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Nakshatra based rainfall variability, trends and its influence on rice-wheat production - A case study over two sites in Bihar, India

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ABSTRACT

An attempt has been made to study the variability and trends of rainfall during nakshatra periods for two sites, Patna and Samastipur of Bihar and verified the relation of four traditional knowledge/ proverbs/ beliefs of nakshatra based rainfall pattern, which are popular in this part of the region with rice-wheat productivity. Maximum rainfall and highest rainy days occurred during punarvasu nakshatra (July 6 – July 19) over both sites followed by pushya (July 20- Aug 2). The coefficient of variation of rainfall shows below 100 % from aridhra (June 22 – July 5) to uttara (Sept 13-26) at Patna and from rohini to purbha (Aug 31- Sept 12) for Samastipur. A significant increasing trend of 0.965 mm y^{-1} and decreasing trend of -0.857 mm y^{-1}, respectively have been noticed during pubbha and hasta at Patna. However, a significant increasing trend of 1.536 mm y^{-1} and decreasing trend of -0.774 mm y^{-1}, respectively have been noticed during aridhra and hasta at Samastipur.

Keywords: Nakshatra, ***R***ainfall variability, Mann-Kendall non-parametric test, Productivity index, Rainfall anomaly index, Correlation

There is considerable traditional/proverbial knowledge about the variability of rainfall patterns and traditional rice-wheat productivity, since rainfed cultivation has been carried out for several centuries in this region. The periods used by the farmer are however, not weeks or months but so-called 'nakshatras' which are 13 or 14 days periods which are also based on the solar calendar (IMD, 1998). The nakshatras stand for the twenty seven constellations through which the sun passes in a year. Hence the period of each nakshatra is about 14 days. The nakshatra commences when the sun enters the specific constellation. The knowledge of the variability is thus these time units rather than weeks or months (Gadgil and Rao, 2000). Golakia (1992) compiled proverbs from different communities for predicting the moods of monsoon over Saurashtra. Varshneya *et al* (2002) developed nakshatra-varsha almanac for Maharashtra and this was designed for farmers to predict rainfall distribution in next rainy season. The techniques gave prediction of onset and withdrawal of monsoon and distribution of rainfall about six months in advance. Based on pictorial assistance, it is possible for the farmers to change the crops to decide area under kharif and rabi season. It is found that there is relative advantage of this calendar for Maharashtra (Vaidya, 2004). Kanani (2006) tested traditional methods of weather forecasting in Gujarat using the participatory approach. They formed a group called "Varsha Vigyan Mandal" including researchers and farmers of Junagadh and validated traditional beliefs across the region. Thus, nakshatra based rainfall periods have more influence on rice and wheat production and studies on variability and trends of rainfall based on nakshatra periods and its influence on rice-wheat production are lacking. In the present study, variability and trends of rainfall during nakshatra periods for two sites viz., Patna and Samastipur, representing different agro-climatological zones of Bihar have been analyzed. Some of the traditional/proverbial knowledge based on nakshatra period rainfall and rice-wheat productivity is also verified over these two sites.

MATERIALS AND METHODS

The daily rainfall data recorded at IARI regional station, Pusa, Samastipur; and Agricultural Research Institute, Patna during the period 1960-2008 were collected. The detailed methodology adopted for quality, completeness and homogeneity was discussed in detail Parthasarathy *et al*. (1993, 1995a, b). These daily rainfall data were converted into nakshatra period rainfall and computed mean, standard deviation and coefficient of variation. The productivity of rainy season (*kharif*) rice over the selected sites were taken from the Directorate of Rice, Ministry of Agriculture, Govt. of India and are available on-line at http://www.dacnet.nic.in and the productivity of wheat were taken from the Directorate of Statistics and Evaluation, Govt. of Bihar.

