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Irrigation requirements of cotton at different agroclimatic regions of the country

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सार – इस शोध–पत्र में देश के विभिन्न कृषि जलवायविक क्षेत्रों में स्थित छः स्थानों में कपास की विभिन्न किस्मों के लिए सिंचाई की आवश्यकताओं का पता लगाने के लिए अध्ययन किया गया है। फसल के संवर्द्धन की विभिन्न स्थितियों तथा विभिन्न क्षेत्रों में विकसित की गई किस्मों के लिए भी सिंचाई की आवश्यकताओं में काफी विभिन्नता होने का पता चला है। सामान्यतः फसल को सिंचाई की आवश्यकता सबसे अधिक या तो फसल में फूल आने के दौरान होती है या फिर बीज के विकास की अवस्था में होती है। अकोला (15.0–47.3 सें.मी.) और कोयम्बतूर (16.9–36.4 सें.मी.) की तुलना में बेलारी (54.2–56.2 सें.मी.), आनंद (45.4–63.4 सें.मी.) और कोविलपट्टी (41.0–63.4 सें.मी.) में उगाई गई फसल के लिए अधिक सिंचाई की आवश्यकता है। विभिन्न क्षेत्रों में वर्षा का अंतर अत्याधिक होने के कारण सिंचाई का समय काफी भिन्न होता है। वर्षा के 70 प्रतिशत लेवल की संभावना के आधार पर कपास की सिंचाई की आवश्यकता का परिकलन किया गया है। कृषि मौसम सलाहकार सेवा के माध्यम से कपास की सिंचाई के समय की योजना की सूचना का उपयोग करने के लिए विशेष दिशा निर्देश जारी किए गए हैं।

ABSTRACT. Studies were made to find out the irrigation requirements of different varieties of cotton grown at six locations situated in different agroclimatic regions of the country. It is found that there is a considerable variation of irrigation requirements at different growth stages of the crop and also among the varieties cultivated at different regions. In general, the crop requires maximum irrigation either at flowering or boll formation stages. The study reveals that more irrigation is required for the crop grown at Bellary (54.2-56.2 cm), Anand (45.4-63.4 cm) and Kovilpatti (41.0-63.4 cm) compared to that at Akola (15.0-47.3 cm) and Coimbatore (16.9-36.4 cm). Irrigation timing differs considerably due to high degree of variability of rainfall in different regions. Based on probability of rainfall at 70% level, irrigation requirements of cotton has been computed. Specific guidelines are generated to utilise the information for irrigation scheduling of cotton operationally through Agromet Advisory Service.

Key words – Cotton, Irrigation requirement, Rainfall probability, Agroclimatic regions, Agromet advisory service.

1. Introduction

Cotton, an important subtropical cash crop normally grown in areas with 750 to 2500 mm rainfall, plays a significant role in the industrial and agricultural economy of the country (IARI Monograph 1977). The production and productivity of cotton cultivated in arid and semi-arid regions of the country depend substantially on the spatial and temporal variations of monsoon and post monsoon rainfall. Aberration of weather, especially the erratic distribution of rainfall in these regions draws special attention to plan different strategies of cotton production.

Adequate and timely supply of water is one of the basic inputs for obtaining potential cotton yield. Economic and efficient utilisation of water becomes a must in water use programme for which precise knowledge of water requirement of cotton crop is essential (Dastane *et al.* 1970). There is also enough scope to increase the yield of rainfed cotton by providing life saving supplemental irrigation at the critical stages of the crop when the rainfall is not sufficient to meet the crop water demand. Irrigation requirements of cotton in India show a wide range of variations because different species having different life duration and grown in different seasons on light as well as heavy clayey soils.

Thus an attempt has been made to achieve optimum productivity of cotton by working out an efficient and economic irrigation scheduling for different agroclimatic regions of the country. Efforts have been made to find out the irrigation requirements of different varieties of cotton grown in different region of the dry farming tract of the country. Operational aspects of irrigation scheduling through Agromet Advisory Services have also been discussed.

