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Characteristics of rainfall pattern for crop planning at Jabalpur region (Madhya Pradesh) of India

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सार – इस शोध–पत्र में साप्ताहिक, मासिक, मौसमी और वार्षिक वर्षा का दीर्घ अवधि औसत तथा इनकी परिवर्तिताओं का पता लगानें के लिए भौतिकी विभाग और कृषि अभियांत्रिकी जबलपुर (मध्य प्रदेश) की कृषि मौसम विज्ञान वेधशाला के पिछले 31 वर्षों (1978–2008) के दैनिक वर्षा आँकड़ों का विशलेषण किया गया है। साप्ताहिक वर्षा की संभावना के आकलन के लिए प्रति सप्ताह 10 और 30 मि.मी. से कम वर्षा होने पर मार्कोव चेन प्रोबेब्लीटी मॉडल का उपयोग किया गया है। इसमें वार्षिक वर्षा का औसत 1309 मि.मी. पाया गया है और इसकी संभाव्यताएँ 27.1 प्रतिशत देखी गई है। वार्षिक और खरीफ ऋतु की अधिकतम वर्षा वर्ष 1994 में क्रमशः 2083 मि.मी. तथा 2052 मि.मी. अभिलेखित की गई है। इसके ठीक विपरीत वार्षिक एवं खरीफ ऋतु की न्यूनतम वर्षा वर्ष 1979 में क्रमशः 620 मि. मी. और 471 मि.मी. अभिलेखित की गई है। इस अध्ययन से पता चला है कि विगत 31 वर्षों में हाल ही के दशक में हुई वर्षा में वृद्धि हुई है। खरीफ, मानसूनोत्तर, शीत और ग्रीष्म ऋतुओं में औसत वर्षा क्रमशः1197.3 मि. मी., 32.1 मि.मी., 49.8 मि.मी. एवं 29.8 मि.मी हुई है। कुल वार्षिक वर्षा का 91.5 प्रतिशत खरीफ ऋतु में, 2.5 प्रतिशत वर्षा मानसूनोत्तर में, 3.8 प्रतिशत वर्षा शीत मानसून में और 2.3 प्रतिशत वर्षा ग्रीष्म ऋतु में हुई है। इस अध्ययन की अवधि के दौरान कुल वर्षों के, 16 प्रतिशत में अत्यधिक वर्षा, 23 प्रतिशत में कम वर्षा और 61 प्रतिशत में सामान्य वर्षा अभिलेखित की गई है। जबलपुर के क्षेत्र में जुलाई का महीना धान के पौधे लगाने के लिए उपयुक्त महीना माना जाता है। अधिकतम वर्षा (33 प्रतिशत) अगस्त के महीने में प्रेक्षित की गई है। 25वें से 37वें मानक सप्ताहों में 30 मि.मी. से अधिक वर्षा हुई जो धान की फसल उगानें की अवधि जून के द्वितीय सप्ताह से सितंबर के अंतिम सप्ताह तक को दर्शाता है।

ABSTRACT. The daily rainfall data of past 31 years (1978-2008) of Agro meteorological Observatory, Department of Physics & Agriculture Engineering, Jabalpur (Madhya Pradesh) has been analyzed for establishing the long term average of weekly, monthly, seasonal and annual rainfall and its variability. The weekly probability of rainfall was estimated using Markov Chain probability model for receiving ≥ 10 and 30 mm rainfall per week. The mean annual rainfall observed as 1309 mm and its variability was 27.1 per cent. The highest annual and kharif season rainfall 2083 and 2052 mm respectively were recorded in 1994. On the other hand the lowest annual and kharif rainfall were 620 mm and 471 mm respectively in 1979. The study revealed that the recent decade rainfall has increased during last 31 years. The seasonal average kharif, post monsoon, winter and summer seasons recorded 1197.3 mm, 32.1 mm, 49.8 mm and 29.8 mm of rainfall. About 91.5 per cent of total annual rainfall was received in kharif, 2.5 per cent in post monsoon, 3.8 per cent in winter monsoon and 2.3 per cent in summer. During the period under study 16 per cent of the years recorded excess, 23 per cent deficit and 61 per cent normal rainfall. The July month is regarded as suitable for transplanting of rice crop in Jabalpur region. The highest contribution has been observed in August (33 per cent). Standard week from 25 to 37 received rainfall more than 30 mm indicating the crop growing period from June 2nd week to September last week.

