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Prospect of double cropping of rainfed rice in West Bengal

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सार — वर्षा के आँकड़ों के विश्लेषण के द्वारा धान की फसल के समय का पता लगाते हुए कृषि-परिस्थितिकी की (तट के खारे क्षेत्र की कैनिंग तथा लाल लेटराइट मिट्टी के क्षेत्र की नागरी) दो स्थितियों में पश्चिम बंगाल में वर्षा के पानी पर आधारित दोहरी धान की फसलें उगाने की सम्भावनाओं का पता लगाया गया है। शुष्क प्रभावसीमा 20 मि.मी. प्रति सप्ताह मानकर वर्षा वाले और बिना वर्षा वाले सप्ताहों का पता लगाने के लिए इन स्थानों की वर्षा के आँकड़ों का विश्लेषण किया गया है। वर्षा वाले तथा बिना वर्षा वाले सप्ताहों की मार्कोव चेन प्रायिकता विश्लेषण से जांच की गई है तथा धान की फसल रोपण की अभीष्ट अवधि का पता लगाया गया है। वर्ष के पहले सप्ताह से (1 - 7 जनवरी) लेकर आगे के समय के तथा पिछले वर्ष के बावनवें सप्ताह (24 - 31 दिसम्बर) के पहले के भी वर्षा के आँकड़े एकत्र किए गए हैं तथा क्रम विन्यास पद्धति से जांच के उपरांत कम पानी की आवश्यकता वाली फसल तथा अधिक पानी की आवश्यकता वाली फसल की वृद्धि की अवधियों का पता लगाया गया है। ये अध्ययन दर्शाते हैं कि प्रायः दोनों स्थानों पर 24 वें से 37 वें सप्ताह (11 जून से 16 सितम्बर) में नम सप्ताहों की संभावना 75 प्रतिशत तक बढ़ जाती है तथा दो क्रमागत शुष्क सप्ताहों की संभावना 20 वें सप्ताह से लेकर 38 वें सप्ताह में (14 मई - 23 सितम्बर) नगण्य हो जाती है। यह भी पाया गया है कि पूर्व मानसून ऋतु से पहले तथा मानसून ऋतु के दौरान तैयार होने वाली कम अवधि की धान की दो फसलों की कटाई व्यवहार्य है।

ABSTRACT. The prospect of double cropping of rainfed rice in West Bengal has been studied in two agroecological conditions (Canning, located in coastal saline region and Nagri, located in Red lateritic region) by identifying growing season through the analysis of rainfall data. The rainfall data of these locations have been analysed for dry and wet weeks by assuming a dry threshold value of 20 mm per week. Wet and dry weeks have been subjected to Markov Chain probability analysis and periods of ideal sowing have been determined. Rainfall data has also been accumulated from 1st week (1-7 Jan) onwards, and 52nd week (24- 31 Dec) backwards and by subjecting it to ranking method, growth periods of dry and wet crops have been determined. The study reveals that generally from 24th to 37th week (11 Jun - 16 Sept) the probability of getting wet weeks exceeds 75% and probability of two consecutive dry weeks is negligible from 20th to 38th week (14 May - 23 Sept) for both the stations. It is also found that harvesting two rice crops of shorter duration is feasible during the growing period covering pre-monsoon and monsoon season.

Key Words - Germination, Probability, Transplanting, Phenological.

1. Introduction

In tropical rainfed rice farming, a good crop yield depends on the appropriate sowing time. The occurrence of early rains often gives a wrong signal for sowing/planting as it may be followed by dry spells which may dry out the top soil and prevent the germination of plants. On the other hand, late sowing/planting, if not abnormal, reduces the risk of crop failures. Thus farmer's cropping strategies are undoubtedly influenced by the variability they have experienced in the onset and end of the rainy season (Morris and Zandstra 1978).

In West Bengal, kharif paddy is sown in nurseries sometimes in second half of June and transplanted to the field in mid July. Crops are harvested during the October or early November depending upon the varieties. Moisture becomes aptly available during the active vegetative growth phase in this cropping as moderate to heavy rainfall normally occurs during August and September. But prolonged and heavy rainfall sometime lead to drastic reduction of yield. In view of this rainfall variability, short and medium duration CSR - 4 and MUT - 1 varieties of paddy are generally grown at Canning and Nagri. The duration of these varieties (*i.e.* transplanting to harvest) varies from 75 to 130 days. The average rice yield is nearly 20 q/ha. · A suitable

model to predict the probability occurrence of dry and wet spell may make it possible to harvest two rice crops during this season, thereby causing substantial increase of the total yield per unit area and to raise the economic returns of the farmers.

