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Research Article

Spatial and Temporal Variability of Extreme Rainfall and Air Temperature related to Jute Production in West Bengal

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ABSTRACT

A study was conducted in West Bengal to assess spatial and temporal variabilities of extreme rainfall, maximum and minimum air temperatures during jute growing season based on 102-year long-term climatic data (1901-2002). For data analysis, jute season was divided into two halves such as April-May (first-half) and June-July (second-half) due to the two distinct prevailing climatic conditions exist during jute growth period. For jute growth in April-May, the requirement of effective rainfall is 229 mm, and maximum and minimum air temperatures are 37°C and 24°C, respectively, however, in June-July, the requirement of effective rainfall is 304 mm, but optimum temperatures remain same. The deviations from these climatic optimum values were computed to assess variation of fibre productivity. During first-half (Apr-May) of jute season, higher maximum and lower minimum air temperatures were found in six districts, and in eight districts, respectively. However, during second-half (June-July) both the maximum and minimum air temperatures were within the optimum range and congenial to jute growth in all the jute growing districts except in Darjeeling and South 24-Parganas where minimum air temperature was found to be lower than the optimum, resulted reduced the jute growth.

Key words: Effective rainfall, air temperature, jute, climate change, West Bengal.

Introduction

Jute (*Corchorus spp*.) is the most important natural bast-fibre crop in India. Jute is grown mostly as rainfed crop in hot and humid climatic condition during March to August in the eastern part of India, but the most favourable period is from April-July. Out of 7.17 lakh ha jute area of India, West Bengal contains about 70% of the national jute acreage, followed by Assam, Bihar and Odisha (Indian Jute, 2019). India produced 1.68 million tonnes of jute fibre and contains about 60% of world jute production (Mahapatra *et al.*, 2009), and also earns good amount of foreign revenues. In India, jute is mainly grown by small and marginal farmers and about 4 million farm families, 0.25 million industrial workers, 0.5 million traders are dependent on jute productions for their livelihood (Mahapatra *et al*., 2009a). Jute is a cash crop and it also generates employment of about 10-million man-days in a year (Mahapatra *et al.*, 2009).

Rainfall and temperature are the two most important climatic factors which influence production and productivity of jute. But due to climate change, fluctuation in air temperature and rainfall due to Nor'wester (locally known as *kalbaishakhi*)/monsoon during jute season has become an important concern for jute cultivation in eastern India, particularly in West Bengal as it contains about 70% of national jute acreage. West Bengal has six different agro-climatic zones such as hill zone, terai zone, old alluvial zone, new

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alluvial zone, red and laterite zone, and coastal saline zone. Most of the jute areas are in terai zone, old alluvial zone and new alluvial zone. As because jute is grown in different agro-climatic regions, the spatial variabilities of climatic parameters are pre-existed and obvious. Recent analysis is also revealed that there is evidence of climate variabilities in temporal scale in West Bengal (Mondal *et al.*, 2013; Mukherjee *et al.*, 2016; Das and Bhattacharya, 2018). Both the spatial and temporal variabilities in climatic parameters such as rainfall and temperature has direct effect on agriculture including jute production and productivity.

The occurrence of the values of the climate variables above (or below) the threshold values is called extreme events (IPCC, 2012). For optimum jute growth throughout its life cycle, the threshold maximum and minimum air temperatures are 37°C and 24°C, respectively (http://www.world jute.com/about_jute/abj_cultivation.html), and the threshold of total rainfall is of 229 mm during April-May and of 304 mm during June-July. Any deviation of these climatic parameters from their threshold values will reduce the production and productivity and can lead to disasters (IPCC, 2012). In India. The losses due to extreme events had increased in the last decade of the twentieth century and impacted agriculture sector including other sectors (De *et al.*, 2005). Therefore, the identification of the extreme climatic events is very important for management of agriculture in general and for jute production in particular. This will also explore the challenge of understanding and managing the risks of climate extremes to advance climate change adaptation. Moreover, weather or climate events, even if not statistically significantly extreme, can still lead to extreme conditions or impacts in a social, ecological, or physical system either by crossing a critical threshold, or by occurring along with other events (IPCC, 2012).