Trend analysis

Mann-Kendall (MK) (Mann, 1945; Kendall, 1975) is a

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Table 1: Mean rainfall and rainy days and its standard deviation (SD) and coefficient of variation (CV) during nakshatra period over Patna and Samastipur districts of Bihar

Nakshatra	Period	Patna						Samastipur					
		Rainfall			Rainy days			Rainfall			Rainy days		
		Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)
Ashwini	April13 to April26	6.1	9.1	148	0.6	0.9	152	10.1	14.8	146	0.8	1.2	141
Bharani	April27 to May10	13.5	21.7	161	0.9	1.0	117	21.1	23.6	112	1.4	1.3	87
Kritika	May11 to 24	21.3	30.2	142	1.2	1.3	113	31.1	35.6	114	1.6	1.5	95
Rohini	May25 to June 7	26.4	39.8	151	1.4	1.4	94	36.8	34.9	95	2.0	1.6	78
Mrigashira	June 8 to 21	60.1	64.6	108	2.7	2.2	80	76.2	54.2	71	3.5	2.2	62
Aridhra	June 22 to July5	116.5	96.3	83	4.6	2.2	47	128.5	86.8	68	5.0	2.2	44
Punarvasu	July6 to July19	176.0	110.3	63	6.5	2.7	41	139.6	99.1	62	6.6	2.6	40
Pushya	July20 to Aug2	131.0	98.9	76	5.9	2.5	43	139.1	112.3	81	6.1	2.5	41
Ashlesha	Aug3 to Aug16	115.8	95.0	82	5.6	2.4	43	132.4	110.5	84	5.6	3.0	54
Makha	Aug17 to Aug30	131.1	73.5	56	5.8	2.1	36	135.6	116.2	86	5.4	2.4	44
Pubba	Aug31 to Sep12	90.3	67.8	75	4.6	2.3	51	106.0	88.9	84	5.1	2.3	45
Uttara	Sep13 to Sep26	90.6	82.8	91	4.0	2.1	51	104.2	105.8	102	4.2	2.1	49
Hasta	Sep27 to Oct9	76.4	85.3	112	2.8	2.0	74	77.8	103.5	133	2.8	2.1	74
Chitta	Oct10 to Oct23	19.9	45.1	226	0.9	1.2	139	22.0	41.6	189	0.9	1.2	129
Swathi	Oct24 to Nov5	4.7	12.8	271	0.3	0.8	240	4.8	12.6	265	0.3	0.8	224
Vishaka	Nov6 to Nov18	5.5	15.4	278	0.3	0.8	249	3.7	10.5	286	0.3	0.7	253
Anuradha	Nov19 to Dec2	1.8	5.1	289	0.2	0.5	292	3.7	10.5	286	0.0	0.0	0
Jyeshta	Dec3 to Dec15	0.9	4.2	482	0.1	0.3	523	1.6	6.1	380	0.1	0.4	318
Moola	Dec16 to Dec28	3.3	9.1	272	0.3	0.7	204	3.2	6.1	193	0.4	0.7	198
Purvashada	Dec29 to Jan10	3.3	5.9	181	0.4	0.7	160	3.3	8.5	255	0.3	0.6	191
Uttarashada	Jan11 to Jan23	4.9	8.0	161	0.5	0.7	147	4.0	6.5	160	0.4	0.6	151
Sravana	Jan24 to Feb5	5.2	8.1	155	0.5	0.9	160	6.0	10.1	169	0.6	0.8	144
Dhanishta	Feb6 to Feb18	7.0	12.6	181	0.5	0.7	147	7.2	12.6	174	0.6	0.9	154
Shatabhista	Feb19 to Mar3	5.8	10.7	186	0.5	0.9	164	4.2	6.8	161	0.5	0.8	157
Poorva Bhadra	Mar4 to Mar17	4.6	10.6	231	0.3	0.7	194	2.3	5.7	246	0.2	0.6	245
Uttara Bhadra	Mar18 to Mar30	2.9	5.5	188	0.3	0.6	217	3.9	8.1	206	0.4	0.7	198
Revati	Mar31 to April12	1.5	4.0	266	0.2	0.5	290	4.0	8.8	221	0.3	0.7	201

nonparametric trend test basically involves the ranks obtained by each data in the data series and is a statistical yes/no type hypothesis testing procedure for the existence of trends and does not estimate the slope of trends. The magnitude of the trends was estimated using Sen Slope (Sen, 1968) and according to Hirsch *et al*. (1982) Sen's method was robust against extreme outliers. The Mann-Kendal test (Mann (1945) and Kendall (1975)) has been used to detect trends in hydrometeorological time series data.

