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Research Paper

Variation of standardized precipitation index (SPI) over southern West Bengal and its effect on jute yield

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ABSTRACT

West Bengal is a key producer of raw jute fiber in the country. Identifying and managing dry spells during the jute growing period is crucial, necessitating contingency crop planning for enhanced productivity. Keeping this view in mind, standardized precipitation index (SPI) was calculated over five locations, representing five different districts of southern West Bengal. These locations are Barrackpore (North 24 Parganas District), Panagarh (Burdwan District), Bagati (Hooghly District), Krishnanagar (Nadia District) and Uluberia (Howrah District). This rainfall dependent dryness index (SPI) was calculated in 1 month and 3 months interval to identify short term dryness as well as mid-term dryness, applicable for seasonal crops. The trend analysis of the SPI values indicated that North 24 Parganas and Nadia experienced increased dryness during vegetative phase of Jute. Nadia district showed a significant increase in both short term and long-term dryness. The yield reduction index is well correlated with SPI values in all the study locations except Howrah. Arrangement of irrigation during the early stages of Jute can help the crop to cope up with the break of monsoon in this region.

Keywords**:** Rainfall, Standardized Precipitation Index, Jute, Yield Reduction Index.

Drought, a devastating natural calamity, profoundly impacts global regions, particularly those in semi-arid and arid climates, causing extensive harm to both the environment and economies of affected countries (Middleton and Sternberg, 2013). Diverse drought indices, simplifying intricate climate variables, have been developed for monitoring and measurement. The widely adopted Standardized Precipitation Index (SPI) stands out due to its reliance solely on rainfall data and standardization ensuring consistency in extreme occurrences across locations and time scales (Sienz *et al*., 2012). SPI values at various intervals quantify drought perseverance, offering real-time monitoring and analysis, crucial for understanding intensity and spatial extension at different time scales (Pandey *et al*., 2019). In India, heavily dependent on monsoonal rainfall for agriculture, temporal variability in rainfall poses a severe threat to crops like rice and jute, susceptible to such fluctuations. Long-term crop-weather relationships, facilitated by SPI, enable prediction of unprecedented drought occurrences within growth stages (Rajasivaranjan *et al.,* 2019; Sridhara *et al.,* 2021).

Jute, known as India's golden fiber, holds significant economic importance, ranking second after cotton and representing a crucial cash crop. India dominates global jute production, with West Bengal, Odisha, Bihar, and Assam contributing 98.41% of total production. West Bengal alone accounts for 71% of raw jute production. However, jute cultivation faces challenges due to its high-water requirement of approximately 500 mm. Insufficient rainfall necessitates irrigation, with studies revealing a 20.8% increase in jute fiber output with irrigation (Kundu and Mukhopadhyay, 2016). Optimal growth requires pre-sowing irrigation and two additional irrigations at 40-60 days after sowing, but drought and waterlogging present obstacles. Post-harvest retting, crucial for fiber production, is highly water-dependent. Adequate monsoon rainfall is vital, and its failure can lead to yield loss and socio-economic devastation. Kundu and Mukhopadhyay (2016) reported substantial water consumption, emphasizing jute production's dependence on monsoonal rainfall.

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Reduced rainfall significantly increases farming costs.

With this context, the study aims to determine the frequency of different dryness variation and develop a relationship between the yield reduction index (YRI) of jute crops and SPI. The objectives align with addressing the impact of drought on jute cultivation, emphasizing the importance of SPI in predicting and understanding drought dynamics. This research holds significance in mitigating the socio-economic impact of reduced monsoon rainfall on jute production and, consequently, the farming community.

MATERIALS AND METHODS

Study location and secondary data used

The present study was carried out in five distinguished stations in the southern part of West Bengal, *viz.,* Barrackpore (22°46' N, 88°24' E) in North 24 Parganas, Panagarh (23°44' N, 86°45' E) in Burdwan, Bagati (22°59' N, 88°22' E) in Hooghly, Krishnanagar (23°24'N, 88°31'E) in Nadia and Uluberia (22°30'N, 88°57'E) in Howrah district. Weekly rainfall data was collected from the respective weather stations for the period of 1980 to 2018 (38 years) from the Regional Meteorological Center, IMD, Kolkata. Yield data of jute were collected for the selected districts within the time frame of 1997 to 2018 from the government website of Ministry of agriculture and farmers welfare.

