An agrometeorological study for crop planning under rainfed condition in Gaya district of Bihar

ABDUS SATTAR, S.A. KHAN* AND MANISH KUMAR

Agrometeorology Division, Rajendra Agricultural University, Pusa, Bihar-848125
*Department of Agricultural Meteorology and Physics,
BidhanChandra Krishi Viswavidyalaya, Mohanpur (W.B.)-741252.

ABSTRACT

Proper rain water management is vital for successful raising of crops in the rainfed regions, since crop production in a vast net sown area of the country is still dependent upon rainfall. So, proper understanding about distribution pattern of rainfall resources analyzed through modern agroclimatic methods at micro-level is required for efficient crop planning under rainfed condition. In the present study, daily rainfall data of Gaya district of Bihar for the period from 1969 to 2006 were analyzed through several approaches for identifying water availability period for crop planning in the district. Based on the results of the investigation, suitable crop planning for the district has been suggested. The average annual rainfall of the district is 1112.1 mm received in 56 rainy days. Of the total annual rainfall, monsoon, post monsoon, winter and summer seasons contributed 86.5, 6.1, 2.9 and 4.5 %, respectively. The coefficient of variation of monthly rainfall from June to September ranged from 39.1 (July) to 72.3 % (June). Monthly rainfall during July and August is relatively more dependable as shown by lower CV values. Rainy season starts in the district during 25 standard meteorological week (SMW) and terminates during 42 SMW and thereby, providing with an average length of rainy season of 16.6 weeks. At 75 % probability, referred to as a probability of obtaining an assured amount of rainfall for crop planning under rainfed condition, at least 25 mm rainfall could be expected from 27 to 33 SMW. Weekly average rainfall during 25-38 SMW ranged from 32.9 to 89.7 mm. After 38 SMW, the amount of rainfall decreased drastically. Moisture availability index (MAI), initial and conditional probabilities of rainfall for critical limits of 20 mm and 30 mm have been computed for suggesting better rainfed crop planning in the district. Crop water demand and irrigation requirement for *kharif* rice during various phenological stages have been worked out. Results of trend analysis in respect of rainfall over different seasons and length of growing season have also been reported.

Key words : *Rainfall probability, Moisture availability, Water requirement, Crop planning.*

INTRODUCTION

In Bihar, agriculture is largely dependent on the performance of southwest monsoon and hence the studies on the variability in the rainfall amount, its distribution, probability of occurrence of effective monsoon, prediction of assured rainfall at different probability levels and wet spell during rainy season are of paramount importance especially under rainfed condition for determining appropriate sowing time and suitable cropping system. Thus, it is necessary to identify duration of water availability for crops sunder rainfed condition for selection of suitable crops and their varieties matching with the water availability period. Rice is a very important *kharif* crop in Bihar. In the recent years, *kharif* rice production has been a gamble owing to erratic monsoon system. Moisture is a limiting factor for successful cultivation of crops. In such background, a study on rainfall variability, probability analysis and moisture availability period assumes significance for evolving better crop management strategy under *rainfed* condition. Several authors have carried out rainfall analysis for crop planning at district level (Ramana Rao *et al*., 1979; Sarker and Biswas, 1980; Gupta *et al*., 2010). In the present paper, an attempt has been made to work out trend and statistics of annual, monthly, seasonal and weekly rainfall in Gaya district of Bihar and to suggest suitable crop planning for the district on the basis of rainfall probability, water availability period and crop water requirement.

MATERIALS AND METHODS

Daily rainfall data for the period from 1969 to 2006 of Gaya district was collected from Directorate of Statistics & Planning, Govt. of Bihar. The rainfall data (1969 to 2006) of the district were analyzed to obtain annual, seasonal and monthly rainfall, rainy days and accumulated rainfall during different phases of growth of *kharif* rice were computed. Using this database, expected weekly rainfall at different probability levels (10, 25, 50, 75 and 90 %) was computed with the procedure followed by Sarkar and Biswas (1986). Initial and conditional probabilities of receiving 20 and 30 mm rainfall per week were computed following the method as suggested by Robertson (1976).

Initial probability : P(D)= Probability of dry week, P(W)= Probability of wet week,

Conditional probability : P(W/W)= probability of wet week followed by wet week : P (D/D) = Probability of dry week followed by dry week, P(D/W)= Probability of dry week followed by wet week, P(W/D)= probability of wet week followed by dry week.