Weather and climate related constraints in agricultural production have social as well as physical dimensions. Therefore, the changes in the frequency and severity of the climatic events in spatially diverse and temporally dynamic in nature need to be studies in regional or local level for understanding the vulnerability of the system (Lucie *et al.*, 2006). Opportunities for managing risks of weather and climate related extremes/ constraints exist or can be developed at local to international level. Effective risk management strategies and climate change adaption options can be done by adjusting the current activities or by transforming the system including fundamental change (IPCC, 2012). The aim of this paper is therefore to analyze the spatial and temporal variabilities of climatic parameters such as rainfall and air temperature, and to find out their deviation from the optimum rainfall, maximum and minimum air temperatures for jute production.

Materials and Methods

Study area

The study area was the major jute growing districts of West Bengal. This is situated in the eastern side of India along the Bay of Bengal. The geographical location of West Bengal is between 85°50′ and 89°50′ E longitude and 21°25′ and 27°13′ N latitude. The entire state is categorized into six agroclimatic zones of which three agro-climatic zones such as terai zone, new alluvial zone and old alluvial zone contain major jute growing regions. The major jute growing districts are Birbhum, Burdawan, Cooch Behar, Hooghly, Howrah, Jalpaiguri, Dakshin Dinajpore, Malda, Murshidabad, Nadia, North Dinajpur, North 24-Parganas, and South 24-Parganas.

Data used

Monthly rainfall, maximum and minimum air temperature data of jute growing season (April-July) for the period of 1901 to 2002 were collected from the website: http://www.india waterportal.org/ for all the districts of West Bengal. Climate data of major jute growing districts were analyzed for this study.

Statistical analysis

For statistical analysis, climate data were categorized into two groups as per the two distinct phases of jute growing season. The climate data of April-May of summer season represented one group and the data of June-July of rainy season represented another group. The maximum and minimum air temperatures data were averaged over April-May and June-July, but rainfall data were the summation of April-May and June-July of the individual year. Minimum, maximum and median values of maximum and minimum air temperatures, and rainfall were computed. Frequency of occurrence of <24°C and >37°C over the 102-year period (1901-2002) were also calculated by taking the Apr-May and Jun-July average temperature data. Deviation of maximum and minimum air temperature, and rainfall for both the phases (April-May and Jun-July) were computed by subtracting the optimum value from the actual value of the individual year. All the statistical analyses were done using SAS 9.3 software.

Results and Discussion

Spatial variability of rainfall

Rainfall data averaged over 102-year period (1901-2002) showed that the total rainfall of April and May, and June and July varied across the jute growing districts of West Bengal (Table 1). From Table 1, it was evident that total rainfall of the months of April-May was highest in the district of Cooch Behar (313.1 mm) followed by Jalpaiguri (309.4 mm), Darjeeling (240.3 mm), and lowest in Birbhum (110.8); but total rainfall of June-July was highest in Jalpaiguri (1030.4) followed by Darjeeling (931.6 mm), Cooch Behar (913.1 mm) and lowest in South 24-Parganas (483 mm). District wise variability of minimum, maximum and median values of total rainfall of the months of April-May and June-July during the period of 102-year (1901-2002) were also presented for showing the spatial pattern of rainfall in jute growing districts (Fig.1). Rainfall in the month of April-May in West Bengal occurs due to Nor'wester (*kalbaishakhi*) which had been uncertain in nature (Barman *et al.*, 2012). For sowing and establishment of jute crop, nor'wester rain has very important role because jute is grown mainly as rainfed crop in West Bengal. However, harvesting of jute for its retting for the extraction

Table 1. District-wise total rainfall, average maximum and minimum air temperatures in jute growing season from 1901-2002 in West Bengal

