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Statistical distribution of different cumulative periods of rainfall in Haryana

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ABSTRACT. The statistical distribution of the accumulated rainfall for one, two, three, four, six, eight and sixteen weeks commencing from the onset of the southwest monsoon (25th standard week) have been studied in respect of a low rainfall station, Hissar and high rainfall station, Ambala in the Haryana State. The study of rainfall distribution indicated that upto a cumulative period of four weeks skewness is very high and, therefore, normal distribution cannot be fitted. In such cases gamma distribution has been fitted and found satisfactory. Whereas, beyond four weeks cumulative period, normal distribution has been found satisfactory. Probability charts have been prepared using the theoretical distribution to study their behaviour with respect to crop planning.

1. Introduction

As 75 to 85 per cent of average annual rainfall of Haryana is received during the southwest monsoon period (June to September), a knowledge of its distribution during this period in terms of probabilities of different amounts of rainfall would be helpful in agricultural crop planning and demarcating the areas suitable for various crops. Rainfall studies giving probability values for shorter periods, pentads, have been made by Krishnan and Kushwaha (1972) and by Mooley and Appa Rao (1970). The methodology followed is largely what has been described in *W.M.O. Tech. Note* 81 (1958) with particular reference to the application of gamma distribution to skew data like weekly, pentad rainfall etc. In this paper the same approach has been followed for finding probabilities of rainfall of two stations in Haryana covering an area of low rainfall and another of higher rainfall.

2. Data

The daily rainfall data for 61 years (1915-75) for Hissar and for 30 years (1941-70) for Ambala have been utilized in this study. The standard weeks from 25th to 40th week during June to September have been taken for obtaining data for different cumulative periods of one to sixteen weeks.

3. Nature of frequency distributions

The histograms were prepared for different cumulative periods to indicate their behaviour. Mean, standard deviation, coefficient of variation skewness parameters g_1 and g_2 of Fisher (1944) with their respective standard errors were determined for both the stations and are given in Table 1. These parameters were determined over the cumulative periods of 1, 2, 3, 4, 6, 8 and 16 weeks, during the 25th to 40th standard weeks for the total number of years of data under study. The n indicates the total number of non-zero values of rainfall during 25th to 40th standard weeks over all the years for the different cumulative periods of rainfall.

g_1/SEg_1 and g_2/SEg_2 for both the stations (Table 1) are less than 1·96 for cumulative period 6 to 16 weeks. Hence the distributions for these periods (6 to 16) are not significantly different from normal. The same result is noted by fitting the normal curve to these data and applying the χ^2 - test for the goodness of fit. χ^2 values are found to be not significant even at 5 per cent level. In view of this it would be easy to evaluate probabilities of occurrence of different amounts of rainfall and these are shown for weeks 6 to 16 in Figs. 3(a) and 3(b).

Regarding the remaining periods of 1, 2 and 4 weeks, the values of g_1/SEg_1 and g_2/SEg_2 are much greater than 1·96 and hence the curves are skew or non-normal. This could be readily seen from the histograms in Fig. 1 for these weeks. Studies by Thom (1958), Krishnan and Kushwaha (1972) and Mooley and Appa Rao (1970) suggest that gamma distribution may be fitted satisfactorily for weekly to monthly data. Details of equations are given in Thom (1958) and these mainly are as follows. For the incomplete gamma function

$$f(x) = \left[\int_0^x e^{-x/\beta} \; x^{\alpha-1} \; dx \right] \Big/ \left[\beta^{\alpha} \; \Gamma(\alpha) \right]$$