Several workers have found Markov chain probability model suitable to describe the long term frequency behaviour of wet or dry weather spells (Hopkins and Robillard 1964, Robertson 1976, Maunder *et al.* 1971, Chowdhury 1981 etc). Gabriel and Neumann (1962) and Bhargava *et al.* (1977) fitted daily rainfall data to a Markov chain model which predicts the probability of occurrence of wet and dry spells. Walter (1967) defined the start of the growing season in terms of the time of receiving a certain amount of accumulated rainfall. Basu (1971) also fitted a Markov chain probability model to the daily rainfall data at Calcutta and found that the wet spell and weather cycle obey geometric distribution. Victor and Sastry (1979) fitted the Markov Chain model to daily rainfall data of the monsoon months in Delhi region. They have computed conditional probabilities and length of dry days with particular reference to development stages of bajra crop. Stern *et al.* (1981) defined it in terms of the time of occurrence of a specified amount of rain within two successive days. Stern and Coe (1982) suggested a method to determine planting dates based on Markov chain analysis of dry and wet days. On the other hand, Olaniron (1983) showed that the start of the growing season cannot be determined according to the time of receiving an accumulated amount of rainfall except in humid climates. According to Berger and Goossens (1983), wet and dry spells in Belgium are best described by Markov chain model of order four. Agnihotri *et al.* (1984) fitted the Markov chain model to the daily rainfall data of Chandigarh and calculated conditional probabilities for occurrence of wet day preceded by wet/dry day. Pandharinath (1991) applied Markov chain model to know the sequence of dry, wet periods over Andhra Pradesh during the monsoon months which is useful for proper agricultural planning.

The objective of this study is to determine the onset and termination of the growing period from different angles based on rainfall data. The present study provides information on probability of various amounts of rainfall during the growth period of paddy over West Bengal. It is possible from the results of the analysis to advise the farmers for scheduling the sowing/transplanting of paddy taking full advantage of the rainfall and to avoid unfavourable periods.

2. Data and methods

Weekly rainfall data on standard week basis for Canning (22° 15′ N, 88° 40′ E) from 1965 to 1991 and for Nagri Farm (26° 50′ N, 88° 23′ E) from 1963 to 1986 have been used. The rainfall figures were obtained from the agrometeorological observatory located near the experimental fields.

The Markov chain method was applied for analysis of dry and wet weeks. A wet week in this analysis is considered as that week receiving equal to or more than 20 mm rainfall; otherwise the week is considered as dry. Actual number of dry weeks $F(D)$ and wet weeks $F(W)$ occurring for any particular week are computed. This is done for all the 52 weeks. For any wet week, the number of cases when the preceding week was dry $F(WD)$ and when it was wet $F(WW)$ are then determined. In the same manner $F(DD)$ and $F(DW)$ were determined. If $P(D)$, $P(WD)$ etc. are the respective probabilities, these can be computed from the following equations :

$$P(W) = F(W)/[F(W) + F(D)] \quad (1)$$

$$P(D) = 1 - P(W) \quad (2)$$

$$P(DD) = F(DD)/[F(DD) + F(DW)] \quad (3)$$

$$P(DW) = 1 - P(DD) \quad (4)$$

$$P(WW) = F(WW)/[F(WW) + F(WD)] \quad (5)$$

$$P(WD) = 1 - P(WW) \quad (6)$$

It is also possible to calculate the probability of 2 or 3 consecutive dry (or wet) weeks from any week as follows:

For two and three consecutive dry weeks the equations respectively are,

$$P(D_2) = P(D) \times P(DD)_{\text{week}\,(n-1)} \quad (7)$$

$$P(D_3) = P(D)_{\text{week}\,n} \times P(DD)_{\text{week}(n+1)} \times P(DD)_{\text{week}(n+2)} \quad (8)$$

where $n = 2$ or $n = 3$ as the case may be in the above equations.

Probability of two or three consecutive wet weeks can be similarly computed.