Districts	Total rainfall (mm)		Avg. maximum temperature (°C)		Avg. minimum temperature (°C)	
	Apr+May	Jun+Jul	Apr-May	Jun-Jul	Apr-May	Jun-Jul
BANKURA	114.9	526.3	38.4	33.7	24.7	25.5
BIRBHUM	110.8	524.5	38.4	34.1	24.5	25.5
BURDAWAN	125.5	528.4	38.1	33.9	24.9	25.7
COOCH BEHAR	313.1	913.1	33.0	32.0	21.9	25.5
S DINAJPORE	164.1	626.5	36.3	33.4	23.4	25.9
DARJEELING	240.3	931.6	31.3	30.6	19.9	23.3
HOOGHLY	143.8	550.1	36.7	33.4	23.1	26.1
HOWRAH	145.2	556.2	35.6	32.9	25.9	26.3
JALPAIGURI	309.4	1030.4	31.6	31.6	21.5	24.8
KOLKATA	144.5	564.4	35.8	33.1	26.0	26.4
MALDA	120.8	561.3	36.6	33.3	22.7	24.9
MEDINIPORE	150.7	548.7	36.2	32.7	24.8	25.4
MURSHIDABAD	135.9	542.6	37.9	34.1	24.2	25.5
N 24 PGS	149.8	583.4	33.0	31.3	25.2	25.5
NADIA	155.3	541.3	37.2	33.8	25.0	25.9
PURULIA	86.1	503.6	38.4	33.4	24.2	25.0
S 24 PGS	118.0	483.4	27.3	26.3	21.6	21.8
N DINAJPORE	150.4	659.9	35.2	32.8	21.9	24.9