when x, α and β are greater than zero, the

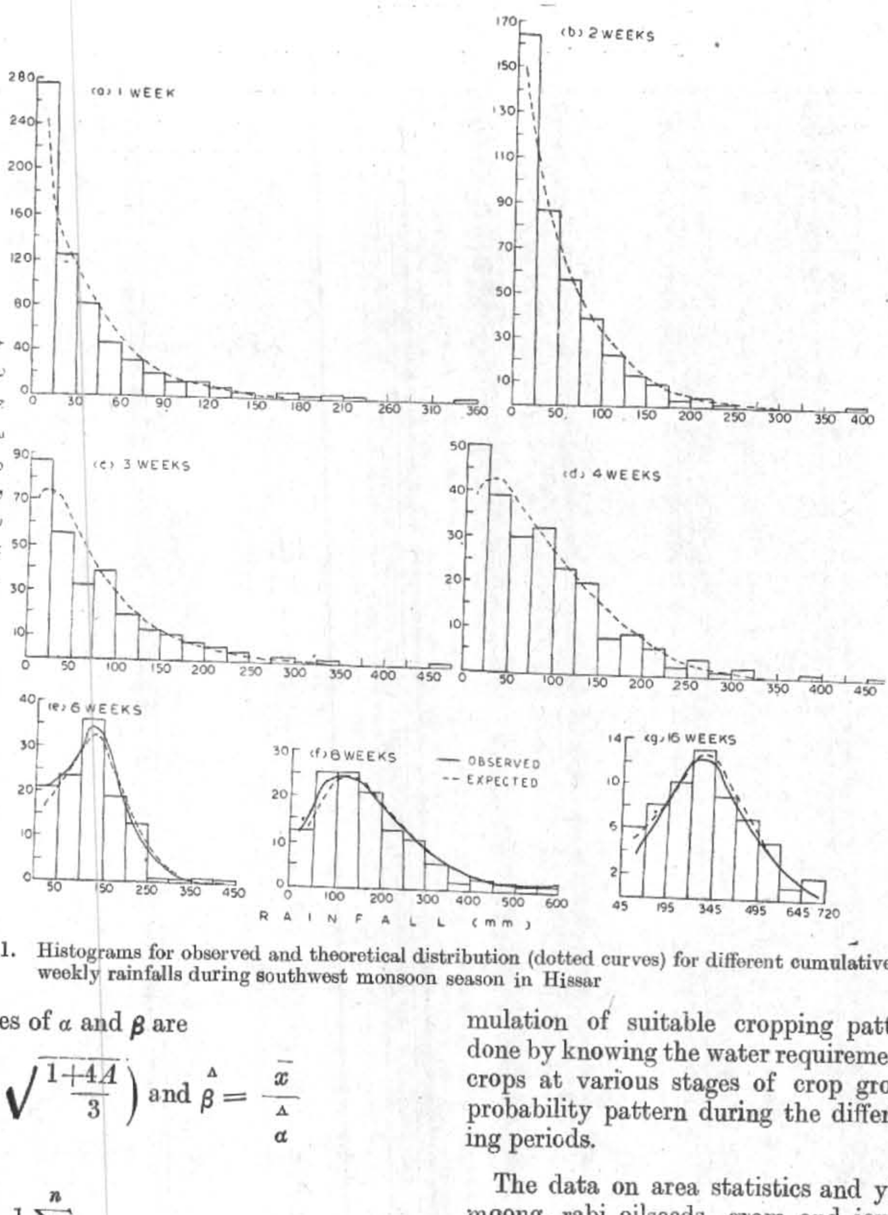

Fig. 1. Histograms for observed and theoretical distribution (dotted curves) for different cumulative weekly rainfalls during southwest monsoon season in Hissar

estimated values of α and β are

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \text{ and } \hat{\beta} = \frac{\bar{x}}{\hat{\alpha}}$$

where,

$$A = \log \bar{x} - \frac{1}{n}\sum_{i}^{n} \log x_i$$

After suitable transformation (Karl Pearson 1946), the relative probabilities and frequencies for various intervals have been calculated. To see the goodness of fit, χ^2 test has been applied and the values of χ^2 are given in Table 2. None of these is significant and the gamma distribution fits well for weekly to monthly data.

