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Rainfall pattern and moisture availability index in relation to rice (*Oryza sativa* L.) crop planning in eastern plateau region of India

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ABSTRACT

Studies were undertaken to identify the quantum and distribution of rainfall with the frequency of dry spell occurrence during monsoon at Giridih, Jharkhand state, India. Rainfall at different confidence levels was calculated using mixed gamma distribution. The normal onset of monsoon at Giridih was 24th standard meteorological week (SMW) and the mean monsoon rainfall was 1112 mm. If monsoon onsets two weeks earlier (22nd SMW) than the normal (24th SMW) the total monsoonal rainfall was more than the normal with increased number of dry spells. The co-efficient of variation of June and September rainfall was very high. Moisture availability index (MAI) indicated possibility of rice cultivation from 25th SMW and the flowering stage of rice should be completed within 39th SMW (normal withdraw of monsoon). Thus to minimize crop failure, conventional cultivation of 135 ± 10 days rice could be replaced by 95 ± 10 days one, particularly in upland (without bund; direct seeded rice) and medium land (low bund land) situation.

Key words: Monsoon rainfall, mixed gamma distribution, potential evapotranspiration, moisture availability index, rice.

Agriculture in the eastern plateau covering total area of Jharkhand and parts of West Bengal and Orissa is characterized by rainfed low productive mono-cropped rice dominated system. The climate here is sub-humid, sub-tropical with hot and dry summer as also with very few winter showers. The amount of total rainfall ranges from 900 - 1500 mm. The normal annual rainfall is 1372 mm, out of which 85 to 90 per cent is received in monsoon months (Sen *et al*., 1984). Even in monsoon months (June to September), the crops are subjected to moisture stress due to occasional dry spells. Although the rainfall is high, the distribution is erratic making the crop vulnerable even during monsoon. The farmer or agricultural planner must know the risk he is going to take in his endeavor. The study by using average or normal rainfall cannot include this risk factor. In rainfed and low productive eastern plateau region, rainfall being the only water resource, agricultural planning should be based on potentially high rainwater utilization technologies. This in turn calls for better understanding of rainfall probability characteristics to fit agro-climatologically suited cropping systems (Singandhupe *et al*., 2000). The scientific analysis of availability and water balance for a given location may help farmers in preparing their crop calendar and improving rice productivity and cropping intensity (Tomar, 2002). Again *Kharif* rice being the dominant one knowledge of rainfall pattern can be effective in crop/variety choice with less risk of failure in monsoon season. With this in view the study was undertaken to identify the quantum and distribution of rainfall with the frequency of dry spell occurrence during monsoon.

MATERIALS AND METHODS

Daily rainfall data were collected from Damodar Valley Corporation and Indian Statistical Institute, Giridih, Jharkhand (previously in Bihar state) for the years 1969 to 2004 (35 years). Rainfall was measured with IMD specified manual and automatic rain gauges. To study the characteristics of monsoon, the individual years were grouped according to the weeks of commencement of rainy season. Onset of monsoon during different years were identified as the week which received more than 20 mm of rain in 1 or 2 consecutive days, provided that the probability of at least 10 mm of rain in the subsequent week is more than 0.7 (Virmani, 1975). Similarly, the date of withdrawal of monsoon is defined as the date up to which a rainfall of at least 30 mm has been received in a week with no subsequent rainfall for at least 3 consecutive weeks towards the end the monsoon season (Shanker *et al*., 1992). Total rainfall for standard meteorological weeks (SMW) was computed for all years. The mean, mode and median dates, standard deviation and co-efficient of variation regarding onset, withdrawal and duration of southwest monsoon were calculated as advocated by Chandel (1978). Rainfall at different confidences was done using mixed Gamma distribution (Shanker *et al*., 1982).

The equations used for computation of minimum assured rainfall are mixed Gamma distribution:

$$G(X) = q + pF(X) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where F (X) is the Gamma distribution and q is the probability of zero precipitation and $p = 1 - q$. F (X) is given by:

$$F(X) = \int_0^X \frac{(x^{\gamma-1} - e^{-x/\beta})}{\beta^{\gamma}(\gamma)^{1/2}} \times dx \qquad \ldots\ldots(2)$$

Where, F (X) = 0 when $X \leq 0$.

In the above γ and β are shape and scale parameters respectively of the distribution and $\sqrt{\gamma}$ is the Gamma function of γ. The distribution is bounded at the left side by zero. G (X) is the probability of rain <X.

The parameters γ and β were estimated from observed data by maximum likelihood.

P (X), the probability of rain => X is given by:

$$P(X) = 1 - G(X) = 1 - q - (1 - q)$$

$$F(X) = (1-q)\left[1 - \int_0^x \frac{x^{\gamma-1} - e^{-x/\beta}}{\beta^{\gamma}(\gamma)^{1/2}} \times dx\right] \ldots\ldots..(3)$$

The rainfall at different confidence levels was obtained by solving the above equation by iteration process for X and for P(X) = 0.3, 0.5 and 0.7 respectively.

