not myths anymore. Increment of atmospheric temperature is one of the outcomes of climate change which may have an adverse effect on crop yield. Here an attempt was made to observe the impact of increased temperature on mustard yield in the study location. Long term average of maximum and minimum temperatures during vegetative and reproductive stages in the study areas were considered as standard for normal mustard production. The detrended yield of mustard was computed at four different increased

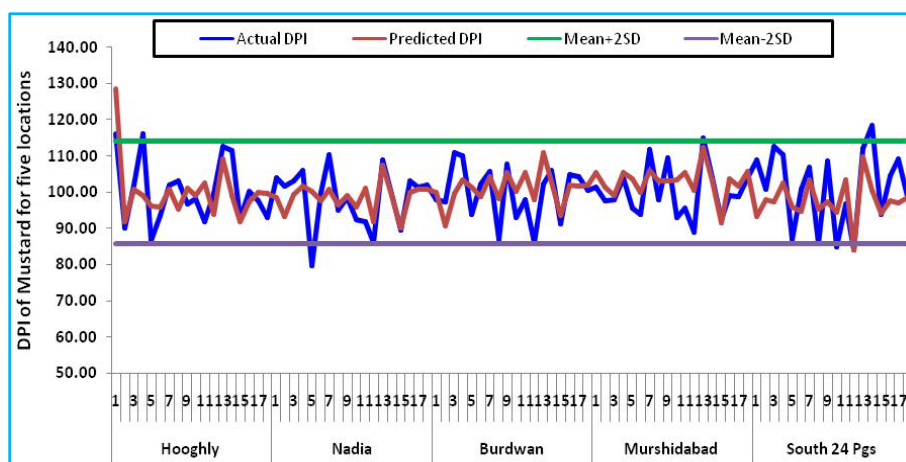


Fig. 3. Variation of actual and fitted DPI

temperature levels (0.5 °C, 1.0 °C, 1.5 °C and 2.0 °C) using the relationship of predicted DPI and temperature data (equation 1).

### 3. Results and discussion

#### 3.1. Year-wise variation of mustard yield

Variation of mustard yield over the study period in different locations is displayed in Fig. 2. The year-wise yields of mustard in five districts were highly variable. Although a definite trend among them existed. Moreover, when all the five locations are considered, overall increase in the year-wise yield was significant, with an  $R^2$  value 0.63. Hence, detrending was necessary.

#### 3.2. Detrended Production Index for the study locations

The Detrended Production Index is used for smoothening the variation. The effect of improved technology, application of fertilizers, better crop pest and disease control, etc., are minimised through this process. The location-specific linear equations for each and every district were derived (Table 3). Some  $R$  squares had poor values. But those low  $R^2$  could become acceptable for detrending purpose. Higher values of  $R^2$  indicated the significance of technological trends in the case of Hooghly ( $R^2 = 0.46$ ), Nadia ( $R^2 = 0.65$ ) and South 24 Parganas ( $R^2 = 0.73$ ) districts, where as it was not significant for Burdwan and Mursidabad. Actual and predicted DPI values were plotted in a graph and the plotting is shown in Fig. 3. Both were in tune with each other. All predicted DPI remained within mean  $\pm$  2SD (standard deviation) limit. It justified the proficient performance of the model for forecast.

TABLE 3

#### Linear regression equations for year-wise trend

Location	Equation	R-squared
Hooghly	$y = 17.10x + 632.6$	0.46
Nadia	$y = 24.11x + 697.5$	0.65
Burdwan	$y = 12.04x + 767.1$	0.24
Murshidabad	$y = 17.57x + 814.9$	0.39
South 24 Parganas	$y = 39.56x + 638.6$	0.73

#### 3.3. Predicting DPI from temperature data

A proper calculation was performed to predict the DPI from temperature data of 18 years. The equation for predicting DPI from temperature data is as follows:

$$DPI = 148.40 - 1.27 T_{max}V - 1.24 T_{min}V - 0.48 T_{max}R + 2.27 T_{min}R \tag{1}$$