2.1. *Backward and forward rainfall accumulation*

In the present analysis we have also applied weekly rainfall accumulations to determine start and end of rainy season (*cf.* Morris and Zandstra 1978).

Accordingly, when 50 mm of weekly rainfall has accumulated from 1st week, the soil is considered to have acquired enough moisture for dry seeding. Similarly for wet land preparation of field, a weekly accumulation of 140 mm rainfall is considered adequate. The termination of the rainy season is determined by backward accumulation of rainfall data from 52nd week. 350 mm and 210 mm accumulated values were considered as representing amounts needed to sustain field crops and determine termination of wet and dry

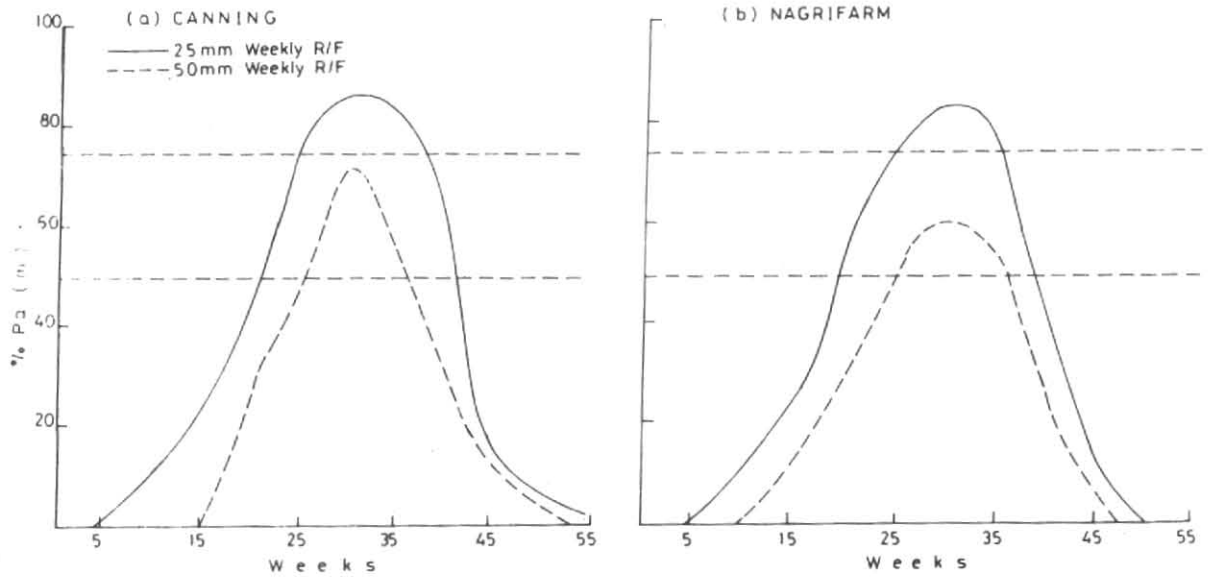

Fig.1. Probability of receiving 25 & 50 mm weekly rainfall

crops respectively assuming a fully charged soil profile at planting. This was done on the probability basis.

2.2. *Ranking order method*

The ranking order method suggested by Doorenbos and Pruitt (1977) has been used in the study.

The basic assumption in this method is that rainfall is more or less normally distributed. For each week the mean rainfall is arranged in decreasing order of magnitude. Each record is then assigned a rank m. The probability of each rank number m is then calculated as follows:

$$P_a\,(m) = 100m/(n+1) \qquad (9)$$

where, n is the number of records.

The ranking method enables to determine the rainfall that could be expected at any probability level without involving complicated statistics. This is achieved by substitution the desired probability value for $P_a\,(m)$ and then determining the rank m. Finally the rainfall corresponding to the rank can be determined. Using again the forward accumulation of 50 and 140 mm weekly rainfall and 210 and 350 mm backward accumulation, dates of onset and termination of crop seasons have also been determined from the method of ranking.

$P_a\,(m)$ values for each week were also suitably used to determine probability of rain of 25 mm and 50 mm per week.