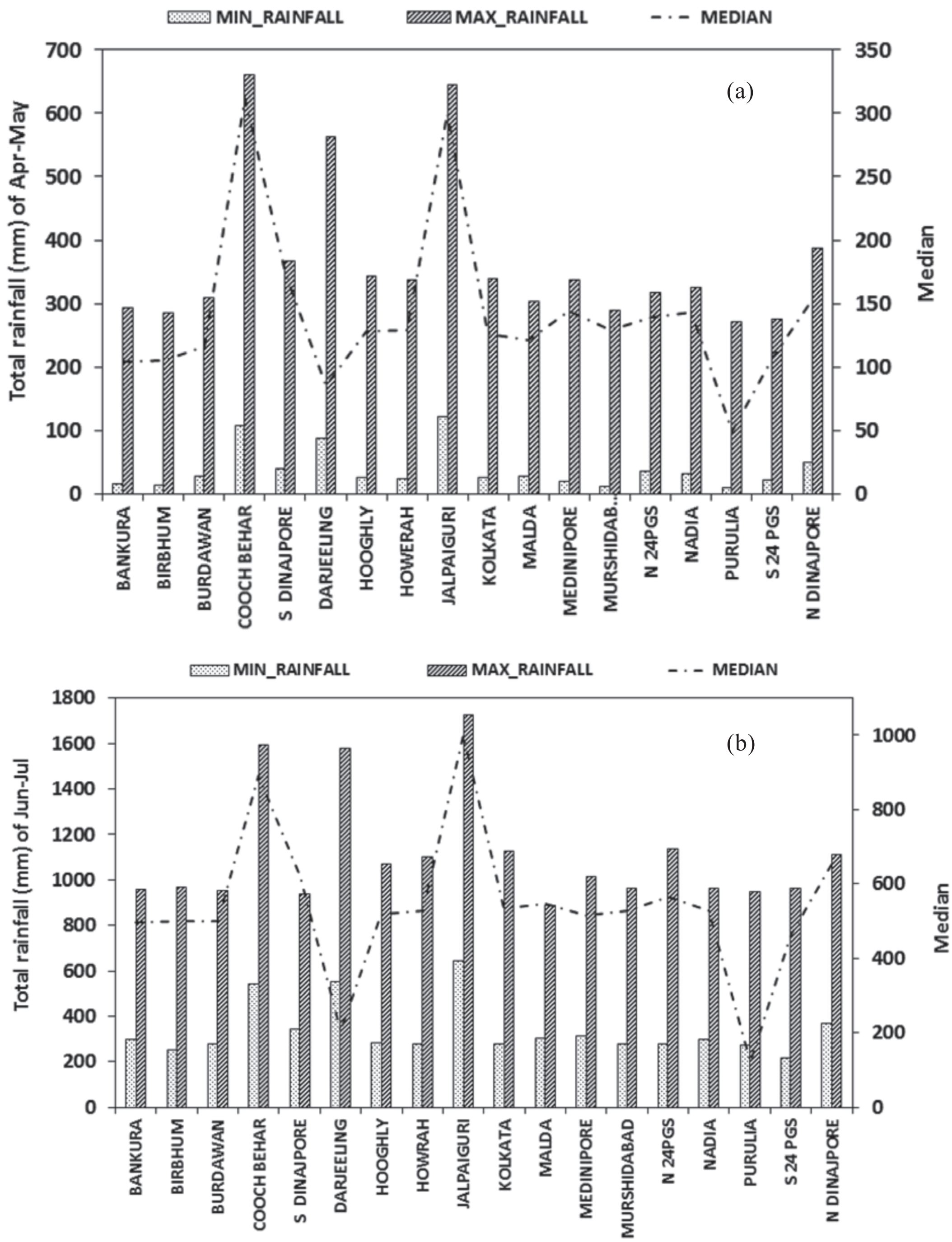

Fig. 1. District-wise variability of minimum, maximum and median values of total rainfall of (a) April-May and (b) June-July during jute growing period in West Bengal. (Monthly data of the period 1901-2002)

of its bast-fibre is dependent on the accumulation of monsoon rain in roadside ditches or ponds during June-July. But due to climate change Nor'wester/monsoon rainfall has become unpredictable in nature.

Spatial variability of maximum and minimum temperatures

Maximum and minimum temperatures data during jute growth period averaged over 102-year period (1901-2002) was presented in Table 1. This showed that average maximum temperature was highest in Birbhum during both the jute growing phases such as April-May (38.4°C) and June-July (34.1°C), and lowest in South 24-Parganas (27.3°C) during April-May (27.3°C) and June-July (26.3°C). Similarly, average minimum temperature during April-May was highest in Howrah and lowest in Darjeeling and during June-July, it was highest in Howrah (26.3°C) but lowest in South 24-Parganas. Minimum temperature during jute showing and establishment period (April-May) is critical for the first phase of jute growth because when minimum temperature is lower than the critical limit of 24°C, flowering starts in jute plants which is called premature flowering that reduces the jute yield and fibre quality. West Bengal represents 70% of the national jute acreage, and therefore the district level rainfall and temperature data were analyzed for variability analysis in spatial (district) and temporal scale of 102 years.

Extreme rainfall variability in relation to jute production in study areas

The requirement of effective rainfall is of 229 mm in the first phase of jute growth from jute sowing to establishment period during the month of April-May, however, in the second phase during June-July, the effective rainfall requirement is 304 mm. The deviation from these optimum values were computed and observed that the long-term average (102-year) actual rainwater was lower in all the districts except in Darjeeling, Cooch Behar and Jalpaiguri (Fig. 2). The negative values indicated that the rainwater was lower in the districts than the optimum values, and the positive values indicated vice-versa. The highest negative deviation was found in Birbhum (-51.6%), followed by Bankura (-49.8%) and Soth 24-Parganas (-48.5%), and lowest was in South Dinajpur (-28.3%). The positive deviations of rainfall were found in three districts, among them the highest was in Cooch Behar (+36.7%) followed by Jalpaiguri (35.1%) and Darjeeling (4.9%). Out of 16 jute growing districts, 13 districts (> 81% districts) experienced deficit water stress in the first phase of jute growth period that is from sowing to crop establishment during April-May, which reduce the crop growth which ultimate reduce the fibre yield.

However, in June-July (second half), actual rainwater was higher than the optimum (304 mm)