4. Probability maps and crop planning

The probability values for the occurrence of different amounts of rainfall for Hissar and Ambala are shown in Figs. 3(a) and 3(b) respectively. These figures can be used for agricultural crop planning and water management practices. Formulation of suitable cropping patterns can be done by knowing the water requirements of various crops at various stages of crop growth and the probability pattern during the different cumulating periods.

The data on area statistics and yield of bajra, moong, rabi oilseeds, gram and jowar crops for Hissar and paddy, maize, gram and wheat crops for Ambala have been plotted against the probability amounts for the years 1951-70 (*Statistical Abstract of Haryana*) and are shown in diagrams 4(a) and 4 (b) respectively. The probability amounts of the various crops have been determined from Figs. 3(a) and 3(b) by taking the value of probability corresponding to the total amount of rainfall received in that year during the crop season. For short duration crop like moong, a period of 8 weeks have been taken, whereas for longer duration crops (more than 100 days) like maize, paddy etc, the period of 16 weeks have been taken. Since the rabi crops are grown on conserved moisture of the southwest monsoon season, the period of 16 weeks have been taken for these crops.

TABLE 1

Rainfall distribution of accumulated weekly periods

Parameters	Cumulative weeks from 25th standard week						
	1	2	3	4	6	8	16
				Hissar (1915-75)			
Mean (mm)	20·3	41·0	62·5	80·0	131·0	159·0	310·0
S.D. (mm)	33·5	48·4	86·1	73·9	79·9	107·1	108·6
CV (%)	165	117	105	92	61	67	54
g_1	3·48	2·03	1·79	1·56	0·37	0·37	0·20
SEg_1	0·0979	0·122	0·1449	0·1612	0·2197	0·2206	0·3085
g_2	15·5	7·1	4·96	3·74	0·69	0·12	0·36
SEg_2	0·1962	0·2433	0·2891	0·3209	0·4348	0·4365	0·6038
n	618	400	282	228	122	121	61
				Ambala (1941-70)			
Mean (mm)	41·0	78·4	118·8	148·4	249·5	300·0	602·5
S.D. (mm)	52·7	81·5	104·3	129·4	138·5	160·3	200·1
CV (%)	127	108	88	87	56	53	33
g_1	2·28	1·82	1·31	0·98	0·47	0·37	0·26
SEg_1	0·13	0·14	0·21	0·23	0·31	0·31	0·43
g_2	5·84	2·01	1·15	0·68	0·26	0·11	0·02
SEg_2	0·26	0·34	0·42	0·45	0·61	0·61	0·83
n	341	204	139	115	60	60	30

TABLE 2

Chi-square values for testing the goodness of fit of distribution fitted

	Cumulative weekly periods from 25th standard week						
	1	2	3	4	6	8	16
			Hissar (1915-75)				
Degree of freedom	10	7	9	9	5	6	6
Calculated	11·46	6·18	8·32	4·1	4·42	7·25	0·96
Values for significance at 5%	18·31	14·06	16·92	16·92	7·80	9·49	9·49
			Ambala (1941-70)				
Degree of freedom	12	10	10	12	4	5	1
Calculated	14·43	3·75	6·86	7·2	2·8	2·9	1·9
Values for significance at 5%	21·03	18·31	18·31	21·03	9·5	11·1	3·8