Key words – Rainfall pattern, Initial and conditional probability, Markov chain models and crop planning.

1. Introduction

The rainfall is the single most important factor in crop production programme particularly under dryland areas. The annual, seasonal and monthly rainfall of the region is useful to design water harvesting structure. Similarly, weekly rainfall analysis gives more useful information for the crop planning (Singh, *et al*., 2007 and 2008). The weekly rainfall data can be used for determining (*i*) date of start (*ii*) date of cessation (*iii*) length of the rainy season (Singh *et al*., 2008). The agricultural strategy to increase production on a sustained

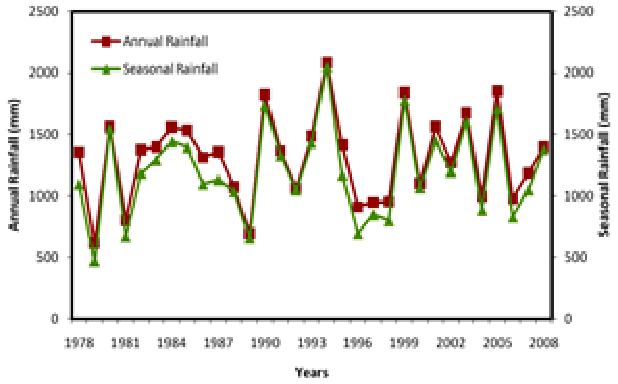


Fig. 1. Annual and seasonal rainfall at Jabalpur from 1978-2008

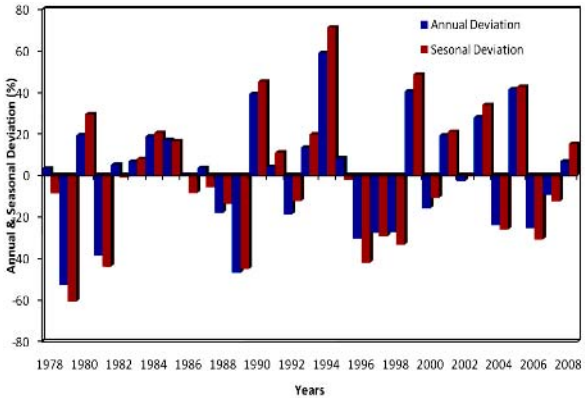


Fig. 2. Percentage departure of annual and seasonal rainfall at Jabalpur from 1978-2008

basis should make use of scientific information already generated by the agro meteorological fraternity. Food production from dryland agriculture is always uncertain, due to large temporal and spatial variation in rainfall. Crop productivity has increased in past four decades. According to Vairavan *et al*., (2002) the climatological data of a location becomes very important to provide necessary information for minimizing risk. Considering these problems under dryland situation and to identify the highest rainfall probability weeks for timely seeding of dryland crops, the rainfall data was analyzed as suggested by Jadhav *et al*., (1999). Verma and Sharma (1989) suggested the criteria for the wet spell in which average evaporation and meteorological rainy days were considered. The Markov-Chain model has been used to study the probabilities of rainfall occurrence (Victor, 2000, Gouranga, 2002, Jat *et al*., 2003, Singh *et al*., 2007, 2008 and Singh, *et al*., 2008).

2. Data and methodology

The daily rainfall data of 31 years (1978-2008) of Agro meteorological Observatory, Department of Physics & Agriculture Engineering, Jabalpur, Madhya Pradesh located at 23.16° N latitude, 79.93° E longitude and 408 meters above mean sea level, were used for analysis. The data were aggregated to weekly, monthly, seasonal and annual rainfall distribution. The mean rainfall, standard deviation and coefficient of variation for annual, seasonal and weekly periods were worked out as described by Deka and Nath (2000), Gouranga (2002), Parasuraman (2003), Singh *et al*., (2007 & 2008).

The annual and seasonal rainfall were classified based on IMD (India Meteorological Department) classification as normal (particular year/season that received +19 to –19 per cent of normal rainfall), excess (year/season that received more than 19 percent of mean annual rainfall) and deficit (year/season that received less than -19 per cent of the mean annual rainfall).