Normal potential evapotranspiration (PET) was estimated through modified Penman method (Dorenbos and Pruitt, 1977). Moisture availability index which is the ratio between expected rainfall at different probability levels and potential evapotranspiration was estimated with the method given by Hargreaves (1971). According to Hargreaves moisture availability index (MAI) concept, moderately deficient period was considered when MAI e" 0.34 and adequate moisture availability when MAI e" 1.0. Weekly PET values were multiplied by crop coefficient (Kc) to determine weekly water requirement (WR) of the rice crop. 3 cm continuous standing water in the rice field has been

considered and added with water requirement of the crop. Crop coefficients were used under light to moderate wind condition as suggested by Doorenbos and Pruitt (1977). The growing season of rice crop was divided into three growth phases viz. vegetative phase (transplanting to 50 % booting stage) during 28 to 38 standard meteorological weeks (SMW), reproductive phase (50 % booting to 50 % flowering stage) during 38 to 41 SMW and ripening phase (50 % flowering to maturity stage) during 41 to 44 SMW. To demonstrate the trend of rainfall, best-fit equations involving years, rainfall and rainy days were developed.

RESULTS AND DISCUSSION

Variability in rainfall

Gaya district receives an annual rainfall of 1112.1 mm in 56 rainy days with a coefficient of variation of 24.7 %. About 962.0 mm rainfall is received during monsoon season in 46 rainy days with a C.V. of 26.7 %. Post monsoon, winter and summer season receive 68.1 mm, 32.0 mm and 50.0 mm rainfall respectively with C.V. of 90 %, 95 % and 79.9 % respectively (Table 1). Annual rainfall is showing increasing trend; rainfall increases by 3.1 mm/year. With increasing rainy days, annual rainfall amount exhibited increasing trend (Fig. 1 & 2). The association between them was highly significant (Fig. 3, r = 0.67**, significant at 1 % level). During *kharif* season, the month of June, July, August, and September receive 155.5 mm, 316.3 mm, 292.3 mm and 198.2 mm rainfall respectively (Table 2). The highest C.V. (72.3 %) was observed in the month of June followed by September (53.3 %). The month of July showed lowest C.V. (39.1 %) indicating rainfall during July and August (C.V. of 46.2 %) is quite dependable as C.V. values are well below the critical value of 50.

Water availability period

Moisture availability indices according to Hargreaves's moisture availability index (MAI) concept, moderately deficient period is considered when MAIe" 0.34 and adequate moisture availability when MAIe" 1.00. According to this concept, water availability period in Gaya district at 50 and 75 percent probability with MAIe" 0.34 was found to occur from 24 to 40 SMW and 27 to 37 SMW respectively. Water availability periods with adequate moisture at 50 and 75 percent probability with MAIe" 1.00 were estimated from 27 to 37 SMW and 30 to 34 SMW respectively (Fig.4). If an MAI of 1.00 in a week is considered as sowing week, sowing/transplanting could be undertaken in 27 and 30 SMW in 50 percent and 75 percent probability respectively.

Rainfall probability & crop water requirement

Kharif growing season starts in the district during 26 SMW and terminates during 42 SMW with an average duration of 112 days of length of *kharif* growing season (Table 3). At 75 percent probability, which is an assured amount of rainfall for crop planning, at least 25 mm rainfall could be expected from 27 to 33 SMW (Table 4). At least 40 mm rainfall could be expected during 26-36 SMW except 33 and 34 SMW at 50 percent probability. Weekly average rainfall during 25-38 SMW

varied from 32.9 to 89.7 mm. After 38th SMW, the amount of rainfall decreases drastically. Results of analysis regarding initial and conditional probabilities of rainfall for critical limit 20 and 30 mm showed that the probability of receiving 20 mm rainfall per week was more than 70 percent during 26 to 36 SMW except week numbers 34 and 35 (Table 5). The probability of a week being wet followed by a wet week (20 mm rainfall) was very high during the corresponding period except week number 34. Likewise, the probability of getting 30 mm rainfall per week was more than 70 percent from 26 to 33 SMW except week number 30. The probability of a wet week followed by a wet week (rainfall limit 30 mm per week) was more than 70 percent from 26 to 35 SMW except week numbers 30 and 34.

In case of short to medium duration rice crop, weekly water requirement and water demand have been worked out (Table 6). K*harif* rice needs 645.7 mm water including 3 cm standing water in the field during entire vegetative phase (transplanting to 50 % booting). The water requirement with 3 cm standing water was 224.4 mm during reproductive phase (50 % booting to 50 % flowering stage) and 221.4 mm during ripening period from 50 % flowering to physiological maturity stage. At 75 % probability, the amounts of irrigation to be applied to the crop during vegetative phase were computed as 149.7 and 387.0 mm at 50 and 75 percent probability respectively. During reproductive phase, the amounts were 170.7 mm and 209.7 mm at 50 and 75 percent probability respectively. Results showed that during ripening period, most of the water requirement of the crop requires to be fulfilled through irrigation (205.7 mm) at 50 percent probability and 217.7 mm at 75 percent probability. Thus, there should be good provision of irrigation water from 50 % flowering to raise *kharif* rice crop as chances of rainfall drastically decreases. Gaya being mostly an undulating topography and receiving most of the annual rainfall during monsoon season (86.5 %), there is scope for rain water harvesting and supplemental irrigations for both *kharif* and *rabi* crops. Such information on rainfall probability, water availability and water requirement of crops would be useful in avoiding moisture stress to crops at critical phenological stages with provision of irrigation. Rainfall during vegetative phase of rice crop showed slightly decreasing trend (Fig. 5). However, during reproductive and ripening phase, increasing trends were observed with significant increasing trend during reproductive phase. (Fig. 6 & 7).