3. Results and discussion

3.1. *Probabilistic estimation of growing season*

Mean monthly or weekly rainfall data give only trends of certain climatic patterns. They can be useful as a tool to indicate agroclimatic homogeneous zones, but they do not give any information on the temporal rainfall variability. In rainfed agriculture it is essential to know the probability of receiving necessary amount of rainfall at certain week for sowing operation. Making use of ranking method given in the previous section, probability of rainfall of 25 and 50 mm/week has been prepared and depicted in Figs. 1 (a & b). It may be seen that in 3 out of 4 years at Canning (Fig. 1a) between 24th week (11 - 17 Jun) to 37th week (10 - 16 Sep) one may expect at least 25 mm rainfall. Sowing operations at Canning could thus be initiated from 24th week (11 - 17Jun) onwards for wet crops. At Nagri Farm these operations can be slightly delayed by a week or so (Fig. 1 b) as 25 mm rainfall per week may be available from 25th week (18 - 24 Jun) to 35th week (27 Aug-2 Sep) at 75% level of probability.

Excessive rainfall of more than 50 mm per week at both locations can be expected in one out of 2 years from 25th (18 - 24 Jun) to 35th week (27 Aug - 2 Sep).

From above, it is evident if we assume start of growing season as the week when at least 25 mm is received, then 24th week (11 - 17 Jun) can generally be considered as the first week of the growing season for wet land rice.