Productivity variability

The production of rice depends on type of soil, seeds used, crop area, availability of irrigation facilities, fertilizers, pesticides and also on the government incentives to the farming sector during a year as well as on the meteorological parameters such as rainfall, temperature, relative humidity and solar energy. The non-meteorological parameters i. e., the total technological inputs to the farming sector have been growing steadily and are difficult to quantify. Therefore, to know the pattern of trends and to quantify the growth rate of total technological inputs to the agricultural sector the actual productivity was fitted into a linear as well as any other best fit (Subash *et al*., 2009; Subash and Ram Mohan, 2010).

To normalize the productivity, another index, the Productivity Anomaly Index (PAI) was taken as the percentage of the technological trend productivity to the actual productivity. The PAI for the i[th] year is

$$PAI_i = \frac{(P_i - TPi) * 100}{P_i} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where PAI_i is the rice/wheat productivity anomaly index for the i[th] year, P_i is the actual rice/wheat productivity for the i^{th} year and TP_i is the technological trend rice/wheat productivity for the i[th] year.

RESULTS AND DISCUSSION

Normal nakshatra based rainfall pattern and its variability

Mean nakshatra periods rainfall and rainy days and its standard deviation (SD) and coefficient of variation (CV) for the selected stations are given in Table 1. Maximum rainfall and highest rainy days occurred during punarvasu nakshatra (July 6 – July 19) over both sites followed by pushya (July 20- August 2). Even though mean rainfall shows that rainfall received in all the nakshatras, as far as agricultural operations/management is concerned, fairly good amount of rainfall have been received from mrigashira (June 8-21) to hasta (September 27 – October 9) at Patna and rohini (May 25- June 7) to hasta at Samastipur. Moreover these periods

Table 2: MK test results of rainfall and rainy days at Patna and Samastipur districts (Z- MK statistics and Q-Sen's Slope)

Sl No.	Nakshatra	Rainfall				Rainy days			
		Patna		Samastipur		Patna		Samastipur	
		Z	Q	Z	Q	Z	Q	Z	Q
1	Ashwini	-0.28	0.000	0.49	0.000	-0.43	-0.0073	0.94	0.0097
2	Bharani	0.41	0.000	0.64	0.000	0.46	0.0049	1.17	0.0151
3	Kritika	0.75	0.000	0.93	0.100	0.90	0.0089	1.77	0.0276
4	Rohini	1.04	0.078	1.21	0.321	1.63	0.0216	1.29	0.0271
5	Mrigashira	-0.13	0.000	0.43	0.203	-0.64	-0.0027	-0.36	-0.0040
6	Aridhra	1.50	1.179	1.87	1.536	2.27	0.0400	1.93	0.0467
7	Punarvasu	0.64	0.817	1.03	1.029	-0.60	-0.0185	0.42	0.0078
8	Pushya	-0.89	-0.817	-0.28	-0.348	-1.05	-0.0266	0.03	0.0064
9	Aslesha	1.11	0.795	0.34	0.264	0.93	0.0211	-0.13	-0.0020
10	Makha	0.74	0.529	-1.01	-0.856	-1.15	-0.0266	-0.18	-0.0063
11	Purbha	1.77	0.965	-0.22	-0.054	0.79	0.0257	0.08	0.0006
12	Uttara	-0.39	-0.263	-0.64	-0.389	-0.62	-0.0148	-0.97	-0.0247
13	Hasta	-1.83	-0.857	-1.86	-0.774	-1.61	-0.0310	-1.57	-0.0313
14	Chitta	-0.72	0.000	0.72	0.000	-0.75	-0.0032	0.87	0.0096
15	Swathi	-0.38	-0.146	-0.55	-0.022	0.37	0.0090	0.08	0.0010
16	Vishaka	0.23	0.043	-0.03	-0.012	0.18	0.0011	0.30	0.0003
17	Anuradha	-0.54	-0.026	-0.03	-0.022	-0.34	-0.0015	0.00	0.0000
18	Jyeshta	-0.19	-0.010	-0.63	-0.025	-0.16	-0.0002	-0.38	-0.0020
19	Moola	-0.89	-0.011	-0.15	0.000	-0.78	-0.0052	-0.27	-0.0030
20	Purvashada	-0.10	-0.025	-0.62	-0.060	-0.03	-0.0028	0.25	-0.0016
21	Uttarashada	-0.41	-0.030	-0.46	-0.022	-0.17	-0.0019	0.22	-0.0032
22	Sravana	-0.87	-0.051	-0.24	-0.016	-0.64	-0.0048	0.10	-0.0015
23	Dhanishta	0.07	0.013	0.43	0.021	-0.13	-0.0010	0.87	0.0083
24	Shatabhista	0.25	0.057	0.84	0.072	0.53	0.0023	0.97	0.0112
25	Poorva Bhadra	-1.60	-0.067	-0.72	-0.098	-1.51	-0.0069	0.61	0.0080
26	Uttara Bhadra	-1.10	-0.103	-0.55	-0.137	-1.61	-0.0130	-0.28	-0.0071
27	Revati	0.34	0.037	0.77	0.167	0.34	0.0048	1.09	0.0104