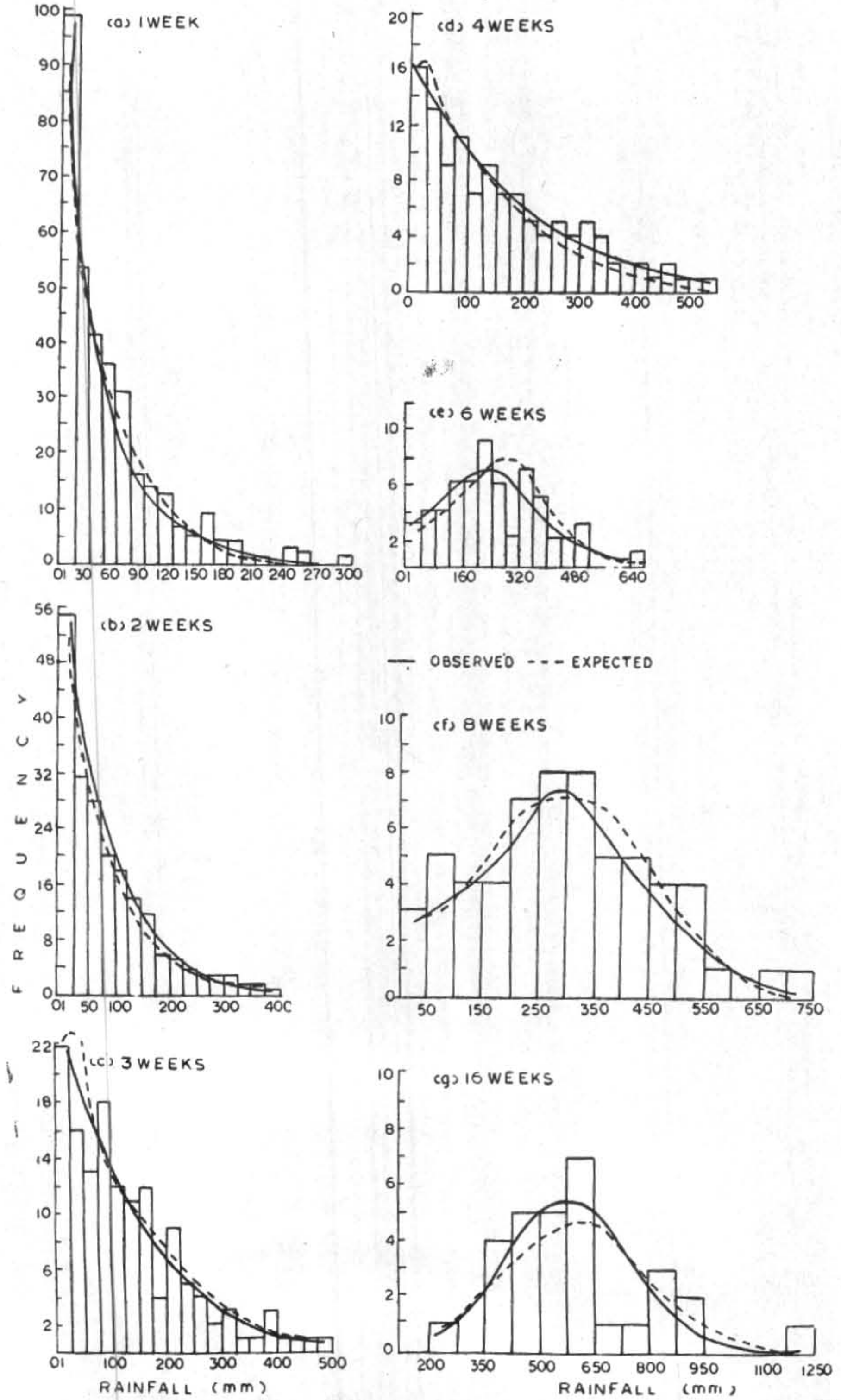

Fig. 2. Histograms for observed and theoretical distribution of frequency (dotted curves) for different cumulative weekly rainfalls during the southwest monsoon season at Ambala

