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Assessing the impact of dry spell during monsoon season on rice productivity - A case study over Patna district

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ABSTRACT

The monthly, seasonal and yearly rainfall characteristics, frequency of occurrence of 10 days or more consecutive dry spells during monsoon season and their influence on rice productivity were investigated using daily rainfall data for 49 years (1960-2008) recorded at Agricultural Research Institute, Patna, Bihar. The results revealed that monsoon season receives 84.4% (959.5 mm) of the annual rainfall (1136.8 mm) followed by 7.9% (89.6 mm) during post-monsoon season. The coefficient of variation of annual rainfall was recorded as 26% and the monthly values ranged from 43.2% (August) to 210.9% (December). The data on rice productivity was fitted into different models in curvefit program and it was observed that R^2 value was higher for 10th degree polynomial fit. The scattering of data points from the trend line (10th degree polynomial curve) indicated higher year-to-year variability. During the study period, 10 days or more consecutive dry spells occurred in four years (1966, 1982, 2004 and 2005) during July. During all the years, the rice productivity was recorded below the technological trend productivity. Similarly, 10 days or more consecutive dry spells during August occurred in four years (1968, 1973, 2004 and 2006) affecting the productivity. This clearly showed that if any 10 days or more consecutive dry spells occur during the months of July and August, there is likelihood of low rice productivity. This study also showed occurrence of 10 days or more consecutive dry spells during September may not have impacted severely rice productivity because of the flooded paddy fields along with higher relative humidity reducing the water demand and thereby the rice crop never experienced severe water stress situations.

1. INTRODUCTION

Rice cultivation has been a gamble in recent years owing to erratic behaviour of monsoon rainfall during different phenological stages of the crop. South-west monsoon rainfall during June through September is the major source of water for rainfed agriculture. But erratic distribution of rainfall coupled with prolonged dry spells during moisture sensitive phenophases of the crop adversely affects the growth and yield of crop. Tillering to flowering is the most critical stage during which rice crop should not be subjected to water stress. Even though Bihar falls under moderate to high rainfall region, recurrent floods and droughts during the monsoon season are the serious concern. The severe rainfall deficit that occurred over Bihar during June and July months incurred a loss of ₹ 1839 crores to state exchequer (Khan *et al*., 2009). Several researchers analysed rainfall pattern over different periods as well as spatial scales for crop planning (Senapathi *et al*., 2009; Subash *et al*., 2009; Singh *et al*., 2007). However, its relation with crop productivity has not been studied. Since short dry spell may not influence the yield significantly, dry spell for a longer duration *i.e.,* 10 days or more may affect the crop productivity significantly. But no studies were undertaken to quantify the impact of dry spell on rice productivity. Hence, in this paper, it has been attempted to find out the quantitative assessment of the influence of long period dry spell on *kharif* rice productivity over Patna district of Bihar.

2. MATERIALS AND METHODS

Daily rainfall data recorded at the Agricultural Research Institute, Rajendra Agricultural University, Patna during the period 1960-2008 was collected to analyze 10 days or more consecutive dry spells during various months of monsoon season. The productivity of *kharif* rice over Patna from 1960 to 2008 was collected from the website (http://www.dacnet.nic.in) of Directorate of Rice, Ministry of Agriculture, Govt. of India. The productivity of rice depends on type of soil, seed material, water availability, fertilizers, pesticides and the meteorological parameters such as rainfall, temperature, relative humidity and solar radiation. The total technological inputs to the farming sector have been growing steadily but their impact is difficult to quantify. Hence, to know the trends and to quantify the growth rate of total technological inputs to the agricultural sector, the actual productivity was fitted in best fit model using "Curvefit" program. In this connection, several studies were reported to fit the productivity into linear/exponential/quadratic equations to define the technological trend (Gopinathan, 2000; Kandiannan *et al*., 2002; Challinor *et al*., 2003 and 2005; Ortiz *et al*., 2008; Subash *et al*., 2009; Subash and Ram Mohan, 2010). To normalize the rice productivity, the actual productivity was converted into indices. The Productivity Anomaly Index (PAI) was taken as the percentage of the technological trend productivity (best fit) to the actual productivity. The PAI for the i^{th} year is:

$$PAI_i \quad \frac{(P_i \quad TPi)*100}{TP_i}$$

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

3. RESULTS AND DISCUSSION

Rainfall Climatology

The mean monthly rainfall, standard deviation and coefficient of variation are given in Table 1. The highest rainfall of 343.5 mm (30.2%) was recorded during July followed by 273.3 mm in August (24.0%). On an average, monsoon season receives 84.4% (959.5 mm) of the annual rainfall (1136.8 mm) followed by 7.9% (89.6 mm) during post-monsoon season. The coefficient of variation of annual rainfall was recorded as 26% and the monthly values ranged from 43.2% (August) to 210.9% (December). The higher variability of rainfall in June and September may be due to the variability of date of onset of monsoon and date of withdrawal of monsoon, respectively.

Table: 1
Monthly, seasonal and annual rainfall, its standard deviation and coefficient of variation (Database: 1960-2008)

Month/ season	Mean rainfall (mm)	Standard Deviation (mm)	Coefficient of variation (%)	Contribution to annual rainfall (%)
January	11.5	10.3	89.9	1.0
February	13.4	17.2	128.3	1.2
March	9.1	14.2	155.8	0.8
April	10.8	13.8	127.4	1.0
May	42.8	40.9	95.6	3.8
June	140.6	94.0	66.8	12.4
July	343.5	164.0	47.7	30.2
August	273.3	118.1	43.2	24.0
September	202.1	118.4	58.6	17.8
October	76.3	86.3	113.2	6.7
November	8.2	16.4	199.3	0.7
December	5.1	10.7	210.9	0.4
Winter	24.9	21.5	86.2	2.2
Summer	62.7	45.9	73.2	5.5
Monsoon	959.5	266.8	27.8	84.4
Post-monsoon	89.6	85.7	95.7	7.9
Annual	1136.8	292.8	25.8	100.0

Rice Productivity Trends and Rice Growing Period

The data on rice productivity was fitted into different models in curvefit program and it was observed that R^2 value was higher for 10^{th} degree polynomial fit. The scattering of data points from the trend line (10^{th} degree polynomial curve) indicated higher year-to-year variability. Normally, in this part of the Bihar, farmers start nursery raising with the onset of monsoon *i.e.,* during the third week of June and start transplanting mostly during July, August and some during first fortnight of September. This reduces the potential yield of rice crop by 50%. Different phenological stages of short, medium and long duration rice varieties sown in optimum times are given in Table 2.

Relation Between Consecutive Dry Spell and Rice Productivity

Out of 49 years, 45% of the years (22 years), rice productivity falls below the technological trend line (Fig. 1). 10 days or more consecutive dry spells did not occur during the monsoon season for eleven years and from this, during three years (1981, 1983 and 2008) rice productivity falls below 15% of the technological trend and in two years (1970 and 1980) the rice productivity was below the technological trend. This showed that more than 50% of the years with no dry spell (10 days or more) during June-September recorded higher rice productivity compared to

Table: 2
Normal rice growing calendar for short, medium and long duration varieties

Transplanting Date	Maximum Tillering	Panicle Development	Flowering	Milky Stage	Grain Hardening	Harvest
Short Duration Varieties, eg. Thuranda, Bala, Cauveri (Maturity 90-100 days after transplantation)						
June 25- July 1	July 23-29	Aug 6-12	Aug 20-26	Sept 3-9	Sept 17-23	Sept. 25-30
Medium Duration Varieties, eg. Sita, Rajasree (Maturity 110-115 days after transplantation)						
June 25- July 1	July 30-Aug 5	Aug 13-19	Sept 17-23	Sept 23-30	Oct 1-7	Oct 7-15
Long Duration Varieties, eg. MTU 7029, MTU 1001 (Maturity 130-140 days after transplantation)						
June 25- July 1	July 30-Aug 12	Aug 27-Sep 2	Sept 28-Oct	7 Oct 24-30	Nov 4-11	Nov 11-17