Crop planning

At 75 percent probability, which is an assured amount of rainfall for crop planning, at least 25 mm rainfall could be expected from 27 to 33 SMW. Beyond this period, the *kharif* rice may face water stress at reproductive to maturity stage, which can be managed by providing supplemental irrigations. At 50 and 75 percent probability levels, water availability periods with MAIe" 1.00 (adequate moisture) were 11 weeks (27-37 SMW) and only 5 weeks (30-34 SMW) respectively. The results on crop water requirement, water availability and rainfall probability analysis suggest that where feasible it is recommended to grow short duration rice varieties and low water requiring crops only during *kharif* season in the district. In upland and medium land conditions, *kharif* maize has good production potential. There is need of harvesting surplus rain water during monsoon season for supplemental irrigation during both *kharif and rabi* seasons.

Table 1

Characteristics of seasonal rainfall in Gaya district

Season	Parameters	Minimum	Maximum	Mean	SD	CV (%)
Monsoon	Rainfall (mm)	534.7	1628.8	962.0	256.6	26.7
	Rainy days	33	66	46	8.4	18.2
Post Monsoon	Rainfall (mm)	0.0	216.3	68.1	61.3	90.0
	Rainy days	0	10	3	2.5	83.7
Winter	Rainfall (mm)	0.0	118.9	32.0	30.4	95.0
	Rainy days	0	7	2.8	2.3	80.2
Summer	Rainfall (mm)	2.8	146.4	50.0	39.9	79.9
	Rainy days	0	11	4	2.7	66.6

Table 2

Observed minimum, maximum, mean and standard deviation and coefficient of variation of monthly rainfall

Month	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D (mm)	C.V. (%)
January	0.0	74.9	17.3	21.1	1221.1
February	0.0	63.3	14.7	18.2	123.8
March	0.0	68.0	10.4	15.6	149.9
April	0.0	102.2	13.2	20.3	154.2
May	0.0	123.0	26.4	31.1	118.1
June	17.8	411.4	155.2	112.1	72.3
July	113.5	599.6	316.3	123.6	39.1
August	65.9	647.3	292.3	135.0	46.2
September	43.1	579.0	198.2	105.7	53.3
October	0.0	210.7	57.4	59.8	104.3
November	0.0	48.5	6.9	14.6	211.6
December	0.0	32.9	3.8	7.5	194.8

Table 3

Duration of kharif growing season in Gaya district

Year	Start week	End week	Duration in weeks	Rainfall (mm)
1969	27	45	18	1096.1
1970	24	40	16	725.7
1971	26	42	16	1161.6
1972	27	47	20	839.4
1973	24	38	14	907.5
1974	27	42	15	837.7
1975	26	41	15	812.5
1976	24	38	14	1145.0
1977	26	51	25	1107.8
1978	24	43	19	1467.9
1979	26	48	22	738.0
1980	25	42	17	912.7
1981	27	39	12	714.9
1982	28	45	17	697.4
1983	26	43	17	1008.3
1984	24	36	12	1450.5
1985	27	42	15	1129.5
1986	26	40	14	921.3
1987	26	36	10	1212.7
1988	25	43	18	704.0
1989	24	50	26	677.4
1990	24	39	15	1240.2
1991	24	38	14	752.5
1992	28	39	11	498.8
1993	27	43	16	773.9
1994	25	40	15	887.3
1995	25	52	27	1102.2
1996	25	39	14	667.2
1997	26	48	22	1102.0
1998	27	42	15	1007.5
1999	24	42	18	1130.6
2000	24	38	14	1061.7
2001	25	40	15	1497.2
2002	26	42	16	1038.1
2003	26	43	17	1179.7
2004	25	42	16	696.2
2005	26	40	17	705.5

Mean start = 26 SMW	Earliest = 24 SMW	Latest = 28 SMW	SD = 1.3 Week
Mean end = 42 SMW	Earliest = 36 SMW	Latest = 52 SMW	SD= 4.0 Week
Mean duration = 16 weeks	Min dur = 10 SMW	Max dur = 27 SMW	SD = 3.9 Week