Potential evapotranspiration (PET) was that calculated from U.S. class 'A' pan evaporimeter values multiplied by 0.7 (Pan coefficient) (Banik, 1996).

Moisture availability index (MAI) has been calculated and it is defined as the ratio of weekly rainfall at different confidence levels to PET of the corresponding period (Hargreaves, 1971). The MAI was, however, worked out for 30, 50 and 70 per cent probability levels. Depending on the threshold values of MAI the agricultural operations for rice cultivation can be recommended (Banik, 1996).

Threshold values of MAI	Agricultural operations
<0.3	No. agricultural operations can be done
0.3 – 0.5	Land preparation
0.5 – 0.75	Direct sowing of rice can be done
0.76 – 1	Transplanting
>1	With out any risk

RESULTS AND DISCUSSION

The normal onset of monsoon was in 24th SMW (11 – 17th June) and it ranged from 22nd – 27th SMW over the years of study (Table 1). Monsoon commenced as early as 22nd SMW in 1970 (30th May), 1980 (31st May), 1991 (28th May), 2000 (6th June) and 2001 (3rd June) and as late as 27th SMW in 1974 (6th July) and 1976 (7th July). Monsoon withdrawal was in the 39th SMW (24 - 30th September). The earliest and latest dates of withdrawal of south-west monsoon were 7th September in 1971 and 14th October 1973.

The total monsoon rainfall was more than average (1259 mm) during the year in which monsoon onset was noted in SMW 22nd and 23rd (Table 2). When onset occurred during the SMW 26th or later, the average monsoon rain was around 819 mm. Heavy deficits in rainfall was found in years when monsoon commenced during SMW of 26 and 27 (Table 2). Irrespective of monsoon withdrawal, if a monsoon onsets within 23rd SMW, the quantum of rain was highest (1259 mm). Early (22 – 23 SMW) onset and early withdrawal (36 - 37 SMW) showed (Table 2) the highest rainfall (1630 mm) followed by normal (24 – 25 SMW) onset and normal withdrawal (38 - 39 SMW) (1116 mm). The commencement of monsoon and average of dry spells duration were inversely related. With early commencement of monsoon the average number of dry spells increased and such dry spells decreased with delay in monsoon onset. The data further indicated that if monsoon onset was within 24th SMW there was possibility of dry spell occurrence in early stages i.e., 22 - 25 SMW and at 34 - 37 SMW.

Rainfall at different confidence levels (Table 3) indicated that rain started around SMW 16th at 0.3-confidence level whereas it was in the 23rd SMW when confidence level is 0.7. The highest PET was 50.03 mm/week in 16 SMW and the lowest was 11.46 mm/week at 51 SMW (Table 3). Higher values (more than 40 mm/ week) of PET were observed from 12 to 22 SMW and as the monsoon advances the PET values decrease.

Moisture availability index (MAI) indicated (Fig. 1) that land preparation for rice could be done around 19th SMW and rice can be sown/transplanted during 22nd SMW as the MAI (0.76) shows more than 0.5 at 0.3 confidence level. MAI at 0.7-confidence level showed that rice can be sown/transplanted not before 26 SMW (MAI = 1.17) and the flowering stage of the rice should be over before 39th SMW. The concept of MAI to characterize rice cultivation is mainly appropriate to upland or low-bunded lands. Singh *et al.*, (2009) reported that seed sowing in paddy nursery in the Palampur region generally took places immediately after initiation of monsoon during 23rd - 25th standard meteorological weeks and transplanting was carried out around 27th or 28th standard meteorological week. The tillering, 50 percent flowering and dough stage were observed

Table 1: Monsoon onset (week), withdrawal (week), quantum (mm) and length (week) of Giridih

Year	Monsoon onset week	Monsoon withdrawal week	Monsoon rainfall (mm)	Length
1969	23	38	1193.7	16
1970	22	39	917.1	18
1971	26	36	887.1	11
1972	26	37	674.5	12
1973	23	41	1119.8	19
1974	27	39	604.2	13
1975	25	40	918.3	16
1976	27	38	589.4	12
1977	24	37	1030.4	14
1978	25	41	1143.5	17
1979	25	39	1176.4	15
1980	22	37	2063.0	16
1981	25	38	990.2	14
1982	23	37	1135.2	14
1983	25	41	1540.3	17
1984	23	37	2684.1	15
1985	23	39	1806.7	17
1986	24	40	1005.8	17
1987	25	39	1347.0	15
1988	24	40	808.0	17
1989	25	40	945.8	16
1990	23	41	1251.2	19
1991	22	39	787.7	18
1992	23	40	822.0	18
1993	23	40	792.8	18
1994	23	38	1066.7	16
1995	24	39	1350.4	16
1996	25	39	851.9	15
1997	25	37	1134.9	13
1998	26	41	1079.5	17
1999	24	41	1362.7	19
2000	22	37	638.4	16
2001	22	40	991.2	19
2002	22	41	990	20
2003	24	41	1246	18
2004	23	40	981	18
Mean	24	39.1	1109	16.1
Mode	23	39	-	16
SE±	0.289	0.246	13.043	0.5308

during 32-33rd, 37-38th and 40-41st standard meteorological weeks respectively.