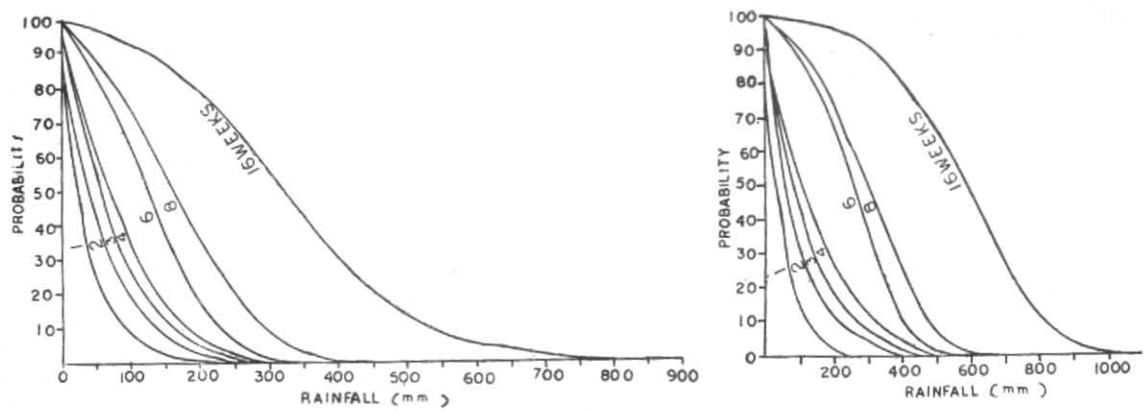

Fig. 3. Probability maps of (a) Hissar and (b) Ambala

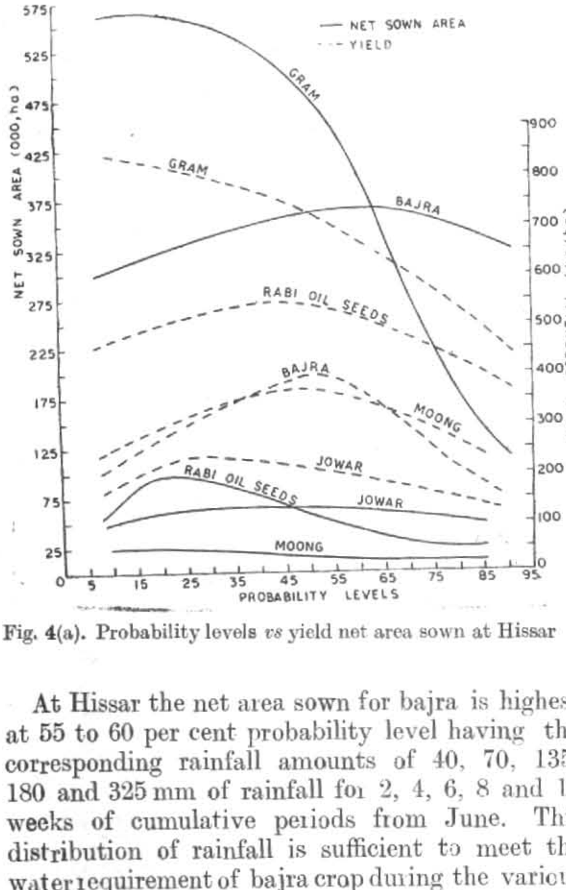

Fig. 4(a). Probability levels *vs* yield net area sown at Hissar

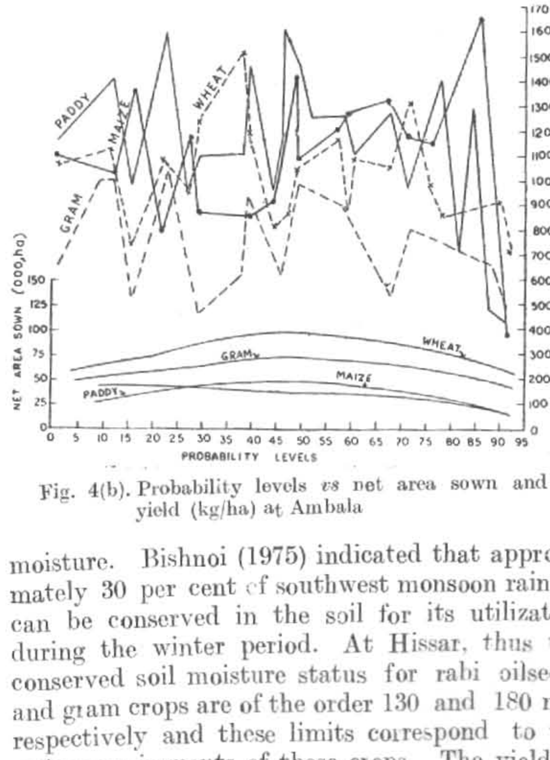

Fig. 4(b). Probability levels *vs* net area sown and yield (kg/ha) at Ambala

At Hissar the net area sown for bajra is highest at 55 to 60 per cent probability level having the corresponding rainfall amounts of 40, 70, 135, 180 and 325 mm of rainfall for 2, 4, 6, 8 and 16 weeks of cumulative periods from June. This distribution of rainfall is sufficient to meet the water requirement of bajra crop during the various crop growth phases from sowing to harvesting. Also the yield potential of bajra crops is maximum at 55 per cent probability level. Moong has shown higher net area sown at low rainfall probabilities. But moong crop is not grown as a pure crop, it is only grown in mixture with the base crop as bajra. Rabi oilseeds and gram crops have shown maximum net area sown at 20-25 and 5-10 per cent probability level respectively. Southwest monsoon rainfall is utilised for these rabi crops as conserved moisture. Bishnoi (1975) indicated that approximately 30 