Table 4

Weekly rainfall amount at different probability level in Gaya

SMW	Weekly rainfall (mm) for the probabilities of					
	90 %	75 %	50 %	25 %	10 %	Mean(mm)
23	0.5	2.8	11.7	32.6	65.1	23.4
24	1.1	5.0	17.5	43.9	83.0	31.2
25	2.2	7.5	21.1	46.8	82.5	32.9
26	6.0	17.9	46.1	96.2	163.9	68.4
27	9.5	26.0	62.8	125.8	209.2	89.7
28	12.2	26.9	55.1	99.1	154.1	71.0
29	18.4	33.0	57.4	91.8	132.4	67.3
30	7.8	20.1	46.4	90.2	147.2	64.1
31	18.7	34.5	61.4	99.8	145.5	72.9
32	16.7	30.6	54.2	87.8	127.6	64.0
33	23.0	40.0	37.8	106.4	151.5	78.5
34	6.0	15.7	36.7	71.9	117.9	50.9
35	5.6	16.7	42.9	89.4	152.1	63.5
36	11.1	25.0	52.1	94.5	147.9	67.6
37	3.0	10.0	28.3	62.6	110.2	44.3
38	1.7	7.2	23.7	57.5	106.8	41.0
39	1.0	4.5	15.1	37.2	69.7	26.2
40	0.2	2.0	10.8	34.8	74.8	25.9
41	0.2	1.0	4.1	11.1	21.9	7.3
42	0.1	1.0	5.8	19.2	41.7	14.0
43	0.1	0.9	4.5	14.2	30.4	10.0
44	0.5	0.8	1.3	1.9	2.6	0.4