Rainfall probability analysis was based on first order Markov Chain as suggested by Virmani *et al*., (1980 & 1982); Victor, (2000); Gabriel and Neuman (1962); Singh and Bhandari (1998); Patil and Kale (1988) and Singh (2005). The initial probability of wet week P(W) and conditional probability of a wet week followed by wet week, P(W/W) were computed using Markov-Chain model for receiving 10 and 30 mm rainfall.

P(W) - Probability of wet weeks

P(W/W) - Probability of preceding wet week / wet week

P(D) - Probability of dry weeks

P(D/D) - Probability of preceding dry week / dry week

3. Results and discussion

The analysis of 31 years daily rainfall data of Jabalpur showed that the mean annual rainfall of the region was 1309 mm with coefficient of variation (CV) and standard deviation (SD) of 26.7 per cent and 349.6 mm respectively. The variation of annual and kharif season rainfall showed and deviation of annual and seasonal rainfall are shown in Figs. 1 and 2 respectively. During the study period of 31 years; there were about 16 per cent (5 years) excess, 61 percent (19 years) normal and 23 per cent (7 years) drought years (Fig. 3). The annual rainfall was the lowest (620 mm) in 1979 and highest (2083 mm) in the year 1994.

As shown in the Fig. 1 the highest and the lowest seasonal rainfall of 2052 mm and 471 mm were received in 1994 and 1979 respectively. The standard deviation and coefficient of variation from mean kharif rainfall was 366.7 mm and 30.6 per cent respectively. The maximum rainfall was recorded (2052 mm) in the southwest