(Valid when  $T_{max}$  is between 22.12 °C to 32.08 °C and  $T_{min}$  is between 9.55 °C to 22.76 °C)

where,

$T_{max}V$  = Maximum temperature (°C) in vegetative stage

$T_{min}V$  = Minimum temperature (°C) in vegetative stage

$T_{max}R$  = Maximum temperature (°C) in reproductive stage

**TABLE 4**

**ANOVA for predicting DPI from temperature**

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>
Regression	4	1454.32	363.579	2.703
Residual	85	11435.29	134.532	
Total	89	12889.61		

$T_{\min}R$  = Minimum temperature (°C) in reproductive stage

The calculated *F* value was more than ‘Table value’ of *F* at 5% level. Hence with 95% confidence, we concluded that there were significant effects on temperatures on predicted DPI (Table 4).

**3.4. Predicting DPI from temperature and rainfall data**

As mentioned in the materials and method part, the simultaneous effect of temperature and rainfall was also worked out. The equation for predicting DPI from both temperature and rainfall data is as follows:

$$DPI = 144.44 - 1.21 T_{\max}V - 0.88 T_{\min}V - 0.04 RF V - 0.75 T_{\max}R + 2.96 T_{\min}R - 0.38 RF R \quad (2)$$

(Valid for  $T_{\max}$ : 22.12 °C to 32.08 °C,  $T_{\min}$ : 9.55 °C to 22.76 °C, *RF*: 0 mm to 295.66 mm)

where,

$T_{\max}V$  = Maximum temperature (°C) in vegetative stage

$T_{\min}V$  = Minimum temperature (°C) in vegetative stage

$T_{\max}R$  = Maximum temperature (°C) in reproductive stage

$T_{\min}R$  = Minimum temperature (°C) in reproductive stage

*RF V* = Rainfall (mm) in vegetative stage

*RF R* = Rainfall (mm) in reproductive stage

It was observed from the ANOVA table that the calculated *F* was more than ‘Table value’ of *F* at 1% level. So, we were able to conclude with 99% confidence that

**TABLE 5**

**ANOVA for predicting DPI from temperature and rainfall**

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>
Regression	6	2854.23	475.705	3.934
Residual	83	10035.37	120.908	
Total	89	12889.61		

there were significant effects of temperatures and rainfall together on predicted DPI (Table 5).

Another DPI predicting equation was developed taking up flowering and pod formation to pod maturity stages separately instead of reproductive stage. The equation is as follows:

$$DPI = 114.9346 - 0.053904 T_{\max}V - 2.20898 T_{\min}V - 0.02718 RF V + 0.98651 T_{\max}F + 3.663021 T_{\min}F - 0.10119 RF F - 1.18446 T_{\max}P + 0.131448 T_{\min}P - 0.24166 RF P \quad (3)$$

Where,

$T_{\max}V$  = Maximum temperature (°C) in vegetative stage

$T_{\min}V$  = Minimum temperature (°C) in vegetative stage

$T_{\max}F$  = Maximum temperature (°C) in flowering stage

$T_{\min}F$  = Minimum temperature (°C) in flowering stage

$T_{\max}P$  = Maximum temperature (°C) in pod formation to pod maturity stage

$T_{\min}P$  = Minimum temperature (°C) in pod formation to pod maturity stage

*RF V* = Rainfall (mm) in vegetative stage

*RF F* = Rainfall (mm) in flowering stage

*RF P* = Rainfall (mm) in pod formation to pod maturity stage

It was observed from the ANOVA table that the calculated *F* was more than ‘Table value’ of *F* at 5% level. So, we were able to conclude with 95% confidence that