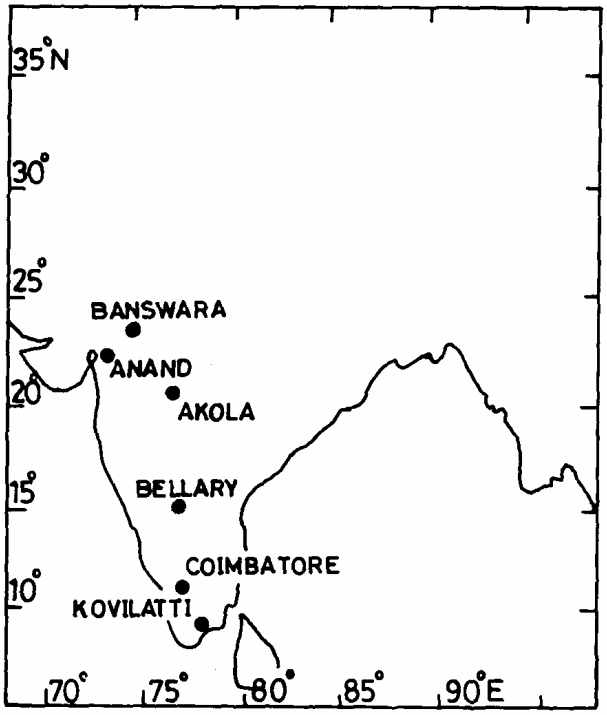

Fig. 1. Locator map of the different evapotranspiration stations under study

2. Data and methodology

Six evapotranspiration observatories of India Meteorological Department located at Coimbatore, Kovilpatti, Bellary, Akola, Anand and Banswara in the dry farming tract of the country were selected for the present study (Fig. 1). Details of the stations *i.e*. location, latitude, longitude and soil characteristics including the varieties of the crop grown at different stations are mentioned in Table 1.

Being a deep-rooted crop, its root penetrates deep into the soil at different growth stages of the crop. The root depths considered here are 20, 40, 80 and 120 cm at seedling, vegetative, flowering and boll formation stages respectively. These information were used to calculate the available stored water at different growth stages of the crop. Climatological approach has been used in this study to estimate the irrigation requirements of the crop. The amount of water to be applied at different stages of the crop under different soils and climatic conditions are determined by the following equation (CAgM Report 2000).

$$Qi = [(QsLa) – Qr] Kc / E$$

Where,

Qi = Volume of water added by irrigation

Qs = Water stored in the respective root zone

Qr = Rainfall

La = Relative loss of allowable water (0.5)

Kc = Crop coefficient

E = Irrigation efficiency (0.6)

Qs, *i.e*., the available soil water at the respective root zone has been calculated in terms of mm by the following equation (Todorov 1982)

$$Qs = (Fc – WP) \times b \times c / 10$$

Where, Fc and WP are the field capacity and wilting point respectively and b is the bulk density of the soil in gm/cc and c is the thickness (height) of the soil layer in cm.

At each station, crop coefficients (Kc) at different phenological stages of the cotton have been determined by the formulae

$$Kc = AE / PE$$

Where, AE = Actual evapotranspiration obtained from lysimeter observations

PE = Potential evapotranspiration calculated by Penman's equation (1948).

Irrigation requirements have been calculated for different growth stages *viz*., seedling, vegetative, flowering and boll formation. Rainfall at 70% probability level has also been used to calculate the irrigation requirement for each of the growth stages.

In order to schedule irrigation based on relative dryness during the growth stage of the crop, Markov Chain Model (Robertson 1982) was used to compute the probability of occurrence of dry week (PD). The criteria for defining a week as dry has been taken as suggested by Gore and Sen (1998).