These results confirmed that if monsoon commenced earlier, though it provides a longer period (22-41 weeks), the probability of occurrence of dry spell at early and later stages become high. Mohsin *et al.*, (1986) presumed onset of monsoon between 10 to 24th June over the eastern plateau region. Paul (1988) suggested 50mm of rainfall as optimum for starting seedbed preparation of rice in Hazaribag (a district of Jharkhand). However, in plateau areas of Jharkhand, co-efficient of variation was very high in June and September rainfall suggesting this to be highly erratic. So to minimize the risk of failure of rice crop it would be better to replace conventional cultivation of medium duration rice (135 ± 10 days) with short duration (95 ± 10) ones

Table 2: Number of years of monsoon onset and withdrawal at Giridih

Onset of monsoon	Withdrawal of monsoon		
	Early (36–37 SMW)	Normal (38–39 SMW)	Late (40–41 SMW)
Early (22-23 SMW[$])	4 (1630)	5 (1154)	7 (993)
Normal (24-25 SMW)	2 (1083)	5 (1143)	8 (1121)
Late (26-27 SMW)	2 (781)	2 (597)	1 (1079)
Amount of rainfall (mm)	1165	965	1064

$ Standard meteorological week

* Figure within the parenthesis is the average monsoon rainfall in mm.

Table 3: Long term average weekly rainfall (mm), weekly rainfall (mm) at different probability level and average weekly PET (mm) of Giridih

Week_No.	Average rainfall (mm)	Rainfall at different Probability level (mm)			Weekly PET (mm)
		P=0.3	P=0.5	P=0.7	
16	9	9	0	0	50
17	6	2	0	0	46
18	7	9	0	0	46
19	10	31	9	0	45
20	13	17	5	0	45
21	14	21	6	0	41
22	13	33	5	0	43
23	32	55	25	7	38
24	40	28	14	5	32
25	60	68	36	16	36
26	96	94	55	28	24
27	64	61	35	18	19
28	51	99	63	34	33
29	72	129	96	53	20
30	86	156	109	55	19
31	68	116	63	34	19
32	64	132	74	39	18
33	46	69	48	33	17
34	59	90	71	41	16
35	71	103	55	28	19
36	60	128	67	35	16
37	53	102	72	40	15
38	42	60	32	14	18
39	54	159	75	32	17
40	31	47	12	0	16
41	23	15	5	0	16
42	10	4	0	0	16

particularly in low bunded medium and unbunded uplands where the harvesting of rain water is minimum or nil.

The study also suggests that if monsoon commences earlier, rice should be kept in seedbed for 4 -5 SMW to avoid the risk of crop failure due to early dry spells. It suggests the advantages of staggered seedbed sowing to escape any early monsoonal dry spell (Banik, 1996).

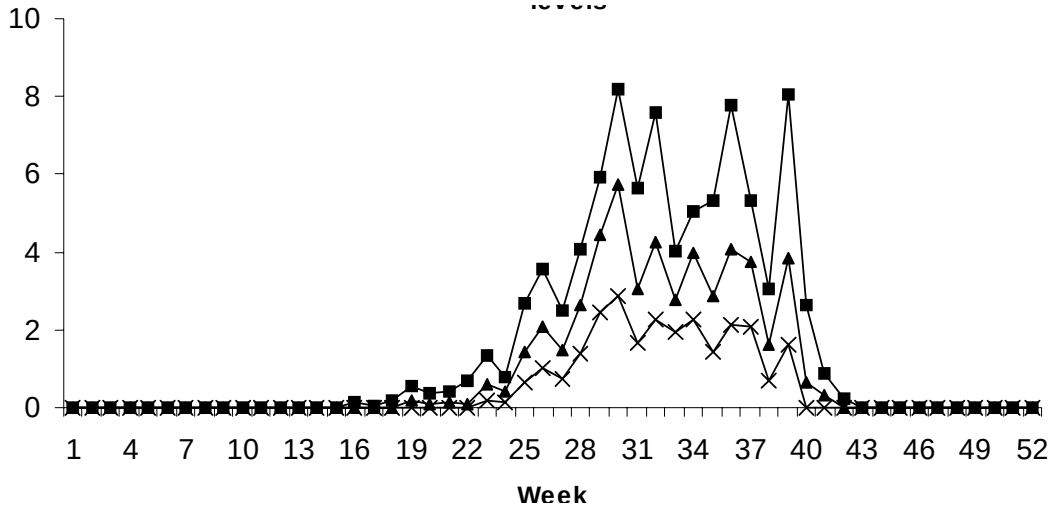

Fig. 1: Moisture availability index of Giridih at different probability levels

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