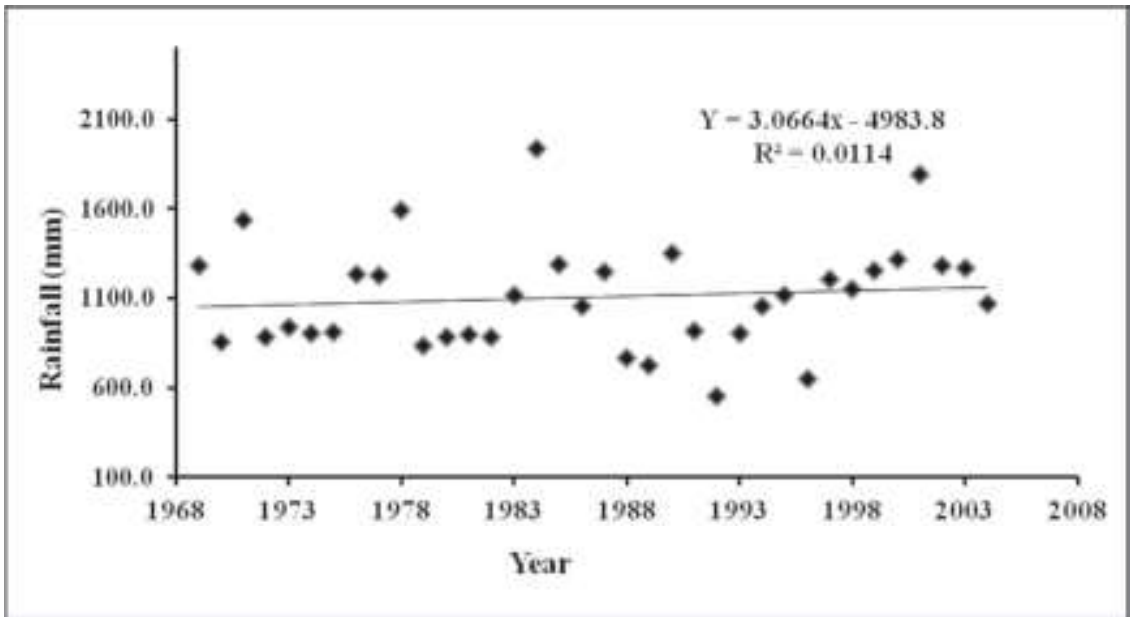

Fig. 1: Variability in annual rainfall in Gaya district

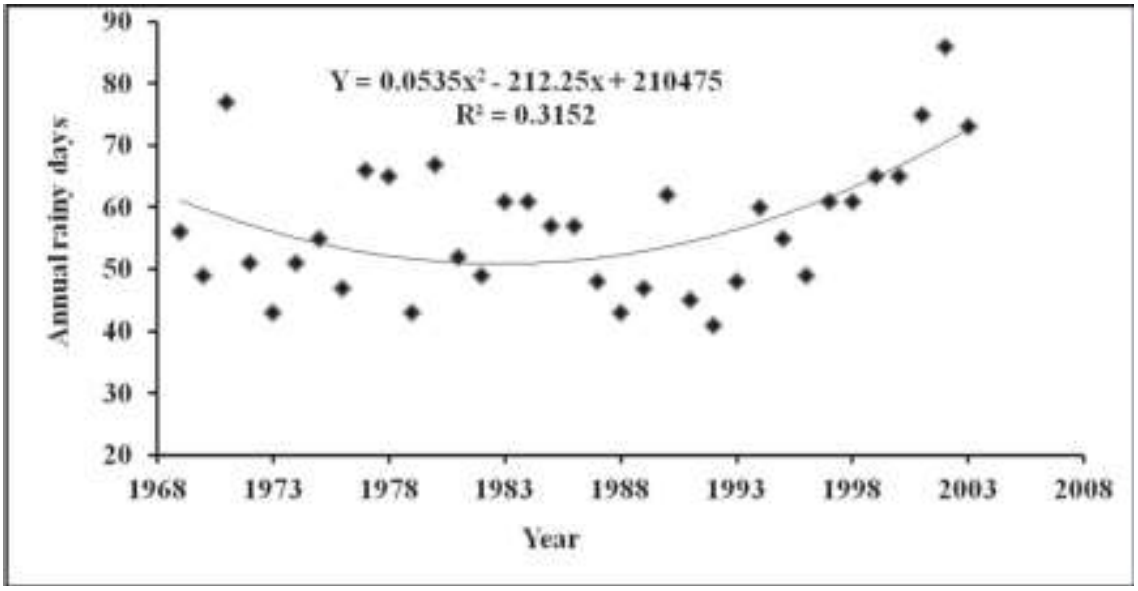

Fig.2: Trend in annual rainy days in Gaya district

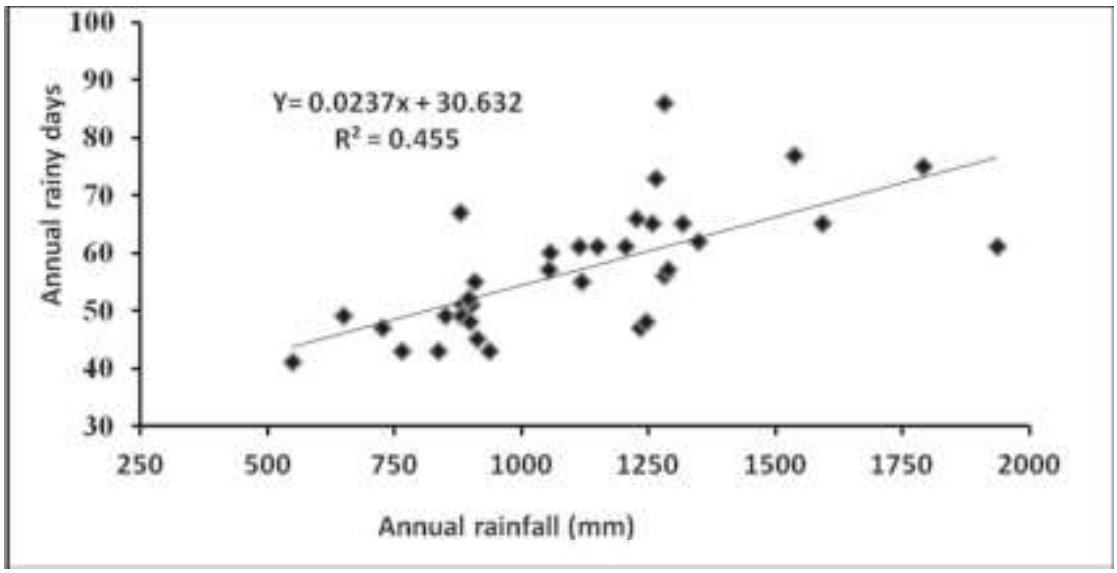

Fig. 3: Relationship between annual rainfall and rainy days in Gaya district

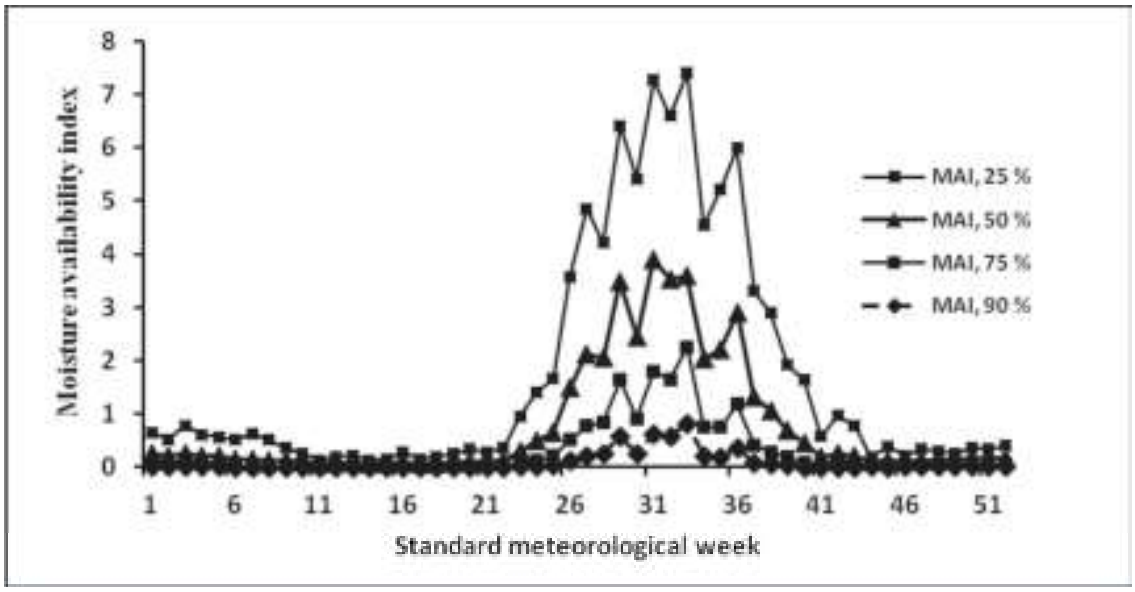

Fig. 4: Water availability period at different probability levels in Gaya district.