3. Result and discussion

Sowing date of cotton varies considerably from location to location due to variation in date of receiving sowing rainfall and optimum soil moisture for

TABLE 1

Agroclimatic zones, soil characteristics, period of study, crop varieties and location of different stations

Items		Coimbatore	Akola	Kovilpatti	Anand	Banswara	Bellary
Agroclimatic Zone *		Southern plateau and hill region (X)	Western plateau and hill region (IX)	East coast plains and hill region (XI)	Gujarat plain and hill region (XIII)	Central plateau and hill region (VIII)	Southern plateau and hill region (X)
Data studied		1981-82 to 1988 – 89 (8 years)	1990 – 91 to 1993 – 94 (4 years)	1985-86, 1987-88, 1989-90, 1991-92 1993-94 (5 years)	1982-83 to 1984-85 (3 years)	1981-82 to 1983-84 (3 years)	1994 - 95 to 1995-96 (2 years)
Soil Characteristics	Texture	Clay loam	Clay	Clay	Sandy loam	Sandy loam	Clay
	Field capacity (%)	26	26.2	35	17	12	38
	Wilting Point (%)	12.5	10.2	15	5	3	22
	Bulk Density (gm/cc)	1.3	1.18	1.25	1.5	1.55	1.2
Latitude		11° 00'N	20° 42'N	09° 12'N	22° 35'N	23° 33'N	15° 09'N
Longitude		76° 58'E	77° 02'E	77° 53'E	72° 55'E	74° 27'E	76° 51'E
Variety		MCU – 9	AHH – 468	MCU – 10	H-6	DIGVIJAY	DCH – 32

* As per Planning Commission, Govt. of India (1989)

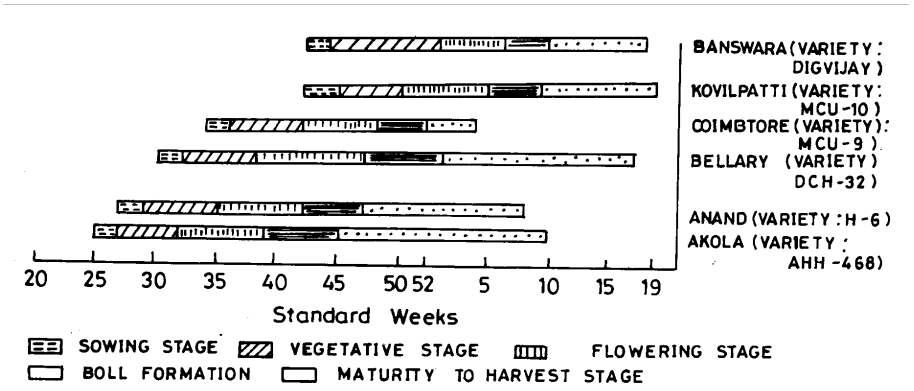

Fig. 2. Average phonological stages of different varieties of cotton grown at different places in the country

germination. The average date of sowing and the period of each growth stages of the crop are distinctly different for the different varieties of cotton under study (Fig. 2). At Akola, Anand and Bellary, the seeds of different varieties of crop are normally sown almost with the onset of Southwest monsoon (SW). Cotton grown at Coimbatore is sown at the fag end of Southwest monsoon so as to get the benefit of SW and Northeast (NE) monsoon rainfall. It is cultivated both in Kovilpatti in Tamilnadu and Banswara in Rajasthan as a winter irrigated crop.

At Coimbatore crop (Var. MCU-9) was sown on clay loam soil at the fag end of monsoon while at Kovilpatti the crop (Var. MCU-10) was sown on clay soil with the