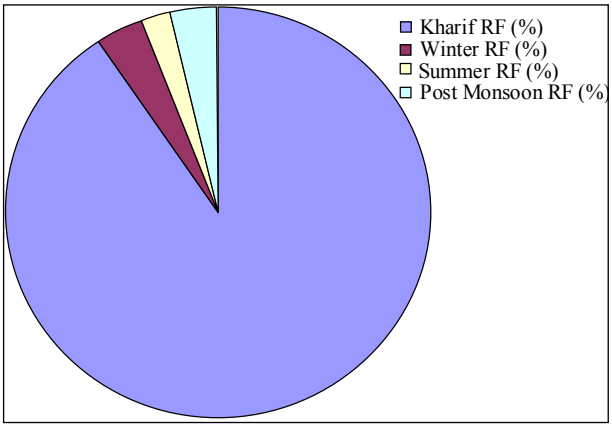


Fig. 3. Percentage of seasonal rainfall at Jabalpur from 1978-2008

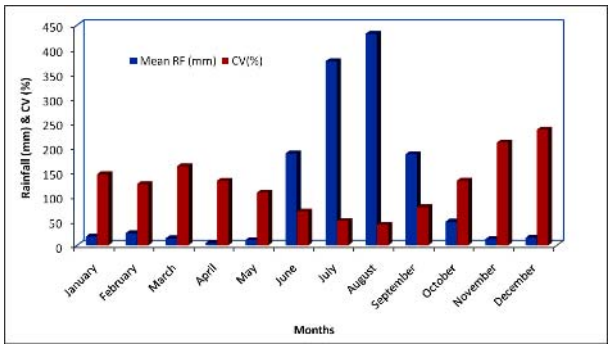


Fig. 4. Monthly rainfall and coefficient of variation at Jabalpur from 1978-2008

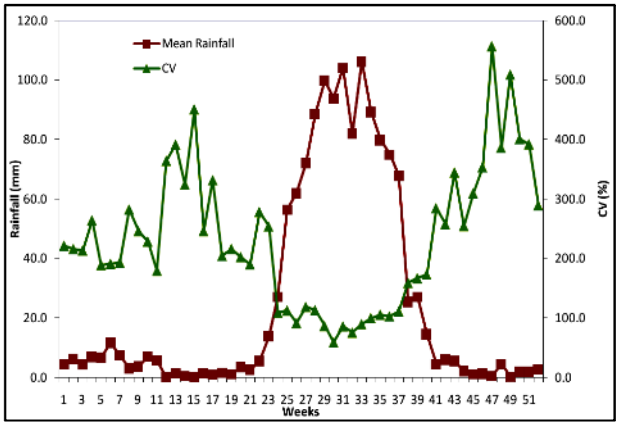
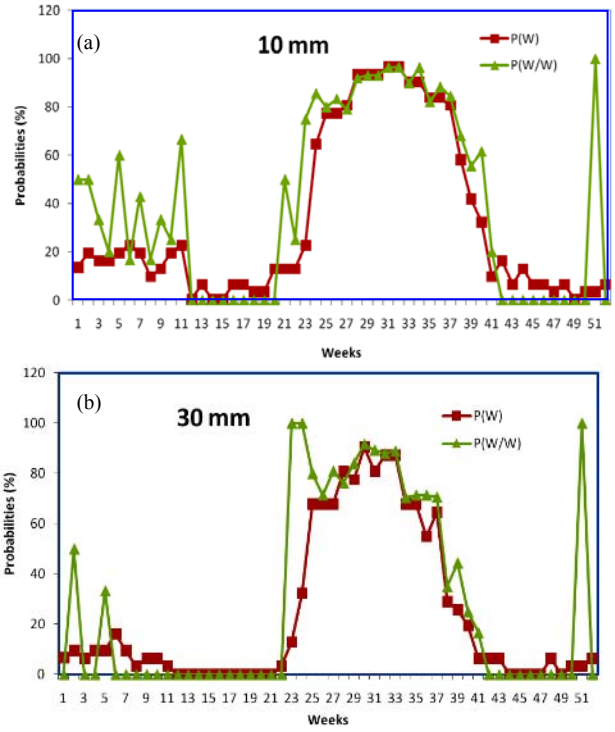


Fig. 5. Relation between weekly rainfall and coefficient of variation at Jabalpur from 1978-2008

monsoon (June to September) but it was minimum (29.8 mm) during the summer season (March to May). The mean rainfall of 1197 mm was received in kharif season contributing 91.5 per cent to total annual rainfall. In 31 years, 91.5 per cent of total annual rainfall was received in kharif, 2.5 per cent in post monsoon, 3.8 percent in winter monsoon and 2.3 per cent in summer season (Fig. 3).



Figs. 6(a&b). Initial P (W) and Conditional P (W/W) probability at different limits of rainfall at Jabalpur from 1978-2008

TABLE 1

Characteristics of rainy season at Jabalpur region from 1978-2008

Parameters	Start of rainy season (week)	Ending of rainy season (week)	Length of rainy season (duration ; weeks)
Mean	25	43	17
Early	22	36	10
Late	29	52	27
SD	1.6	4.6	4.4
CV (%)	6.2	10.9	25.7

The mean monthly rainfall and coefficient of variation are shown in Fig. 4. The data on monthly rainfall revealed that the highest (431.2 mm) rainfall was recorded in the month of August was followed by the July (327 mm). The highest monthly contribution was observed in August (33 per cent). April was observed to be the least rainfall month contributing only 0.4 per cent. The period from June to September was the most dependable month (coefficient of variation ranges 42.4 to 77.7 per cent (Fig. 4).

The mean weekly rainfall distribution and CV at Jabalpur are presented in Fig. 5. At least two distinct sets of weeks are evident, *i.e.*, from 1 to 23rd week when weekly rainfall is below 30 mm. The total rainfall during

TABLE 2 (a)

Contingency crop planning for early monsoon (Normal crop /crop planning system - Rice-wheat and Soybean-Gram) at Jabalpur region

Suggested Contingency measures	
Change in crop / cropping system including variety	Agronomic measures
Rice - *Upland field* : IR-36, JR-201, JR-503, Vandna, Porrnima, Ananda, Narendra 97, Govinda and hybrid rice JRH 4, 5 and 8 *Lowland field* : WGL-32100, MR-219, Mhamaya, IR-36, IR-64, HMT, Swarna, Madhuri, Pusa basmati, Karnal basmati, Pusa sugandha 3, 4 and 5 and Hybrid rice (PRH-10, PA6201, PHB71, Pro Agro 6444) Maize - Jawahar Maize-12, Jawahar Maize-8, Jawahar Maize-216, Jawahar Maize-13, JVM-421 Soybean - JS-335, JS 80-21, JS 97-42, JS 94-60 and JS 9305	• Use of blade harrow (Bakhar) for moisture conservation and weeding. For higher production sowing of soybean, arhar, moong and urd on bunds is recommended. • Selection of higher production potential late maturing varieties. • Seed treatment with mixture of Thiram (1.5g)+ Carbendazim (1.5g)/kg seed followed by biofertilizer. • Use of balanced fertilizer and biofertilizer according to recommendation to crop and application of zinc in deficient soil. • Sowing of crops against the slope. • Timely weeding and plant protection as per requirement. • Under traditional system of planting of 3-4 seedlings of 18-21 day ages in 20 × 10 cm at one place for late mature rice. For early mature varieties plating in 15 × 15 cm geometry but seedlings are not more than 18-21 day old.