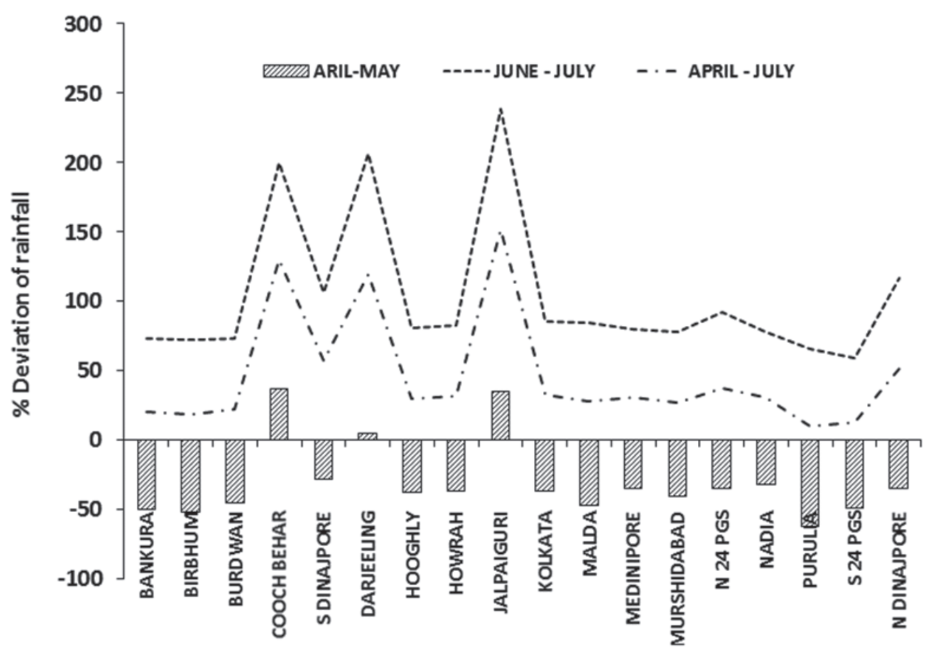

Fig. 2. District wise variability of rainfall deviation from optimum rainfall (Apr+May: 229 mm; Jun+Jul = 304 mm and Apr+Jul = 533 mm) required during jute growth period in West Bengal. (Purulia and Kolkata have no jute area)

for all the districts that means there was no shortage of rain water for jute production during that period. But excess rain water causes the stagnation of water in jute field due to which the basal portion of stem produces adventitious roots which is detrimental to fibre quality.

Frequency analysis of 102-year rainfall data showed that rainfall was deficit (<229 mm) from optimum more than 90 times in the nine jute growing districts in the first phase during April-May, but in the second phase during June-July more than 100 times excess rainfall occurred in 13 districts (Table 2). This depicted that jute experienced drought and flood (stagnation of water) in its first phase and second phase of life cycle, respectively, which was in similar line of the earlier study of Barman *et al*. (2012).

Extreme maximum temperature variability in relation to jute production in study areas

For jute growing season (April-July), the requirement of maximum air temperature is 37°C.

Table 2. Spatial variability of frequency of occurrence of total rainfall of < 229 mm in April+May and > 304 mm in June+July from 1901-2020 in West Bengal.

Districts	<229 mm rainfall in April+May	>304 mm rainfall in June+July
Bankura	98	102
Birbhum	98	100
Burdawan	97	95
South Dinajpore	91	102
Darjeeling	51	102
Hooghly	90	100
Howrah	88	86
Jalpaiguri	20	102
Kolkata	88	100
Cooch Behar	20	102
Malda	100	101
Medinipore	86	102
Murshidabad	97	100
Nadia	14	100
North 24 Parganas	89	101
Puruliya	101	99
South 24 Parganas	96	96

Fig. 3a showed that the extreme maximum air temperature in the first phase (April-May) was found in the Bankura, Birbhum, and Murshidabad districts but for rest of the districts of West Bengal it was within the optimum value. However, in the second phase (June-July), maximum temperature was within the optimum range of jute growth for all the districts of West Bengal. Extreme maximum air temperature is detrimental for jute growth in Bankura, Birbhum, and Murshidabad, but it is congenial for rest of the districts.

Extreme minimum temperature variability in relation to jute production in study areas

For jute growing season (April-July), the requirement of minimum air temperature is 24°C. From Fig. 3b, it was evident that the minimum air temperature in the first phase (April-May) of jute growth period was lower than the optimum temperature in Cooch Behar, South Dinajpur, Darjeeling, Hoogly, Jalpaiguri, Malda, South 24-Parganas and North Dinajpur, but it was within the optimum range in the rest. In the second phase (June-July), minimum air temperature was lower only in two districts such as Darjeeling and South 24-Parganas. Jute growth and yield was observed lower in the norther districts of West Bengal which may be due to the low minimum air temperature that enhance premature flowering and reduce jute growth and yield. In Nigeria, Fawusi and Ormrod (1981) studied the effect of minimum temperature on jute growth and reported higher physiological performances when minimum temperature is more than 24°C.