per cent of southwest monsoon rainfall can be conserved in the soil for its utilization during the winter period. At Hissar, thus the conserved soil moisture status for rabi oilseeds and gram crops are of the order 130 and 180 mm respectively and these limits correspond to the water requirements of these crops. The yield of gram is higher at low probability level and decreases with higher probability levels. Also the rabi oilseed crops give higher yield potential covering a wide range of 25 to 60 per cent of probability level. The yield substantially decreases after 65 per cent of probability level. With lower amount of conserved soil moisture at higher probability levels, taramira (*Eruca sativa*) crop is given preference and at low probability with

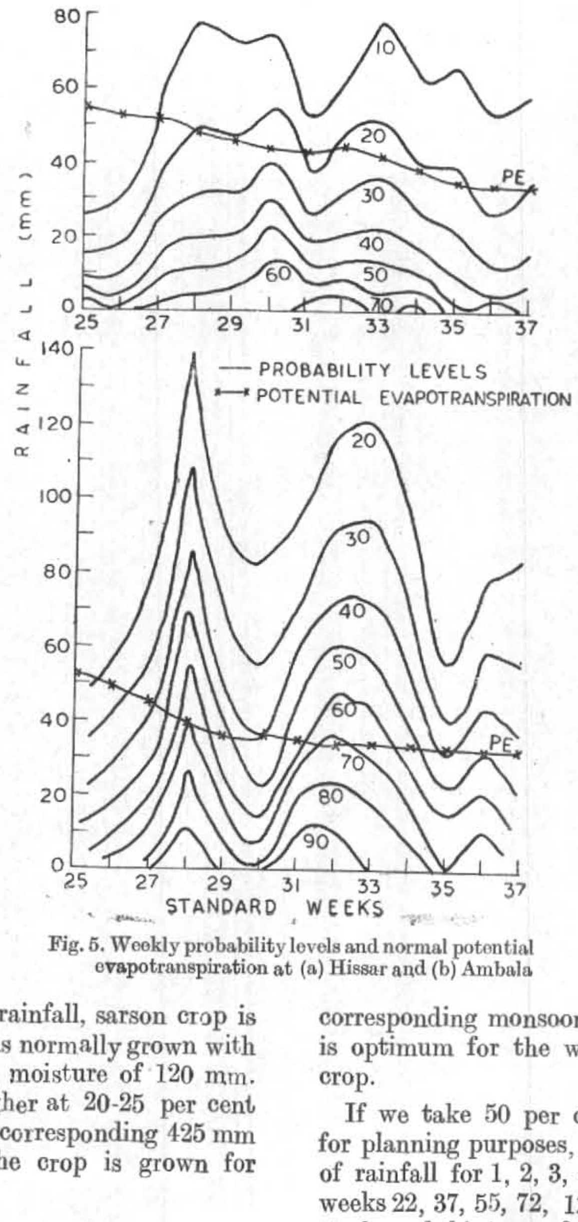

Fig. 5. Weekly probability levels and normal potential evapotranspiration at (a) Hissar and (b) Ambala

higher receipt of monsoon rainfall, sarson crop is given preference. But raya is normally grown with the optimum conserved soil moisture of 120 mm. In case of jowor yield is higher at 20-25 per cent probability level having the corresponding 425 mm of rainfall. But mostly the crop is grown for fodder only.