received ≥ 2 rainy days for both sites. The CV of rainfall shows below 100 % from aridhra (June 22 – July 5) to uttara (September 13-26) at Patna and from rohini to purbha (August 31- September 12) at Samastipur. This indicated that 7 and 8 nakshatra periods received somewhat dependable rainfall over Patna and Samastipur, respectively. Punarvasu nakshatra receives lowest CV of 62 and 63 per cent, respectively for Patna and Samastipur districts.

Trends of nakshatra based rainfall pattern

Time series of nakshatra rainfall and their trends at different stations are shown in Figs. 1 and 2. The results of the MK tests on rainfall and rainy days are given in Table 2. As far as rice-wheat system is concerned, based on normal crop calendar and growing period, kritika to swathi (13 nakshatras) are considered for rice and vishaka to uttara bhadra (11 nakshatras) are considered for wheat. Out of 13 nakshatras during rice, rainfall shows decreasing trend in 6 nakshatras (mrigashira, pushya, uttara, hasta, chitta & swathi) at Patna and 6 nakshatras (pushya, makha, purbha, uttara, hasta & swathi) at Samastipur. A significant increasing trend of 0.9 mm y^{-1} and decreasing trend of -0.0.9 mm y^{-1}, respectively have been noticed during purbha and hasta at Patna. However, a significant increasing trend of 1.5 mm/ year and decreasing trend of -0.8 mm y^{-1}, respectively have been noticed during aridhra and hasta at Samastipur. This significant decreasing trend of rainfall during hasta nakshatra may affect the subsequent wheat crop, particularly during germination. As far as during wheat growing period is concerned majority of nakshatra periods showed decreasing trend of rainfall for both sites. But none of the trends are statistically significant. During aridhra nakshatra a significant increasing trend in number of rainy days at the rate of 43.3 and 46.3 per cent, respectively have been noticed over Patna and Samastipur. The increasing trend of rainfall during aridhra and decreasing trend of rainfall during pushya nakshatra may provide an indication of shifting/moving of rainfall pattern early ie., shifting of maximum rainfall period from pushya to punarvasu/aridhra.