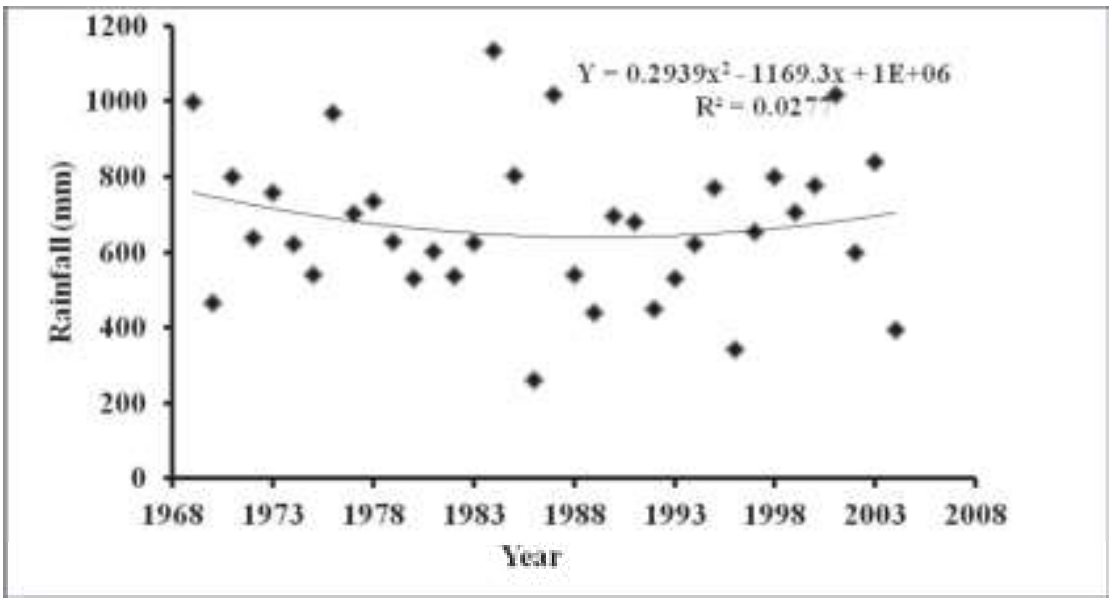

Fig. 5: Variability in rainfall during vegetative phase of rice crop in Gaya district

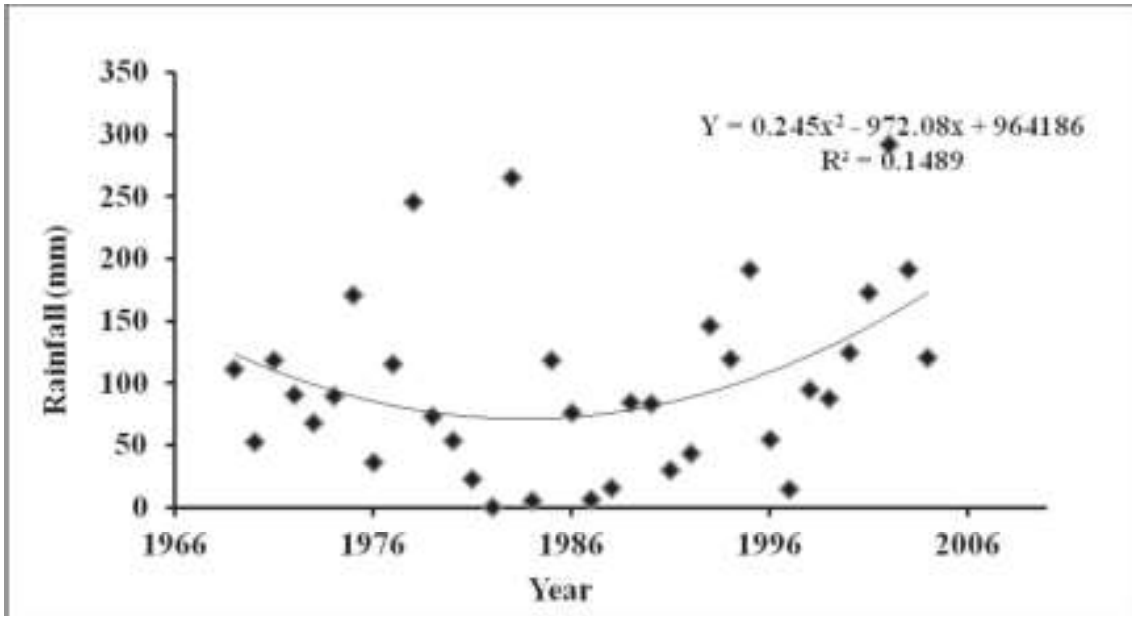

Fig. 6: Variability in rainfall during reproductive phase of rice crop in Gaya district