In the first phase of jute growth (April-May), the frequency of maximum air temperature of more than 37°C and minimum air temperature less than 24°C during the 102-year period (1901-2002) were categorized into four groups, viz. <10, 10-25, 25-50 and >50 and presented in Fig. 4. In general, this showed that the frequency of extreme maximum air temperatures was lower, but of extreme minimum air temperatures was higher in the northern part of West Bengal than the other jute growing areas of the state.

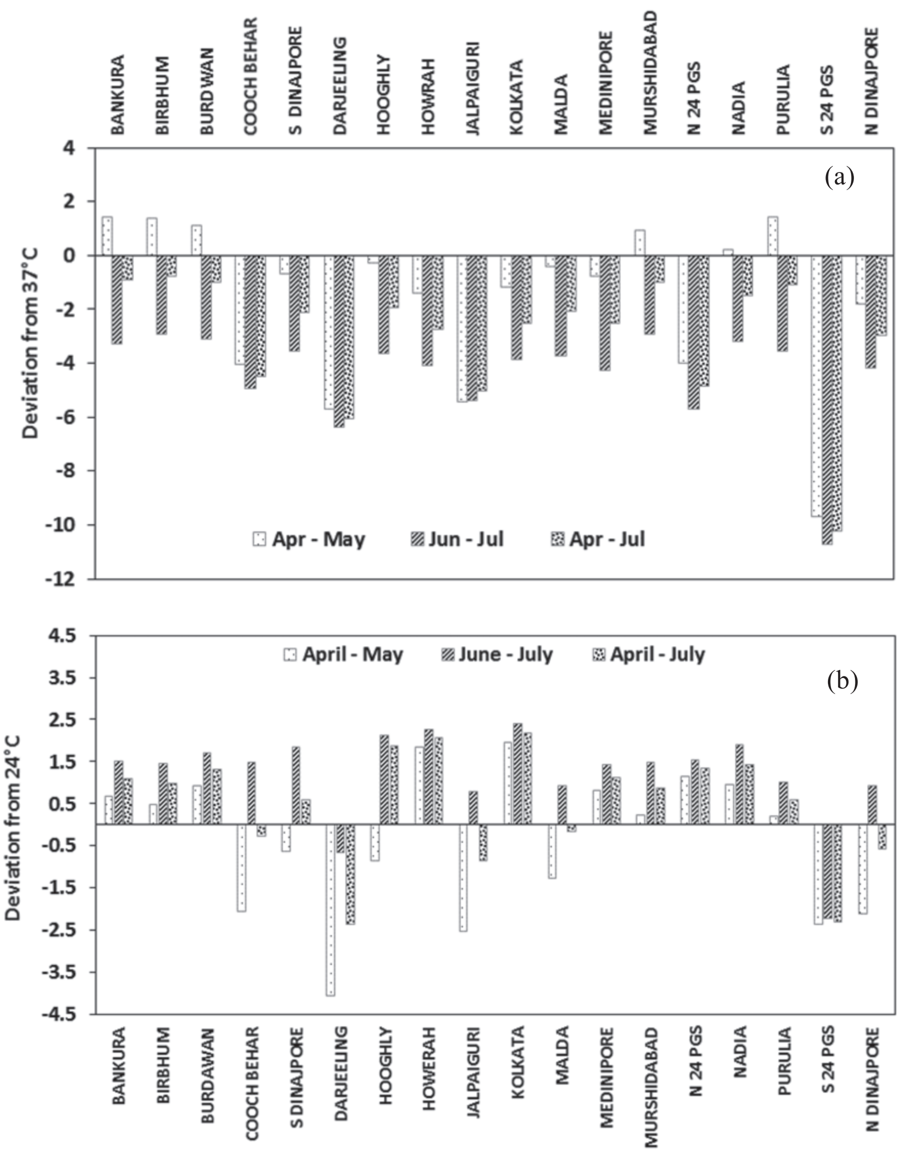

Fig. 3. District wise variability of deviation of (a) maximum air temperature from 37°C (b) minimum air temperature from 24°C during jute growth period in West Bengal (Monthly data of the period 1901-2002)