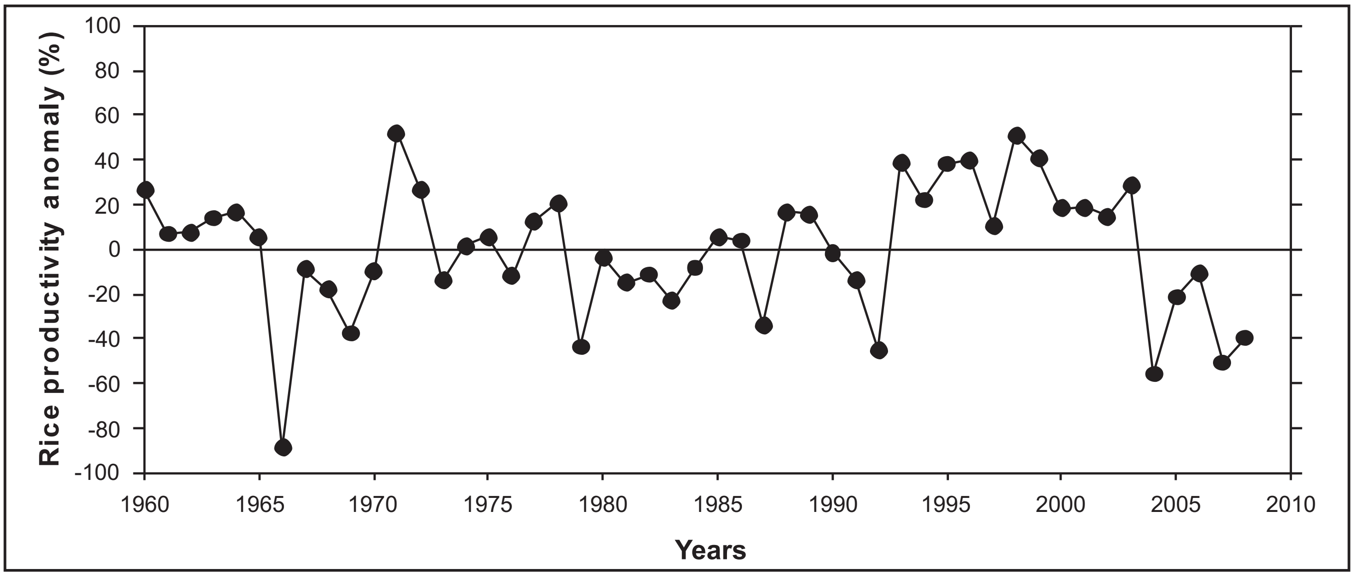

Fig.1. Rice productivity anomaly over Patna

technological trend productivity. However, out of 49 years, at least one 10 days or more consecutive dry spells occurred in 32 years during the month of June, but rice productivity fell below technological productivity in 12 years only (Table 3), indicating the dry spell occurred because of weak onset of monsoon or break in monsoon after early onset and these dry spells have not affected the rice productivity in majority of the years.

During the study period, 10 days or more consecutive dry spells occurred in four years (1966, 1982, 2004 and 2005) during July. During all the years, the rice productivity was recorded below the technological trend productivity. Similarly, 10 days or more consecutive dry spells during August occurred in four years (1968, 1973, 2004 and 2006), affecting the productivity. This clearly showed that if any 10 days or more consecutive dry spells occur during the month of July and August, there is likelihood of low rice productivity. As far as the range of rice productivity anomaly is concerned, the anamoly of -10.54% in 2006 to -88.69% in 1966, indicated that there will be at least 10% low rice productivity as compared to technological trend productivity if 10 days or more consecutive dry spells occurred in July and August. Higher rice productivity anomaly during the years 1966 and 2004 may be due to occurrence of multiple number of 10 days or more consecutive dry spells during crop growing season.