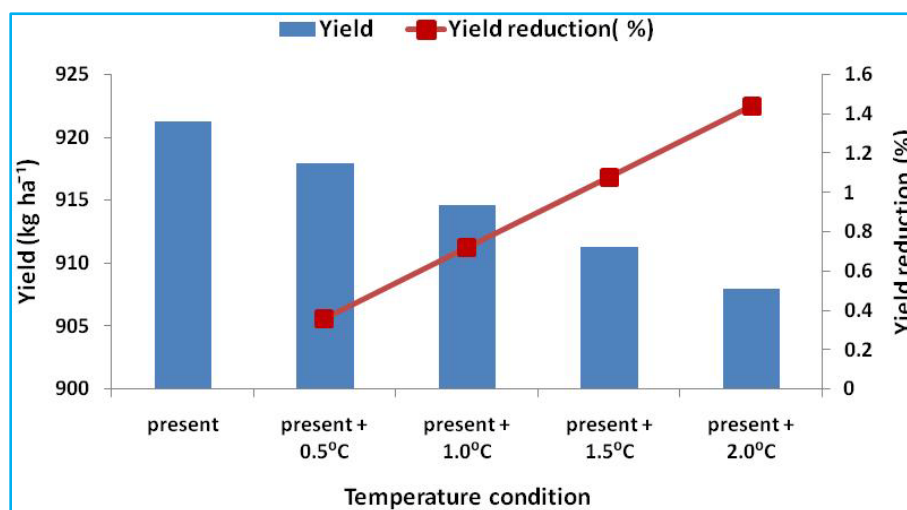


Fig. 4. Effect of enhanced temperature on mustard yield

TABLE 6

ANOVA for predicting DPI from temperature and rainfall considering and pod formation to pod maturity stages separately instead of reproductive stage

	df	SS	MS	F
Regression	9	1990.045	221.1161	4.203134
Residual	80	4208.595	52.60743	
Total	89	6198.639		

there were significant effects of temperatures and rainfall together on predicted DPI (Table 6).

### 3.5. Effect of enhanced temperature on mustard yield through developed equation

Effect of enhanced temperature on mustard yield was observed through the equation 1. It was developed considering the impact of temperature only. The effect of enhanced temperature on mustard yield in the study region is shown in Fig. 4. It displays future yields as well as the yield reduction percentages at four different increased temperature levels. A gradual decrease from present yield was observed with temperature increment from 0.5 °C to 2.0 °C. The equations indicated a reduction of 0.36%, 0.72%, 1.01% and 1.4% in mustard yield at 0.5 °C, 1 °C, 1.5 °C and 2 °C increased temperatures respectively. The declined yield of mustard will be 908 kg ha<sup>-1</sup> in the study location at +2 °C temperature condition. That implies the future scenario of mustard production for the areas considered. In that condition, alternation of the present sowing time may be a solution to avoid the possible yield loss. Equation 1 says that yield reduction is more if a

higher temperature coincides with the vegetative stage. The time of sowing should be adjusted so that the vegetative stage can escape the high temperature period. But all other required management practises should be performed along with the mentioned one. Otherwise, several other biotic and abiotic stresses may lower the yield too.

## 4. Conclusion

The present study clearly indicates the efficiency of Detrended Production Index to elucidate the prediction model. The effect of temperature and rainfall as well as their interaction is clarified through the generated DPI. The yield variation of mustard in the five districts of West Bengal due to prime weather parameters are shown by this process. Two equations, one based on temperature (both maximum and minimum temperature) and another incorporating the combined effect of temperature and rainfall, are the outcomes of the study. They can be easily utilized to form models of yield forecast. In addition, the probable impact of increased temperature conditions is also discussed in this study. The clear indication towards yield reduction due to enhanced temperature will guide in decision making process. Modification of the sowing window is an important solution for mustard cultivation in the study region if the temperature continues to increase in the future. Thus, the results of this work strongly support the idea of engaging DPI to evaluate the impacts of prime weather parameters on crop production and generate the yield forecasting models based on that.

*Disclaimer* : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.



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