Calculation of SPI

The Standardized Precipitation Index (SPI) is determined by the precipitation for any duration, its long-term mean and standard deviation through the following equation. It is expressed as-

$$SPI = \frac{(Xij - Xim)}{SD} \quad \text{----------- (1)}$$ (McKee *et. al.,* 1993)

where, Xij is actual precipitation of a given duration.Xim is long-term mean a given duration.

SD is the standard deviation. The dryness-based SPI value is given in Table1. The SPI tools downloaded from the National Drought Mitigation Centre (NDMC) are used here to calculate the drought.

Table 1: Dryness based on SPI value

SPI	Category
0 to -0.99	Mild dryness
-1.00 to -1.49	Moderate dryness
-1.5 to -1.99	Severe dryness
< -2.0	Extreme dryness

Trend analysis

Parametric trend along with Sen slope and Z statistics (Man-Kendall test) was calculated for the jute growing week period (i.e.; SMW 11 to 31) at 5% significance level from 1981-2018.

Yield reduction index (YRI)

Yield reduction for a particular year calculated from a long-term average yield is used to access the impact of biotic and abiotic factors. In this study, a function of decreased rainfall as indicated by SPI is considered as the factor responsible for yield reduction. The formula for extracting the yield reduction index is stated below:

$$Yr = \frac{Yi - Yavg}{Yavg} x100 \quad \text{-----------(2)}$$

Where, *Yr* is yield reduction index, *Yi* is normal yield of any particular year and *Yavg* islong term average yield.

Regression analysis

An attempt was made to establish the simple linear relationship between yield reduction index and SPI index at difference time scale, considering that the jute production is solely influenced by the drought situation caused due to insufficient rainfall. During construction of the relationship, the sign of yield reduction index value and standard precipitation value were tallied. The value of the respective two parameters was looked mainly incases where there was positive - positive interaction and where there was negative - negative interaction. Other combinations were excluded.

RESULTS AND DISCUSSION

Trend of SPI values in jute growing period

The SPI values calculated in one month interval during the period 1981-2018 depicted that Hooghly district did not experience any significant change in small scale drought occurrences which was verified by the Z statistics value (|Z|<1.6 in all SMW in Hooghly). In the Burdwan district both the parametric and non-parametric trends of SPI1 were significantly increasing in SMW 18 to 22 and SMW 28 to 31. This indicates that the crop experienced a decrease in dryness in the particular SMW's in Burdwan the maximum increment of SPI1 was 0.044/year. In North 24 Parganas and Howrah an increase in dryness was observed in SMW 23, 22, 21 and 19 respectively. Whereas in Nadia district, a decrease in dryness during the period of SMW 27 to 29 was observed.

The SPI values calculated using three-month interval SPI3 during the period 1981-2018 depicted that Burdwan district received significant decrease in dryness in maximum number of weeks (SMW 18 to 31). The SPI3 showed an increment from 0.026 to 0.044/year during the said time period. The other districts namely Hooghly, Howrah, Nadia and North 24 Parganas experienced an increase in long duration dry spell within 17 to 27 SMW. The maximum increase in dry spell varied a lot, for example, the trend of SPI3 variation was 0.042 per year in Nadia District. For Howrah this variation was -0.026 per year.

From the trends calculated using the one-month interval and three-months interval indicated that a significant change in dryness occurred in the jute growing period over the Southern districts of West Bengal. In Burdwan District due to increase of rainfall over years, the dryness showed a decreasing trend which was depicted through both the SPI1 and SPI3 values. While Nadia showed declined in dryness in SPI1 scale but increased in dryness in SPI3 scale. This indicates that the rainfall is getting highly sporadic in temporal scale which may affect the crops having higher crop