As far as the month of September is concerned, 10 days or more consecutive dry spells occurred in nine years (1960, 1963, 1965, 1966, 1971, 1984, 1990, 1996 and 2002); out of these, only three years (1966, 1984 and 1990), below normal rice productivity. Moreover, among these 3 years, the rice productivity anomaly reached-88.69% during 1966, which is the highest during the 49-year study period, perhaps due to occurrence of 4 times 10 days consecutive dry spells during the growing period. The rice productivity falls between 0 and -10% only in remaining ten years. The study showed that the occurrence of 10 days or more consecutive dry spells during September may not have impacted severely rice productivity because of the flooded paddy fields along with higher relative humidity may have

Table: 3
Dry spell of 10 days or more during monsoon season and rice productivity anomaly

Year	No. of 10 days or > 10 days dry spell				1^{st} and 2^{nd} maximum dry spell	Rice productivity anomaly	Year	No. of 10 days or > 10 days dry spell				1^{st} and 2^{nd} maximum dry spell	Rice productivity anomaly
	J	Ju	A	S				J	Ju	A	S		
1960	2	-	-	1	June 22(12)								
					Sept 15(11)	26.49	1985	-	-	-	-	-	5.59
1961	-	-	-	-	-	6.87	1986	1	-	-	-	June 1(14)	3.79
1962	-	-	-	-	-	7.80	1987	1	-	-	-	June 6(12)	-33.92
1963	1	-	-	1	Sept 17(11)								
					June 1(10)	14.01	1988	1	-	-	-	June 1(11)	16.72
1964	1	-	-	-	June 1(18)	16.60	1989	1	-	-	-	June 22(10)	15.69
1965	1	-	-	1	June 1(21)								
					Sept 12(11)	5.38	1990	1	-	-	-	June 1(14)	-1.52
1966	1	2	-	1	Sept 12(19)							June 18(13)	
					June 1(15)	-88.69	1991	1	-	-	1	Sept 18(13)	-13.78
1967	1	-	-	-	June 1(33)	-8.83	1992	1	-	-	-	June 1(13)	-45.07
1968	-	-	1	-	Aug 28(16)	-18.03	1993	1	-	-	-	June 1(19)	38.72
1969	1	-	-	-	June 23(10)	-37.69	1994	1	-	-	-	June 1(15)	22.22
1970	-	-	-	-	-	-9.38	1995	1	-	-	-	June 8(13)	38.23
1971	-	-	-	1	Sept 12(15)	51.95	1996	1	-	-	-	June 7(15)	40.06
1972	1	-	-	-	June 1(33)							June 12(13)	
						26.68	1997	2	-	-	1	Sept 16(12)	10.49
1973	-	-	1	-	Aug 21(10)	-13.92	1998	1	-	-	-	June 1(19)	51.17
1974	-	-	-	-	-	1.44	1999	-	-	-	-	-	40.60
1975	1	-	-	-	June 2(18)	5.47	2000	-	-	-	-	-	18.32
1976	1	-	-	-	June 19(10)	-11.87	2001	1	-	-	-	June 1(14)	18.69
1977	-	-	-	-	-							June 1(13)	
						12.61	2002	1	-	-	1	Sept 12(12)	14.64
1978	2	-	-	-	June 13(10)							June 7(13)	
					June 28(10)	20.58	2003	1	-	-	-		28.56
1979	1	-	-	-	June 1(23)							June 1(13)	
						-43.59	2004	1	1	1	-	Aug 29(12)	-55.84
1980	-	-	-	-	-							June 1(21)	
						-3.43	2005	1	-	2	-	Aug 25(11)	-21.41
1981	-	-	-	-	-							June 9(21)	
						-14.94	2006	1	1	-	-	July 22(10)	-10.54
1982	-	1	-	-	July 1(13)							June 1(12)	
						-11.01	2007	2	-	1	-	June 16(11)	-50.70
1983	-	-	-	-	-	-22.94	2008	-	-	-	-	-	-39.26
1984	-	-	-	1	Sept 20(11)	-8.33							

reduced the water demand and thereby the rice crop never experienced severe water stress situations.

4. CONCLUSIONS

The higher variability of June and September rainfall may be due to the variability of date of onset of monsoon and date of withdrawal of monsoon, respectively. The occurrence of 10 days or more than 10 days dry spells during the month of July and August, may lead to poor crop yield. The study highlighted the degree of rice crop failure with the occurrence of 10 days or more consecutive dry spells during the monsoon months. Based on this information, the policy makers and researchers may advocate suitable water management strategies to reduce the ill effect of moisture stress during the critical phenophases of the rice crop.

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