Verification of nakshatra based rainfall and rice-wheat

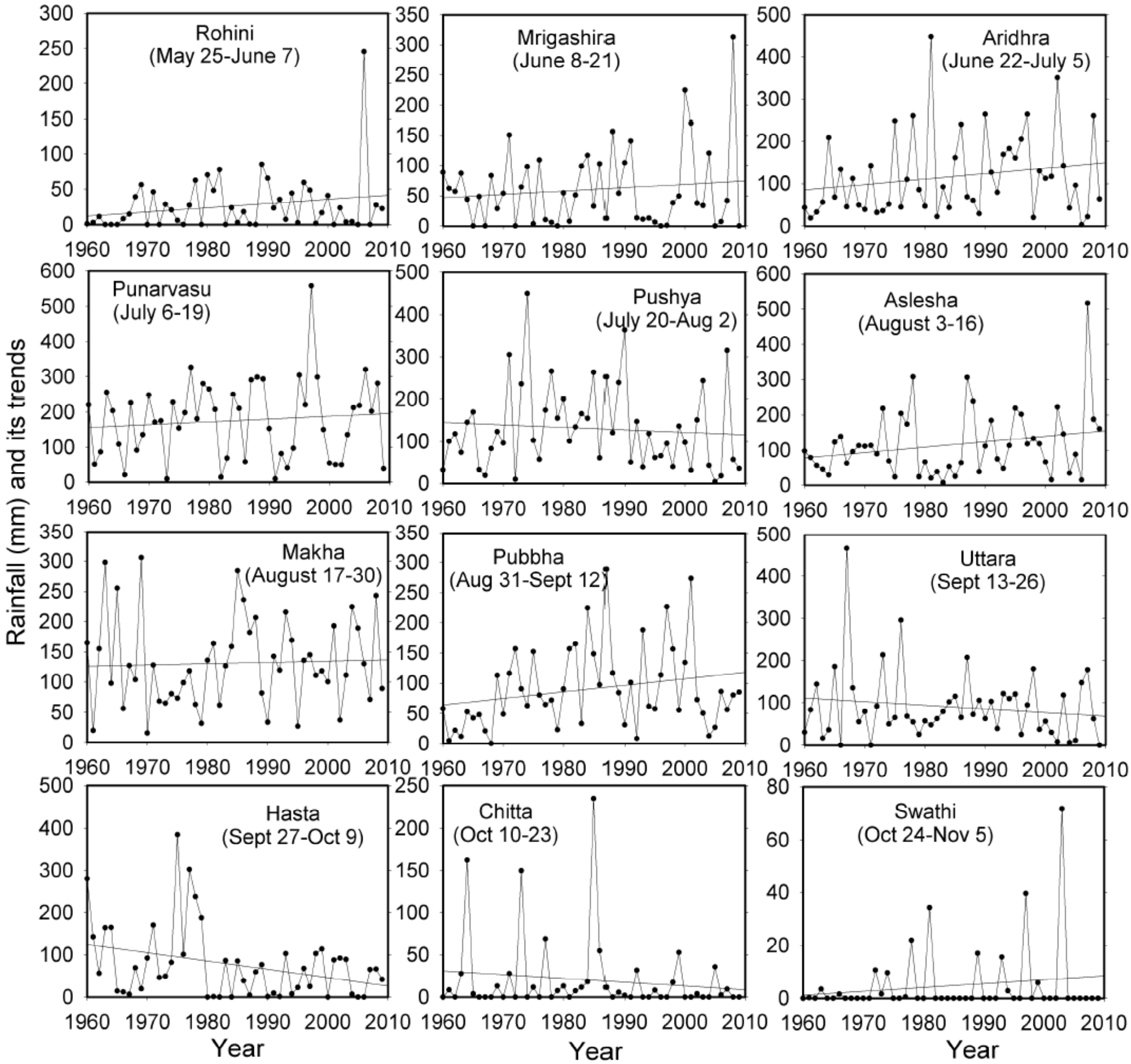

Fig 1: Rainfall variability and trends according to nakshatras at Patna district during 1960-2009

productivity variability

Relation between aridhra rainfall and rice productivity: Out of 30 negative rainfall anomaly years, 57 % of the years (17 years) rice productivity also decreased below technological trend at Patna. Interestingly, out of 25 deficit rainfall years with ≥ 20 % rainfall anomaly, 11 years rice productivity anomaly fall below 10 % of the technological trend. However, out of 19 deficit rainfall years with ≥ 50 % rainfall anomaly, 7 years rice productivity anomaly fall below 10 % of the technological trend. The correlation coefficient between rice yield anomaly and rainfall anomaly index during aridhra is very small (Table 3). As far as Samastipur is concerned, out of 9 negative rainfall anomaly years during aridhra, 6 years (67 %) rice productivity fall below technological trend. This shows the percentage contribution of aridhra rainfall on rice productivity vary with the location also.

Relation between swathi rainfall and rice productivity: The mean rainfall of 4.8 and 7.2mm, respectively have been occurred during swathi nakshatra over Patna and Samastipur. At Patna, eleven years received rainfall ≥ 2.5mm and only 3 years (1974, 1981 & 1997), the rice productivity fall below technological trend productivity (Table 4). Similarly, at Samastipur 5 years received rainfall e" 2.5mm and only 2 years (1989 & 2002), the rice productivity fall below technological trend productivity. It is also seen that rice productivity increased drastically from technological trend