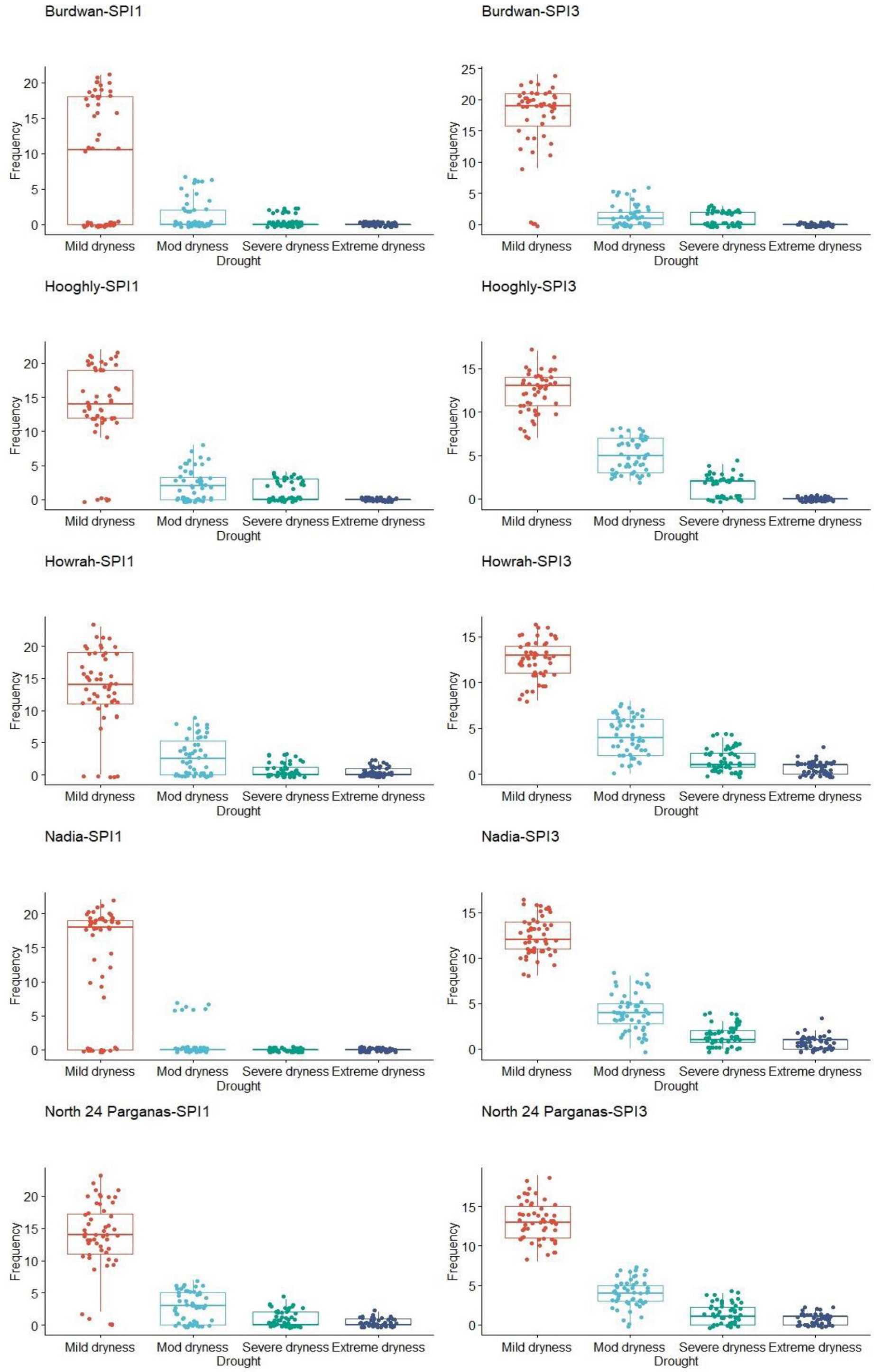

Fig. 1: Frequency of different dryness across five locations

length, specially for the varieties which mature in 120 to 150 days.

Frequency of various dryness levels

The location wise dryness condition is presented in Table 2 based on the SPI1and SPI3 values. Frequency of four dryness levels was calculated in 52 meteorological weeks in the five locations for 2-time interval SPI values from 1980-2018. The occurrence of small-scale mild dryness (as depicted by SPI1) was maximum in Nadia and minimum was in Burdwan while the medium scale mild dryness (as depicted by SPI3) was maximum in Burdwan. It was observed that all the five locations were experienced no mild dryness in small scale SPI some year. Except Burdwan no location experienced less than five number of mild dryness situation in medium scale SPI.