Conclusion

West Bengal represents 70% of the national jute acreage and it is an important cash crop of the state. Scrutiny of 102-year climatic data revealed that jute growth period can be divided into two halves due to the distinct prevailing climatic conditions, first half (60 days) during April-May and second half (60 days) during June-July. Out of 23 total districts of West Bengal, there are 16 major jute growing districts, and district level spatial and temporal climatic variability was observed during jute growth period (April-July). For jute growth in April-May, the requirement of effective rainfall is of 229 mm, and maximum and minimum air temperatures are of 37°C and 24°C, respectively, however, in June-July, the effective rainfall requirement is 304 mm, but optimum temperatures remain same. Jute crop experiences water stress in all the districts except in Darjeeling, Cooch Behar and Jalpaiguri as evident from the deviation of rainwater from these optimum values of the respective districts. During first phase (April-May) minimum air temperature is lower and not congenial for all the districts of

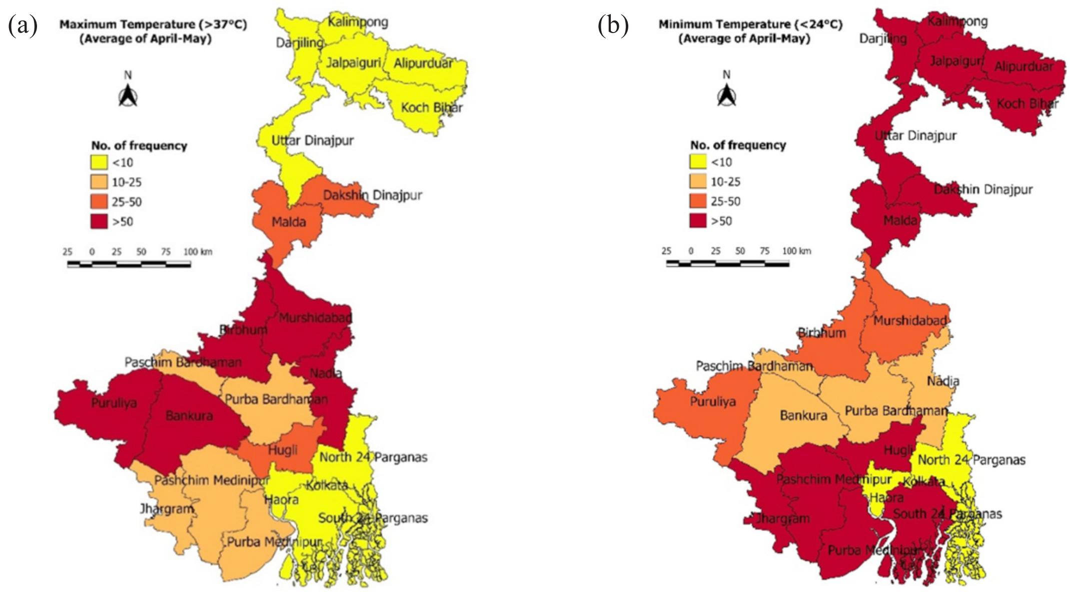

Fig. 4. Frequency map of (a) maximum air temperature more than 37°C (b) minimum air temperature less than 24°C during initial jute growth period (April-May) in last 102 years (1901-2002).

northern part of West Bengal (North Bengal), but in second phase (June-July) both the maximum and minimum air temperatures are within the optimum range and congenial to jute growth in all the jute growing districts except in Darjeeling and South 24-Parganas where only minimum air temperature was found lower than the optimum which reduces the jute growth. This analysis will help in taking action in jute production for all the jute growing districts of West Bengal. The fluctuation in air temperature and rainfall due to uncertain Nor'wester (*kalbaishakhi*)/monsoon during jute season has become an important concern for jute cultivation in West Bengal.

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