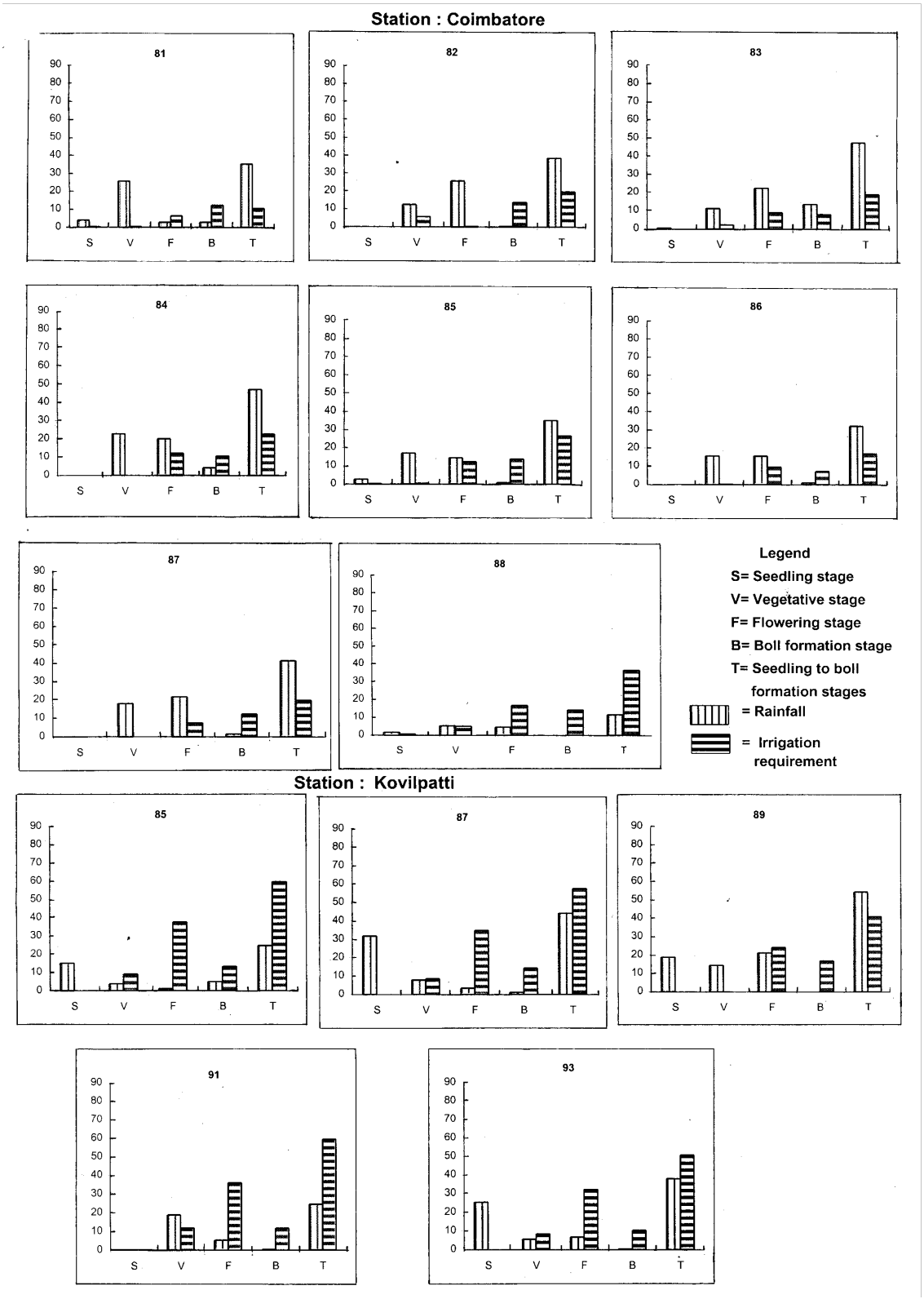

Fig. 3(a). Actual rainfall (cm) and irrigation requirement (cm) at different growth stages of cotton in different years at various stations