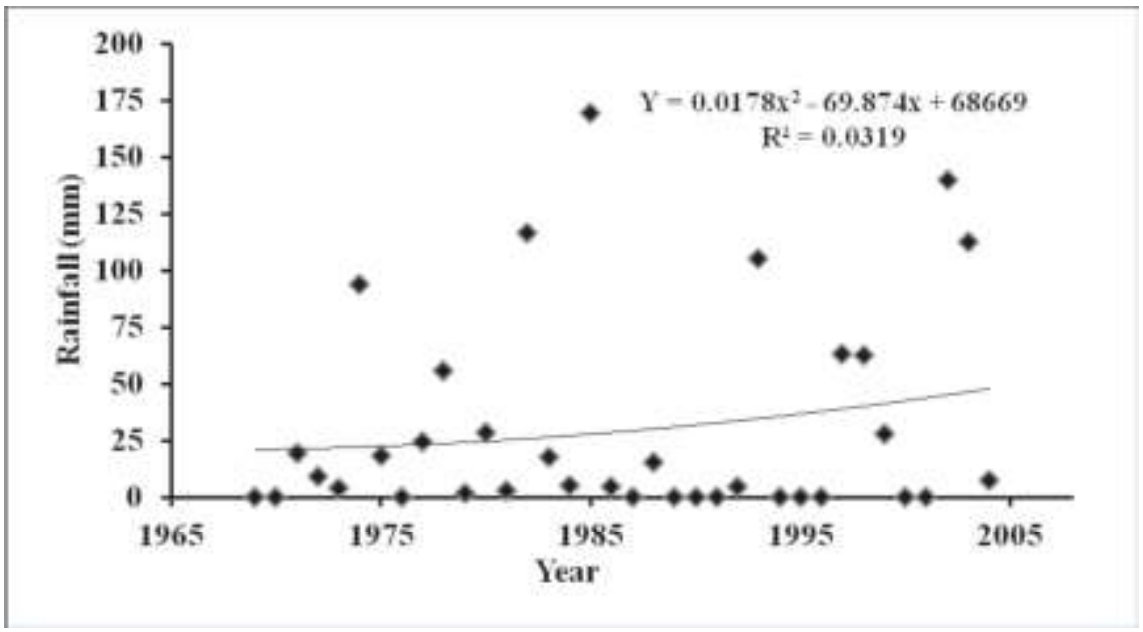

Fig. 7: Variability in rainfall during ripening phase of rice crop in Gaya district

Table 5. Initial and conditional probabilities of weekly rainfall at Gaya

SMW	Initial probability				Conditional probability							
	Rainfall 20 mm/week		Rainfall 30 mm/week		Rainfall 20 mm/week				Rainfall 30 mm/week			
	P(W)	P(D)	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
22	0.0149	0.8571	0.0857	0.9143	P(W/W)	P(D/W)	P(D/D)	P(W/D)	0.0000	1.0000	0.9091	0.0909
23	0.2571	0.7429	0.2286	0.7714	0.0000	1.0000	0.8333	0.1667	0.6667	0.3333	0.8125	0.1875
24	0.4571	0.5429	0.3714	0.6286	0.6000	0.4000	0.8000	0.2000	0.6250	0.3750	0.7037	0.2963
25	0.4000	0.6000	0.3429	0.6571	0.5556	0.4444	0.5769	0.4231	0.4615	0.5385	0.7273	0.2727
26	0.8000	0.2000	0.7143	0.2857	0.6250	0.3750	0.7895	0.2105	0.7500	0.2500	0.3043	0.6957
27	0.8286	0.1714	0.7714	0.2286	0.8571	0.1429	0.2381	0.7619	0.8400	0.1600	0.4000	0.6000
28	0.8000	0.2000	0.7143	0.2857	0.8929	0.1071	0.4286	0.5714	0.7037	0.2963	0.2500	0.7500
29	0.9143	0.0857	0.7714	0.2286	0.8276	0.1724	0.3333	0.6667	0.8000	0.2000	0.3000	0.7000
30	0.7429	0.2571	0.6857	0.3143	0.9643	0.0357	0.2857	0.7143	0.5926	0.4074	0.0000	1.0000
31	0.8571	0.1429	0.7429	0.2571	0.7188	0.2813	0.0000	1.0000	0.7917	0.2083	0.3636	0.6364
32	0.8000	0.2000	0.7714	0.2286	0.9231	0.0769	0.3333	0.6667	0.8462	0.1538	0.4444	0.5556
33	0.9143	0.0857	0.8000	0.2000	0.8333	0.1667	0.4000	0.6000	0.8148	0.1852	0.2500	0.7500
34	0.6857	0.3143	0.6286	0.3714	0.9643	0.0357	0.2857	0.7143	0.5714	0.4286	01429	0.8571
35	0.6857	0.3143	0.6286	0.3714	0.6563	0.3438	0.0000	1.0000	0.7273	0.2727	0.5385	0.4615
36	0.8286	0.1714	0.7143	0.2857	0.7500	0.2500	0.4545	0.5455	0.6364	0.3636	0.1538	0.8462
37	0.5714	0.4286	0.4571	0.5429	0.8333	0.1667	.01818	0.8182	0.4800	0.5200	0.6000	0.4000
38	0.5143	0.4857	0.4000	0.6000	0.5172	0.4828	0.1667	0.8333	0.5625	0.4375	0.7368	0.2632
39	0.4571	0.5429	0.2857	0.7143	0.6000	0.4000	0.6000	0.4000	0.3846	0.6154	0.7727	0.2273
40	0.3429	0.6571	0.2857	0.7143	0.5000	0.5000	0.5882	0.4116	0.3846	0.6154	0.7727	0.2273
41	0.1143	0.8857	0.0571	0.9429	0.4375	0.5625	0.7368	0.2632	0.0000	1.0000	0.9200	0.0800
42	0.2286	0.7714	0.1714	0.8286	0.0833	0.9167	0.8696	0.1304	0.5000	0.5000	0.9485	0.1515
43	0.1143	0.8857	0.1143	0.8857	0.5000	0.5000	0.8065	0.1935	0.1667	0.8333	0.8966	0.1034