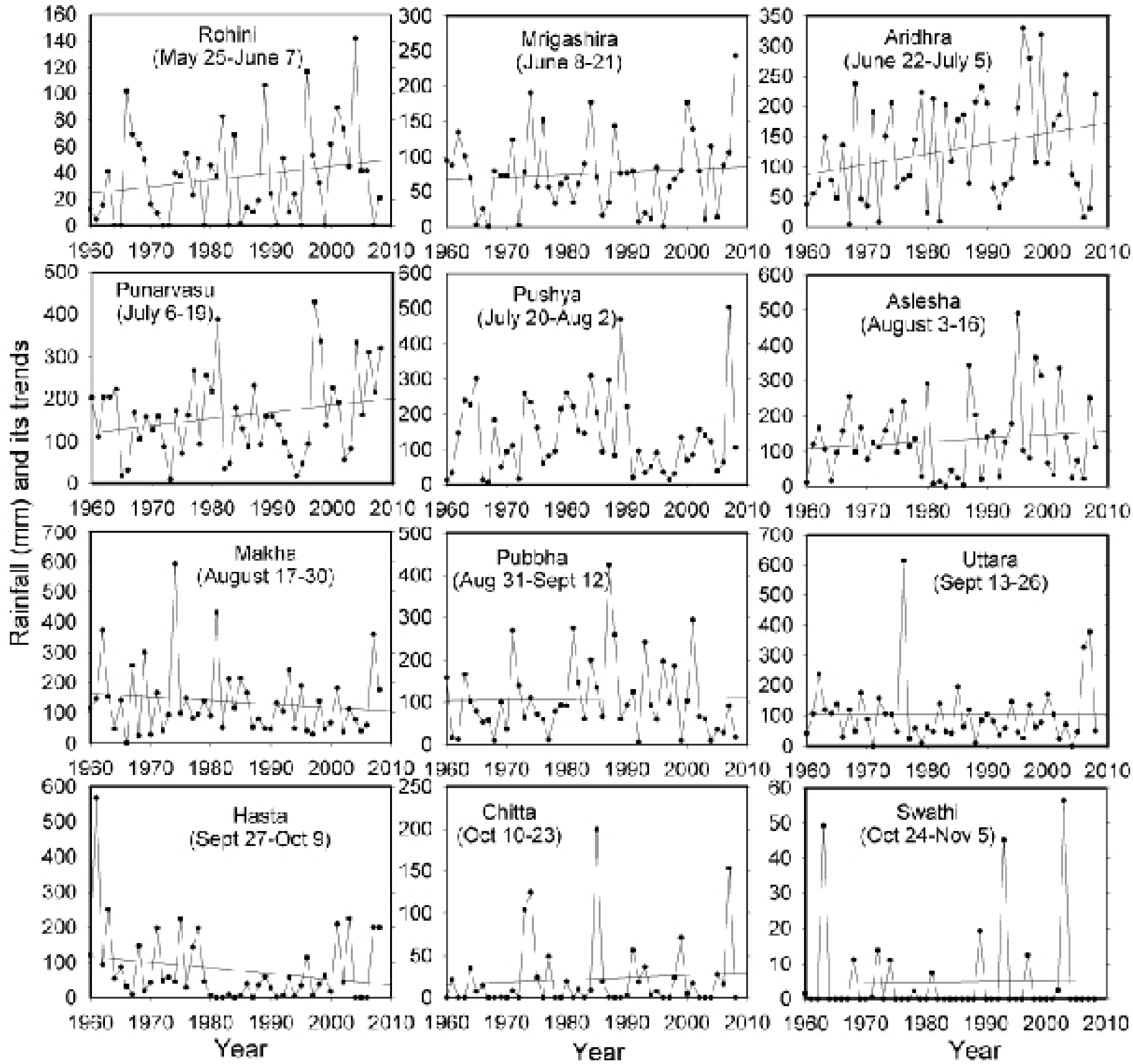

Fig 2: Rainfall variability and trends according to nakshatras at Samastipur district during 1960-2009

during the highest rainfall of 71.7 mm (about 29%) in 2003 at Patna. Similarly, at Samastipur also recorded highest (50.5%) positive rice productivity in 2003 with a highest rainfall of 56.5 mm. All these years, except 1978 and 2003, received only one rainy day during swathi nakshatra over Patna. In year 1997 and 2003, the rainfall distributed in 3 and 4 days respectively. Moreover, in year 1997, the rainfall received in two spells during the 14 day period, but 2003 it occurred in a single spell. This may be the reason for the negative productivity anomaly in 1997. Due to the occurrence of two different rain spells, the length of moist period may have increased and thereby spoiled the grains. But in Samastipur interestingly more rainy days (≥ 2) during swathi nakshatra helped to achieve higher rice productivity. Correlation statistics also show that higher F-value and significant relation between higher rice productivity and swathi nakshatra rainfall for Samastipur district (Table 3).