At Ambala the spread in the net area sown is less as compared to Hissar because of less variation in the receipt of southwest monsoon rainfall. But the variation in yield at Ambala is higher than Hissar. Paddy and sugarcane have higher net sown area at lower probability level having the corresponding rainfall more than 800 mm. Wheat and gram the rabi crops have shown a higher net sown area at 45 to 50 per cent of probability level with correspondig rainfall of 650 mm. The conserved soil moisture at this level is of the order of 180-195 mm. Also 125-150 mm winter rainfall is received at this station which helps in successful cultivation of the crops. Maize has also shown a *relatively higher percentage of net* sown area at 45-50 per cent of probability level indicating the corresponding monsoon rainfall of 625 mm which is optimum for the water requirement of maize crop.

If we take 50 per cent probability as reliable for planning purposes, then the expected amounts of rainfall for 1, 2, 3, 4, 6, 8 and 16 cumulative weeks 22, 37, 55, 72, 125, 160 and 345 mm respectively and this type of distribution of rainfall over the various cumulative periods, only shorter and medium duration crops like moong, moth, bajra, cowpea, jowar, taramira, raya and gram can be successfully planned. Similarly for Ambala at 50 per cent probability level, the expected amounts of rainfall are 32, 58, 85, 100, 240, 300 and 590 mm during 1, 2, 3, 4, 6, 8 and 16 cumulative weeks respectively. In such a case medium and high water requirement crops like jowar, maize, groundnut, paddy, arhar, urd, sarson, gram, barley and wheat can be planned.

The irrigation and agronomic practices can be better understood by finding out the probabilities at weekly periods over the individual weeks during the growing season of the crop. Figs. 5(a) and

5(b) indicate expected amount of rainfall at different probability levels by using incomplete gamma distribution for individual weeks (25th to 37th week) for Hissar and Ambala respectively. The weekly values of potential evapotranspiration determined from modified Penmen's formula (1948) have been also indicated in Figs. 5(a) and 5(b) so as to indicate the periods of water surplus and water deficiency over which the agronomic practices are based. At 50 per cent probability level, there is water deficiency around 30th standard week and after 34th standard week at Ambala. First deficiency occurs at nearly after 25 days of sowing of kharif crops. At this critical time, the crops are at vegetative phase and the supplimental irrigation is very necessary; otherwise plant population and the vegetative growth of the crops are retarded. After 34th week, the crops are at seed setting and crown formation stage, the supplimental irrigation is very essential to save the crop yields. However, the water surplus is occurring during 25, 32 and 33 standard weeks; therefore, the soil moisture conservation and adjusting plant population, fertilization and other suitable agronomic practices based on the individual crops can easily be followed for the better production of kharif crops.

Similarly at Hissar, at 50 per cent probability level, the potential evapotranspiration is not met by the expected amount of rainfall throughout the southwest monsoon season. Therefore, supplimental irrigations are highly desired for successful cropping under rainfed conditions, otherwise we will have to go for drought resistant and low water requirement crops whereby obtaining some optimum yields rather than the maximum value. Therefore, with the receipt of the rainfall in the monsoon season, it is possible to adjust the relative acreage under the various crops to formulate an optimum crop planning so as to utilize the available resources. Also the irrigation scheduling can be formulated with the advancement of the season if the probability levels are not compatible with the probability level corresponding ta the water requirements of crops during the various growth phases of the crops.

5. Concluding remarks

Gamma distribution can be successfully fitted for rainfall distribution at shorter periods; their probability maps are highly useful for crop planning, irrigation scheduling and to understand the role of agronomic practices during the growing season.

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