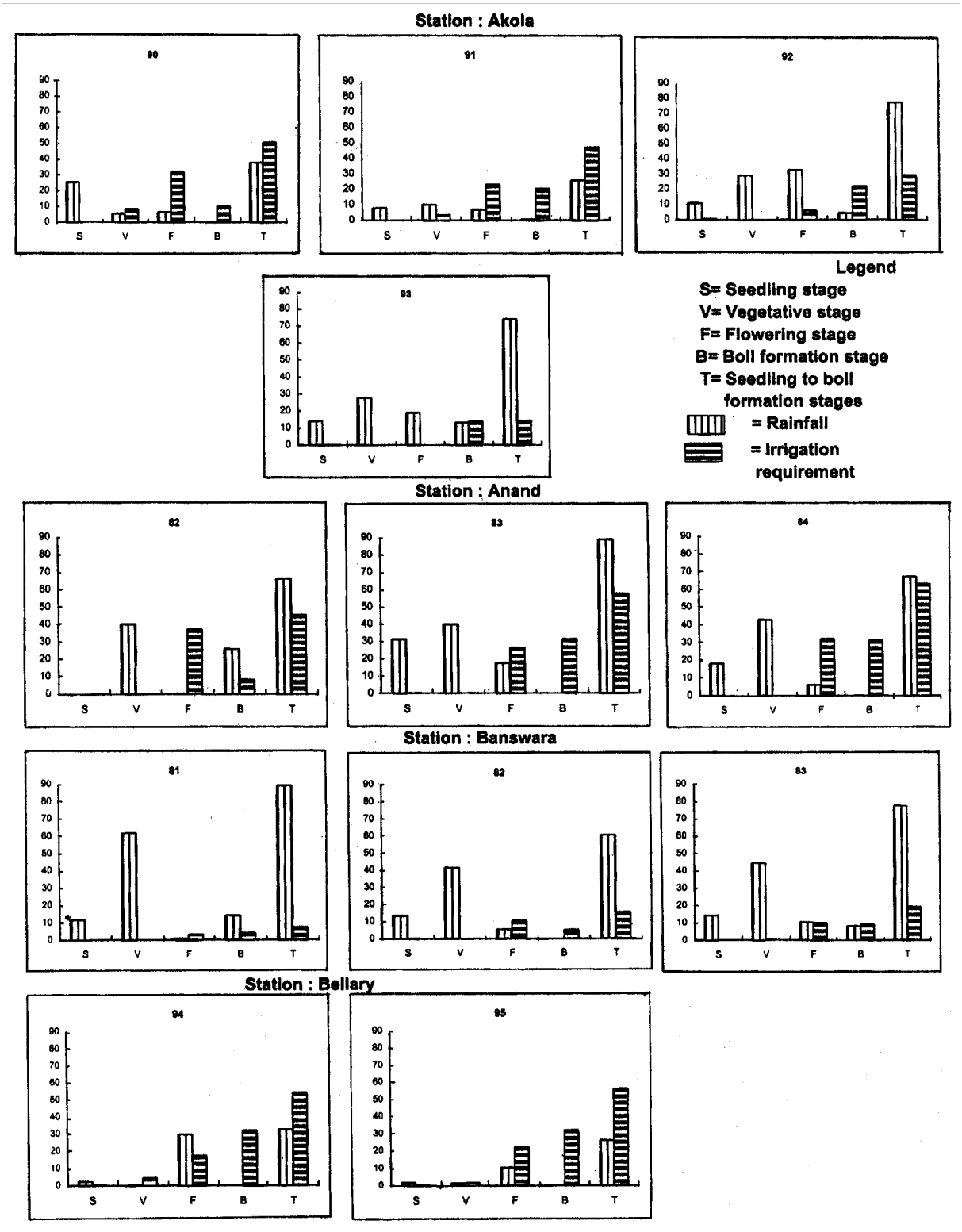

Fig. 3(b). Actual rainfall (cm) and irrigation requirement (cm) at different growth stages of cotton in different years at various stations