TABLE 2 (b)

Contingency crop planning for normal monsoon (Normal crop /crop planning system –Rice-wheat and Soybean-Gram) at Jabalpur region

Suggested Contingency measures	
Change in crop / cropping system including variety	Agronomic measures
Rice - *Upland field* : IR-36, JR-201, JR-503, Vandna, Porrnima, Ananda, Narendra 97, Govinda and hybrid rice JRH 4, 5 and 8 *Lowland field* : WGL-32100, MR-219, Mhamaya, IR-36, IR-64, HMT, Swarna, Madhuri, Pusa basmati, Karnal basmati, Pusa sugandha 3, 4 and 5 and Hybrid rice (PRH-10, PA6201, PHB71, Pro Agro 6444) Maize - Jawahar Maize-12, Jawahar Maize-8, Jawahar Maize-216, Jawahar Maize- 13 and JVM-421. Arhar - Asha, No-148, JKM-7, JA-4, ICPL-85063 (Laxmi), JKM-189. Moong - Pusa vishal, K851, JM721, Jawahar 99 -37, Hum-1, Hum-2, Tarme-1, L.G.450, T.M.98-50, JM-98-90, PDM 11, 54 and 139 Urd - JU-2, JU-3, JU-86, T-9, JBG-623, LBG684, TAU-1, Berkha, PU-30, 35, 19 Soybean - JS-335, JS 80-21, JS 97-42, JS 94-60, JS 9305	• Use of blade harrow (Bakhar) for moisture conservation and weeding. Selection of higher production potential varieties. • Seed treatment with mixture of Thiram (1.5g) + Carbendazim (1.5g) /kg seed followed by biofertilizer. • Use of balanced fertilizer and biofertilizer according to recommendation to crop and application of zinc in deficient soil. • Sowing of crops against the slope. • Timely weeding and use of weeds as mulch between row of crops for moisture conservation. • Adoption of plant protection as per requirement. • Under traditional system of planting of 3-4 seedlings of 18-21 day ages in 20 × 10 cm at one place for late mature rice. For early mature varieties plating in 15 × 15 cm geometry but seedlings are not more than 18-21 day old.

TABLE 2(c)

Contingency crop planning for late monsoon /delay monsoon (Normal crop /crop planning system – Rice-wheat and Soybean-Gram) at Jabalpur region

Suggested Contingency measures	
Change in crop/cropping system	Agronomic measures
Rice – *Upland field* : Don't sown the rice crop and sowing of alternate crops, Arhar, Urd, Moong, Til, Ramtil, Castor, Kodo, Kutki	• Use of blade harrow (Bakhar) for moisture conservation and weeding
Lowland field : Sowing of JR-201, JR-503, Poornima, Vandna, Narendra-97, Govinda by Lehi system	• For higher production adaptation of recommended package of practice
Arhar - Pragati, Jagriti, Asha, Nmuber-148, JKM-7, JA-4, Type-21-Pusa-855, ICPL-85063 (Laxmi), JKM-189	• 100 kg seed /ha required for lehi system in rice.
Moong - Pusa vishal, K851, JM721, Jawahar 99 -37, Hum-1, Hum-2,Tarme-1, L.G.450, T.M.98-50, JM-98-90, PDM 11, 54 and 139	• Don't sow soybean and maize
Urd – JU-2, JU-3, JU-86, T-9, JBG-623, LBG684, TAU-1, Berkha, PU-30, 35, 19	• Intercropping of moong, urd, til and niger with arhar

this period was 120.5 mm. In other set (24 to 40 weeks), there was quantum jump in rainfall from 24th week (≥ 30 mm upto 40 week).

A stable weekly rainfall period was essential for sustainable agricultural practices of different durations. As rice is predominantly grown at Jabalpur and water requirement of rice is about 50 mm per week. Hence, the week that has rainfall greater than 50 mm and corresponding coefficient of variation less than 100, has been considered as a stable rainfall period. In the present study stable rainfall period of 9 weeks which spread over 26th to 34th week has been found suitable for rice. The coefficient of variation of weekly rainfall during this period varied from 58.7 to 118.5 per cent (Fig. 5).