SMW: standard meteorological week

Table 6. Weekly water requirement & irrigation demand of *Kharif rice* in Gaya

SMW	PET (mm)	K_c	WR+30 mm standing water	Expected rainfall (mm) at probability		Irrigation water (mm) to be applied at probability	
				50 %	75%	50 %	75%
28	28.3	1.10	61.1	55.1	26.9	6.0	34.2
29	25.4	1.10	57.9	57.4	33.0	0.5	24.9
30	25.1	1.10	57.6	46.4	20.1	11.2	37.5
31	28.6	1.10	61.5	61.4	34.5	0.1	27.0
32	28.7	1.10	61.6	54.2	30.6	7.4	32.0
33	24.5	1.10	57.0	37.8	40.0	19.2	17.0
34	26.7	1.10	59.4	36.7	15.7	22.7	43.7
35	28.1	1.05	59.5	42.9	16.7	16.6	42.8
36	26.8	1.05	58.1	52.1	25.0	6.0	33.1
37	25.0	1.05	56.3	28.3	10.0	28.0	46.3
38	24.5	1.05	55.7	23.7	7.2	32.0	48.5
39	24.1	1.05	55.3	15.1	4.5	40.2	50.8
40	25.2	1.05	56.5	10.8	2.0	45.7	54.5
41	25.6	1.05	56.9	4.1	1.0	52.8	55.9
42	24.9	1.05	56.1	5.8	1.0	50.3	55.1
43	24.1	1.05	55.3	4.5	0.9	50.8	54.4
44	22.0	1.05	53.1	1.3	0.8	51.8	52.3

REFERENCES

1. Gupta, A., Khan, S.A. and Saha, A.2010. Characterization of agricultural climate for crop planning under rainfed condition in laterite region of West Bengal. In: "*Agrometeorological Services for Farmers*".(Ed.Vyas Pandey). Pp. 90-97. (Anand Agricultural University, Anand).

2. Ramana Rao, B.V., Biradar, B.R., Supur,S.S. and Rao, M.G. 1979. A climatological study on water availability to crops in different types of soils in Gulbara region. *J. Indian Soc. Soil Sci.* 27: 441-446.

3. Robertson, G. W. 1976. Dry and wet spells. (ed.). 1. Project Field Report, Agrometeorology,A-6. United Nations Development Programme. *Food and Agriculture Organisation.*Rome. Italy. 16 pp.

4. Sarkar, R.P. and Biswas, B.C.1980. Agroclimatc classification for assessment of crop potential and its application to dry farming tracts of . In: Climatic classification: A consultants' Meeting". (Eds. S.M. Virmani and M.V.K. Sivakumar) pp.89-119. (ICRISAT Centre, Patancheru, A.P. 502324, India).

5. Sarkar, R.P. and Biswas, B.C.1986. Agroclimatic classification for assessing crop potential and its application to dry farming tracts of India. *Mausam*, 37 (1): 27-38.

6. Thorthwaite, C.W. and Mather, J.R.1955. The water balance. Publication in Climatology, *Drexel Inst. Tech., Centerton.*, N.J. 8:1-104.