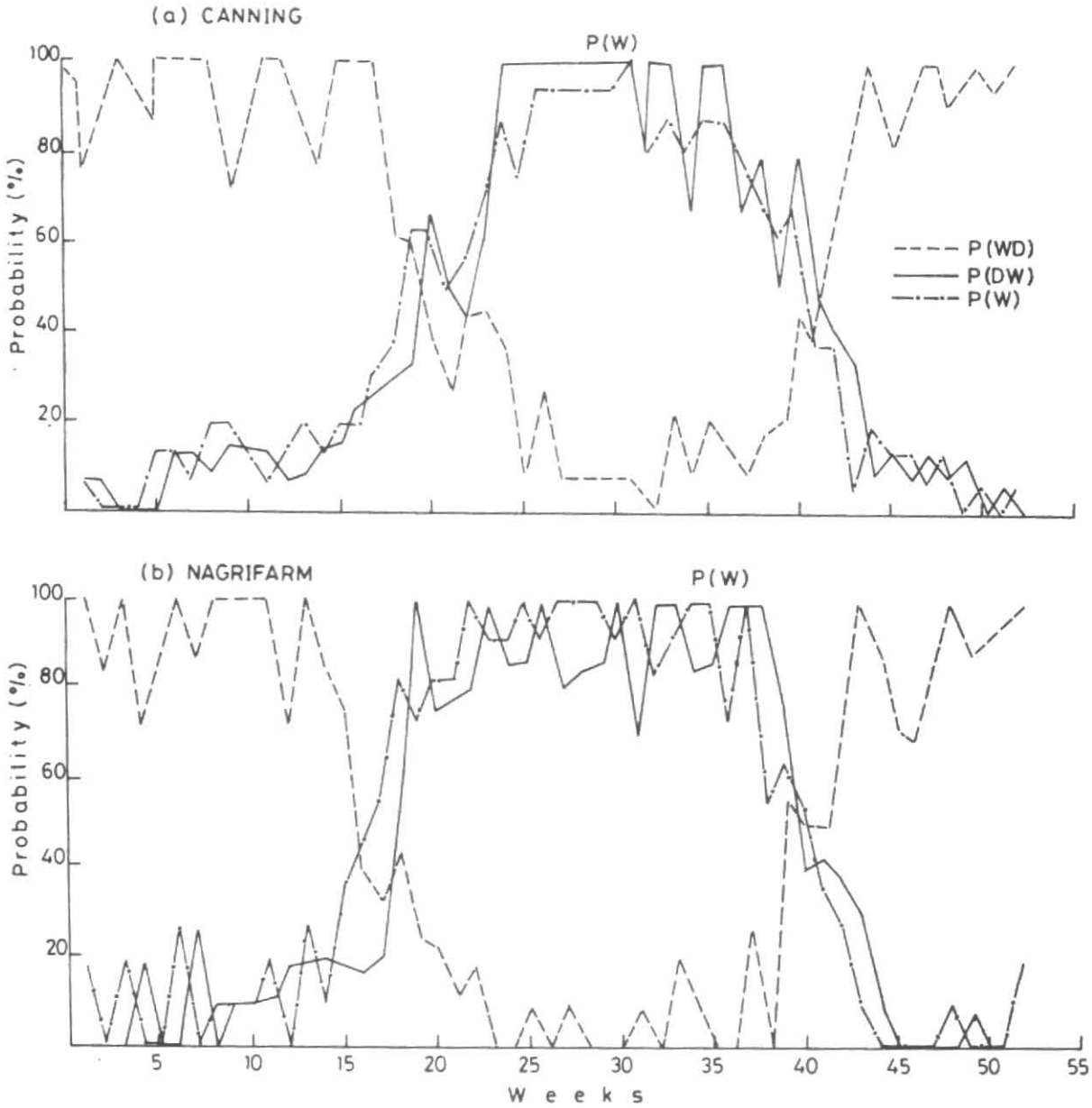

Fig.2. Probability of wet day, *P(W)*; wet day followed by dry day *P(DW)* and dry day followed by wet day *P(WD)*

3.2. *Probability of dry and wet spells*

In regions where rainfall is erratic or where short dry periods can be expected within the wet seasons, it is important to know, for example, what the probability is of having a consecutive dry period of two or three weeks during the growing season of a crop. If such a period coincides with a sensitive phenological stage this could damage the crop development. On the other hand, dry period at the ripening stage of the crop are sometimes beneficial.

At Canning high probability (more than 75%) of wet weeks occurs from 24th week (11-17 Jun) to 37th week (10-16 Sep). Wet weeks with more than 50% probability can be expected during 19th week (7-13 May) to 41st week (8-14 Oct).

For Nagri Farm, the probability of wet weeks exceeding 75% occurs from 20th week (14-20 May) to 37th week (10-16 Sep). At 50% probability level, this duration of wet weeks is from 16th week (16-22 Apr) to 40th week (1-7Oct).

Probability *P (WD)* of a dry week succeeded by wet week and *P(DW)*, *i.e.*, wet week followed by dry week is

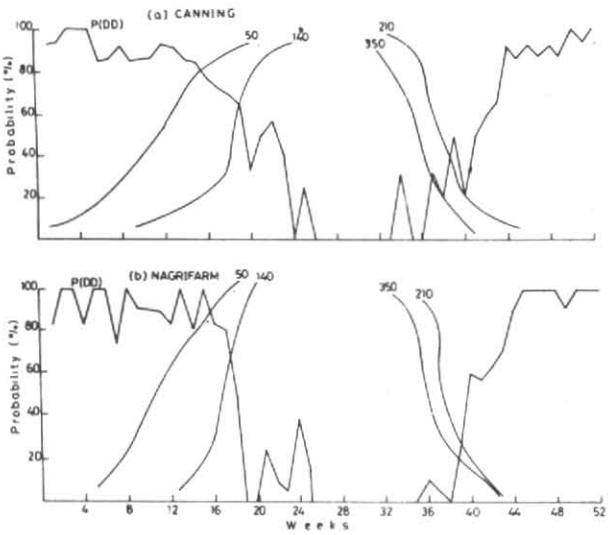

Fig.3. Cumulative probability of 50 & 140 mm rainfall from the start and 210 & 350 mm from the end alongwith the probability of two consecutive dry weeks

depicted in Figs. 2 (a & b). It is seen that between 19th (7-13 May) and 40th week (1-7 Oct) at Canning a dry week has 50% or less probability to be followed by a wet week. For Nagri Farm this period could be taken as 16th (16-22 Apr) to 39th week (24-30 Sep) at the 50% probability level. On the other hand, probability of a wet week followed by dry week, *i.e.*, *P(DW)* is quite large during the active monsoon period. It exceeds 50% from 20th (14-20 May) to 41st week (8-14 Oct) at Canning and 18th (30 Apr-6 May) to 39th week (24-30 Sep) at Nagri Farm.

At Canning there is generally zero or near zero probability of having two consecutive dry weeks from 24th (11-17 Jun) to 36th week (3-9 Sep); also the same situation is observed from 19th (7- 13 May) to 38th week (17-23 Sep) at Nagri Farm.