The frequency of small-scale moderate dryness was confined below five irrespective of the location. With the increase in level of the dryness, the capability to identify the drought using

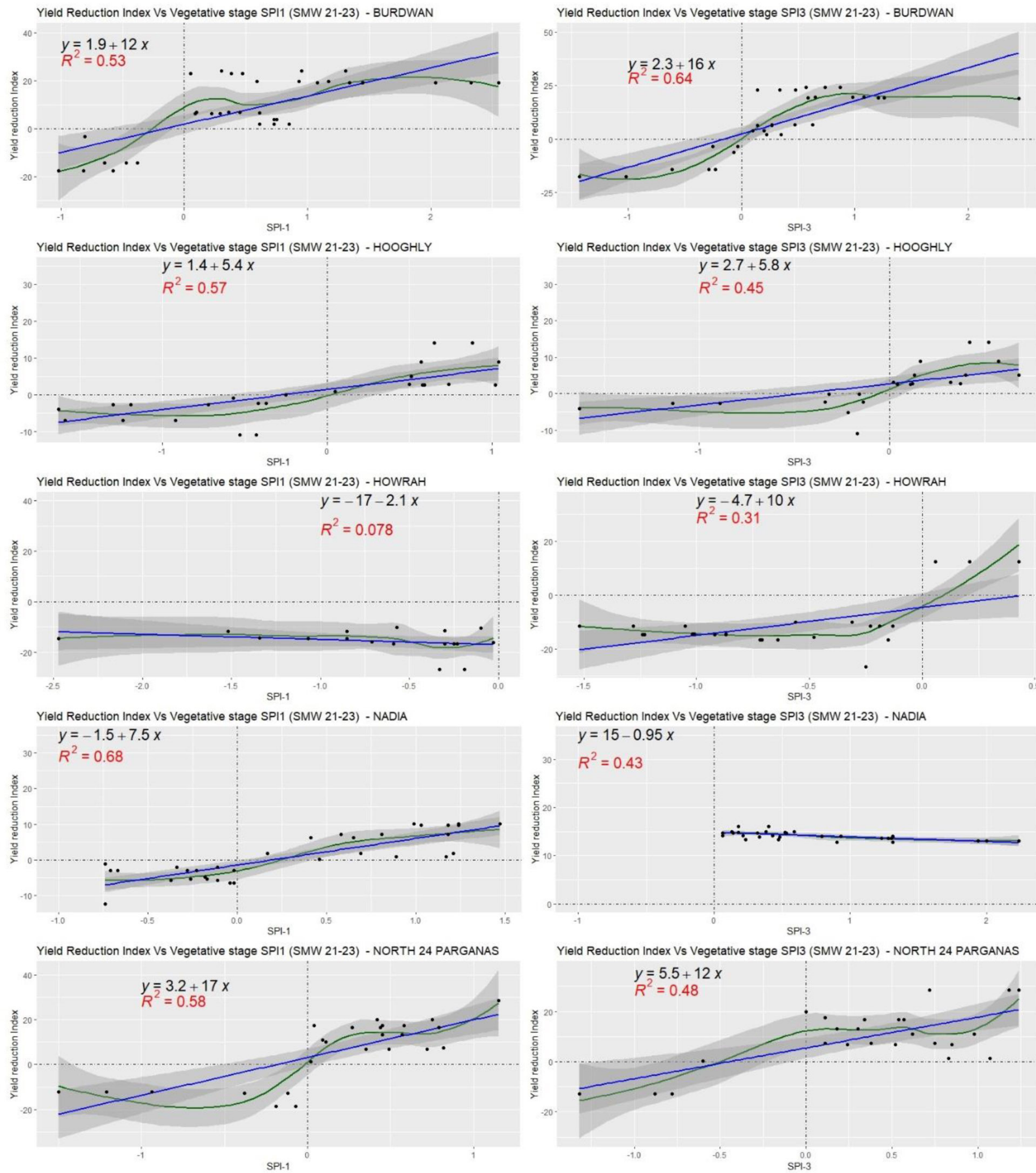

Fig. 2: Relationship between (long and short duration dryness) and YRI of jute

small-scale SPI is highly reduced (Manikandan and Tamilman, 2015) and for this reason SPI1 showed better spatial variation within the study area (Table 2). The moderate dryness frequency was higher in SPI3 time scale over SPI1. Hooghly experienced the highest moderate drought occurrence in SPI3 scale (Fig.1). The location is the part of New and Old Alluvial region of Gangetic plain which generally receives ample amount of rainfall in monsoon season. So, the occurrence of severe dryness event is rare.