Relation between rohini, mrigashira, aridhra nakshatra rainfall and rice productivity: Rains occurred in six years during rohini and break during mrigashira (8 June – 21 June) nakshatra and low rainfall during aridhra at Patna (Table 5). Out of these 6 years (1969, 1977,1980, 1982, 1989 & 1992), 3 years the rice productivity falls below technological trend value. This means 50 % of the years this proverb holds well. Moreover, it is seen that in 1969 & 1992, the rice productivity

Table 3: F-Statistic and the Spearman Rank Correlation Coefficient (r_s) between rainfall anomaly index during nakshatra and rice/wheat productivity anomaly index at Patna and Samastipur districts

Sl. No.	Rainfall anomaly indices	Patna		Samastipur	
		F-Stat	r_s	F-Stat	r_s
Rice					
1	Aridhra	0.580	0.11	0.776	0.21
2	Swathi	1.354	0.12	14.470**	0.68++
3	Rohini	1.817	0.19	2.335	-0.35+
4	Mrigashira	0.069	-0.04	0.229	-0.12
Wheat					
5	Hasta	0.011	0.02	0.064	-0.06

(* - 5 per cent level, **- 1 per cent level
+ - Significant at 0.05 level, ++- Significant at 0.01 level)

declined drastically. As far as Samastipur is concerned, this situation occurred in only in 1992 and rice productivity reduced considerably to -60.9 % of the technological trend productivity.

Relation between hasta nakshatra rainfall and wheat productivity: Out of 25 years received deficit rainfall during hasta nakshatra, 14 years i.e., 56% of the years the wheat productivity recorded negative anomaly at Patna. However at Samastipur, out of 13 years received deficit rainfall during hasta, 8 years i.e. 62 % of the years the wheat productivity recorded negative anomaly. Rainfall failed completely during hasta period in 4 years, out of these, two years wheat productivity fall below the technological trend at Patna while at Samastipur, out of 3 years, 2 years wheat yield recorded negatively. Moreover, the good rainfall during hasta nakshatra may be beneficial for proper uniform / higher germination as well as larger coverage of cultivation of wheat and also increase the ground water table, so that farmers can afford recommended number of irrigations. Thus this traditional knowledge explains more than 50 % of yield anomaly in rice and wheat, which is more than the scientific findings of rainfall and yield of rice (Subash *et al.* 2009) and therefore, combining scientific and traditional knowledge may be more appropriate for forecasting yield in advance.

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Table 4: Rice productivity anomaly index and rainfall anomaly index during swathi nakshatra in deficit years at Patna and Samastipur districts

Year	Rice productivity anomaly index (%)	Rainfall anomaly index (%)
Patna		
1963	13.21	-29.2(1)
1972	18.18	120.8(1)
1974	-4.26	100.0(1)
1978	27.18	358.3(1)
1981	-6.05	614.6(1)
1989	21.5	254.2(1)
1993	22.82	225.0(1)
1994	2.56	-41.7(1)
1997	-17.78	725.0(3)
1999	4.41	20.8(1)
2003	29.41	1393.8(4)
Samastipur		
1989	-1.44	169.4(1)
1993	54.13	527.8(2)
1997	15.61	73.6(2)
2002	-9.04	-65.3(1)
2003	50.50	684.7(3)

( ) parenthesis indicates number of rainy days

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Table 5: Relation between rohini, mrigashira, aridhra nakshatra rainfall anomaly index and rice productivity anomaly index

Year	Rainfall anomaly index (%) during			Rice productivity anomaly index (%)
	Rohini	Mrigashira	Aridhra	
Patna				
1969	112.1	-53.5	-58.2	-32.99
1977	3.4	-83.5	-6.8	15.61
1980	165.7	-11.1	-60.8	5.67
1982	193.6	-17.5	-81.5	-1.20
1989	222.6	-12.4	-75.4	21.50
1992	32.8	-78.5	-32.9	-48.77
Samastipur				
1992	4.9	-90.3	-79.4	-60.90

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