3.3. *Start and end of the growing season*

Farmers generally will plant or sow seed when a certain amount of rainfall has sufficiently moistened the top soil. Morris and Zandstra (1978) chose 75 mm accumulation of rainfall at the onset time for the growing season for dry seeded crops and 200 mm accumulated rainfall for initiation of puddling wet land preparation of rice fields. The termination of the wet season was determined by backward summation of rainfall data. Figs. 3 (a & b) gives forward and backward accumulations of dry and wet land soil preparation for both Canning and Nagri farms. These results suggest that at Canning one may expect accumulation of at least 50 mm at 14th week (2-8 Apr) in 3 out of 4 years (75% probability) and the accumulation of 140 mm at 20th week (14-20 May) at the same probability level. Similarly one may expect that in 3 out of 4 years at least 350 mm rainfall can be realised latest by 34th week (20-26 Aug) from the earliest date and that 210 mm can be expected till 37th week (10-16 Sep). In case of Nagari Farm, at 75% probability level, at least 50 mm and 140 mm gets accumulated by the 14th week (2-8 Apr) and 18th week (30 Apr-6 May) resspectively, while at least 350 mm and 240 mm rainfall at the same probability level can be expected from earliest dates till 35th (27 Aug-2 Sep) and 37th week (10-16 Sep) respectively.

The onset of the rainy season at Canning appears gradual compared to the end of rainy season for both criteria. At the 75% probability level, it takes nearly 3 weeks to accumulate from 50 to 140 mm at Canning, but it takes only 2 weeks at the end of the rainy season to drop from an accumulated 350 mm to 210 mm. For both criteria, 37th week (10-16 Sep) seems to have a very sharp cut off date of the rainy season. In general, one may conclude that the rainy season lasts from nearly the 20th week to 37th week (10-16 Sep). The season with heavy rainfall sufficient to grow rice, is thus from the 20th week to 37th week. It is clear that this season is too short to grow two rice crops, even of shorter duration unless the farmers use the dry seed method for the first crop sown in the 14th week (2-8 Apr) and store all water that is still to be expected after 37th week (10-16 Sep) to be utilised for the subsequent rabi crop.

The representation of only rainy or crop season does not indicate if there are dry spells to be expected during the growing season. The probability of having two consecutive dry weeks with less than 25 mm is also given in the Figs. 3 (a & b). As can be seen from the figure (Fig. 3a), there is a great chance (over 30%) that 20th (14-20 May) to 24th week (11-17 Jun) will be consecutively dry at Canning. The crop may experience dry weeks from 34th week (20-26 Aug) onwards also. But this may not pose a serious problem if rice fields have sufficient high bund and the soil is fully saturated from the high rainfall during earlier weeks.

The situation at Nagri Farm is more or less similar to Canning (Fig.3 b) excepted that the onset of the rainy season is much more sharp than at Canning. The end of the rainy season also is abrupt for both criteria at this location. 37th week (10-16 Sep) is also found to be cut-off date at 75% probability level as the end of the rainy season. The rainy season for this station is from 18th week (30 Apr-6 May) to 37th week (10-16 Sep) for the wet crops although the up-land paddy can be initiated even during 14th week (2-8 Apr) and crop season could terminate on 37th week (10-16 Sep).

There is 50% probability of having two consecutive dry weeks between 20th (14-20 May) and 24th week (11 - 17 Jun) which may not pose much problem for the farmers.

4. Conclusions

The follolwing broad conclusions could be drawn from the analysis:

(*i*) At 75% probability level, 25 mm rainfall may be expected between 29th week (16 - 22 Jul) to 37th week (10 - 16 Sep) in Canning, whereas the same amount may be expected at Nagri Farm during 25th (18 - 24 Jun) to 38th week (17 - 23 Sep).

(*ii*) Probability of wet weeks exceed 75% generally between 24th (11 - 17 Jun) to 37th week (10 - 16 Sep) at Canning, whereas its duration at Nagri Farm is from 20th week (14 - 20 May) to 37th week (10 - 16 Sep). Probability of two consecutive dry weeks is negligible from 24th (11 - 17 Jun) week of 36th week (3-9 Sep) and from 19th (7-13 May) to 38th week (17 - 23 Sep) at Canning and Nagri Farm respectively.

(*iii*) From the forward and backward rainfall accumulation, it appears that two rice crops of short duration, out of which one is upland rice can be grown both in Canning and Nagri Farm.

(*iv*) The wet land crop season has a shorter span at Canning than at Nagri Farm.

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