The relationship between SPI and YRI of jute

Generally, the yield is driven through multiple factors

Table 2: Frequency of SPI 1-month and 3- month interval dryness

Study location	Mild dryness		Moderate dryness		Severe dryness		Extreme dryness	
	1-month	3- month	1-month	3- month	1-month	3- month	1-month	3- month
Barrackpore	709	648	149	212	40	79	21	33
Panagarh	708	638	110	259	64	78	0	0
Bagati	669	648	44	212	0	79	0	33
Krishnanagar	711	682	145	211	51	80	20	32
Uluberia	455	889	68	74	22	49	0	0

including climate, seed quality, variety, socio-economic factors, cultivation practices, etc. So, the sole representation of climate impact on crop yield is tricky. Hence years having very high deviation of yield from mean were ignored and the rest was considered for relationship study. Moreover, the SMW 21 to 23 was emphasized for this relationship as this particular period coincided with critical water requirement period of jute. The higher R^2 values during 21st (R^2 = 0.85), 22nd (R^2=0.66), 23rd (R^2= 0.50) established a strong relationship between the SPI1 values and yield reduction index. Similarly, SPI3 also showed strong relationship with YRI.

The SPI values of SPI1 and 3 scale were used to establish relationship with the yield reduction index. The relationship describes the dependency of yield with the SPI values worked out for different SMW. The jute growing period generally falls in between SMW11and SMW31, within which the SMW21 to 23 is identified as late vegetative phase of the Jute. Moreover, it can be recalled that the SPI1 value accounted the cumulative dryness of previous 1 month (4SMWs) while the SPI3 value accounted the cumulative dryness of 3 months (12SMWs). The relationship established with SMW21-23 SPI1 scale values is the composite dryness computed from the SMW 18 (only vegetative stage). While the SMW21-23 SPI3 scale values are the composite dryness computed from the SMW 10 (one week prior to sowing to vegetative stage).

The overall relationship indicates that only the Burdwan (R^2 = 0.77) and Hooghly (R^2 = 0.82) district showed higher positive relationship between the SPI3 values and the YRI. This clearly shows that the lower monsoonal rainfall (starts from SMW12) has a negative impact on jute yield. While in Howrah and Nadia no significant relationship was observed between the drought period during vegetative growth of the Jute and YRI. The relatively higher R^2 value in SPI1 for SMW14 in Howrah and Hooghly indicate that the break of monsoon hampers the crop establishment in these districts. The relationship established beyond the SMW23 were found significantly correlated with Burdwan, Hooghly and Howrah districts. If SMW31 is considered, Burdwan, Howrah and Nadia established the positive yield reduction with respect to SPI values which indicated the low availability of fresh water for jute retting.

The relationship between the SPI values in both the time scale with the YRI is presented in Fig. 2 which clearly indicates that the composite impact of dryness in vegetative phase is reliably correlated (SPI1: 0.53-0.68 and SPI3: 0.43-0.64) in all the districts except Howrah (SPI1: 0.078 and SPI3: 0.31). Similar findings were observed by different scientists for rice and other crops (Kamble *et al*., 2019). Moderate dryness experienced during vegetative phase can cause 5 to 10% yield reduction of Jute.

CONCLUSION

From the above results, it can be concluded that the SPI values showed the different trends at different geographical locations. In North 24 parganas and Howrah mild season dryness during jute growing period has increased. On the other hand, Nadia district showed a decreasing trend of dryness during maturity period of the crop. However, the small-scale mild dryness was maximum in Nadia and minimum in Burdwan. The medium scale mild dryness was maximum in Burdwan district. The spectral distribution of dryness impacted the spectral distribution of YRI. Significant relationship (at 1% level) was observed between SPI3 and YRI off Hooghly, Burdwan, North 24 parganas districts. Overall, 5 to 10% yield reduction was associated with moderate dryness experienced during vegetative phase of Jute.

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