4. Onset and end of rainy season

The onset, end of rainy season and length of growing season is presented in Table 1. The earliest start of the rainy season has occurred at 22nd week and latest by 29th week, the normal start of the rainy season is found to be 25th week and coefficient of variation 6.2 per cent. The earliest end of rainy season had occurred by 36th week and latest by 52nd week. The normal end of the rainy season was 43rd week and coefficient of variation of 10.9 per cent. The length of duration ranges from 10 to 26 weeks with a mean of 17 weeks and coefficient of variation of 25.7 per cent.

5. Initial and conditional probability

Initial, P (W) and conditional, P (W/W) probabilities of getting 10 and 30 mm of rainfall in a week are shown in Figs. 6 (a&b). Probability of getting 10 mm rainfall per week is more than 75 per cent at 25th week and continues to be so up to 37th week. An amount of 10 mm rainfall per week can be taken as the minimum requirement for land preparation and sowing rainfed summer crops. On the other hand initial probability of 30 mm rainfall per week exceeds 75 per cent from 28th to 33rd week. However, conditional probability of wet week followed by wet week of 30 mm rainfall exceeds 75 per cent from 23rd to 33rd week and 30 mm rainfall at 75 per cent level can be utilized for sowing of crops. If the land is not properly prepared in advance of the receipt of rains, the early monsoon rainfall is likely to produce runoff even before the soil profile is filled.

6. Crop planning

Based on the above analysis the following recommendation for the region could be made to increase the crop production per unit area under rainfed conditions. About 91.3 per cent of the total annual rainfall coincides with kharif season and received during June to September in southwest monsoon season. Rainfall received during April-May months can be utilized for summer ploughing to make the land ready for the final field preparations. The earliest start of rainy season had occurred at 22nd week and delay in start of monsoon was as late as 29th week [Table 2(a)]. The normal start of rainy season was observed at 25th week in this region with coefficient of variation of 6.2 per cent. With the normal onset of monsoon, sowing of kharif crop like rice (JR200, JR503, IR 36 and hybrid rice JRH8 and JRH5), soybean (JS80-21, JS97-52, JS335, JS94-60, JS93-05, NRC-12, Indira soy-9, JS-9305) and sorghum (CSH-18 and JJ1102)

should be started from second fortnight of June [Table 2(b)]. In case of delayed start, short duration maize crop and low water requiring crops like green gram and black gram, vegetables like finger millet, fox tail millet, bottle guard, tomato etc can be raised during the summer season [Table 2(c)]. Normal rainfall condition can be utilized for raising rice seedling of short duration or direct sown rice. After two or three weeks of onset, the transplanting of kharif rice in first week of July will have additional advantages of almost assured water supply through rain during August and September. Most of the rainfall observed during 30th to 35th week when the crop is in vegetative and flowering stages. If crop is sown earlier than 25th week then crop may escape the period of low rainfall during grain development stages and yield may increases. Since the winter rainfall is uncertain and erratic residual moisture in lowland area can be utilized for growing a second crop under rainfed conditions. However, wheat (JW-1142, JW-3042 and GW-273), chickpea (JG-6 and JG-322) and lentil (JLS-3) can be grown only with assured irrigation during rabi season. In case, the timely sowing of rabi crops could not be done due to inadequate soil moisture, wheat variety MP-4010 and chickpea variety JG-14 could be sown with the receipt of late winter showers for taking remunerative crop yields.

7. Conclusions

Markov Chain probabilities (≥10 and 30 mm rainfall per week) were worked out. The annual, kharif, post monsoon and pre-monsoon rainfall was observed 1309 mm, 1197 mm, 46.8 mm, 49.8 mm and 29.8 mm respectively. About 91.5 per cent of total annual rainfall was received in kharif for the study period under consideration. The July month is regarded as suitable for transplanting of rice crop at Jabalpur region. The earliest start of the rainy season is observed at 22nd week and latest by the 29th week. The normal start of the rainy season is found to be 25th week and coefficient of variability 6.2 per cent. Each standard week from 25th to 37th received rainfall more than 30 mm indicating the crop growing period from June to September. Probability of getting threshold rainfall amount of 30 mm is from 35th week which indicates the chance of dry spell. The study may help in establishing sustainable crop production and adaptation of suitable moisture conservation technique including water harvesting structures in the region.

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