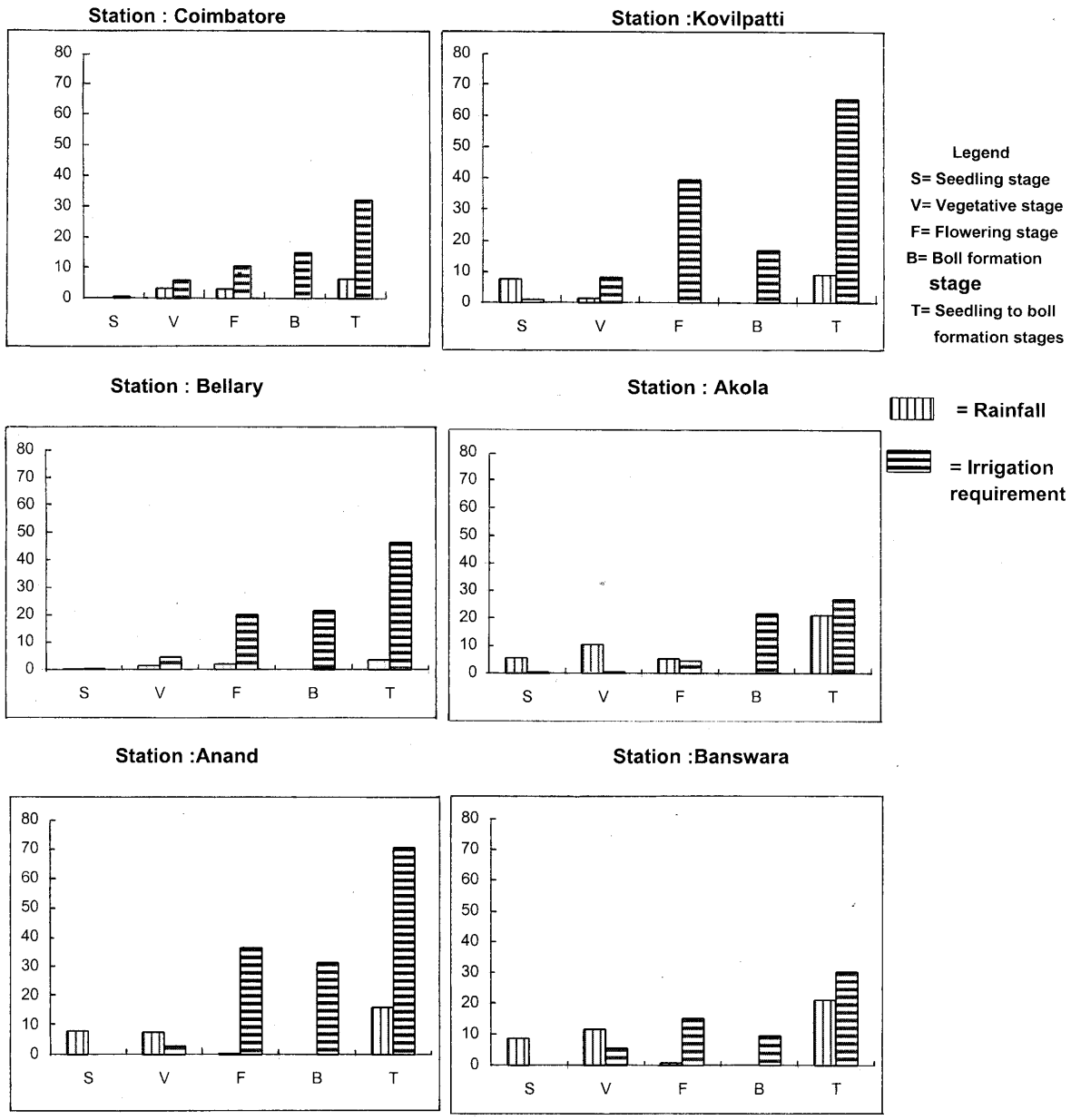

Fig. 4. Irrigation requirement (cm) at 70% rainfall probability level in different growth stages of cotton at different stations

onset of NE monsoon. Crops grown at both these stations were benefited from the NE monsoon rainfall. Irrigation requirements of different stages of crop were computed for eight (1981-88) and five (1985, 87, 89, 91, 93) years respectively at Coimbatore and Kovilpatti. In general, there was adequate rainfall in seedling as well as vegetative stage (Fig. 3) for most of the years considered in this study and as a result irrigation requirements were less at early stages of the crop at Coimbatore (Fig. 4). At Kovilpatti, except 1989, irrigation requirements ranged from 8.4 to 11.8 cm at the vegetative stage. In 1989 the station received more rainfall at seedling (18.8 cm) and vegetative stage (14.3 cm) and as a result there was no irrigation required by the crop at vegetative stage. At Kovilpatti the flowering stage was comparatively extended (7 weeks) and the crop required more irrigation (24.1-35.9 cm) under low rainfall condition. There existed a high degree of variability in irrigation requirements (0.2-16.7 cm) at flowering stage of the crop grown at Coimbatore. In both the stations, irrigation requirements at

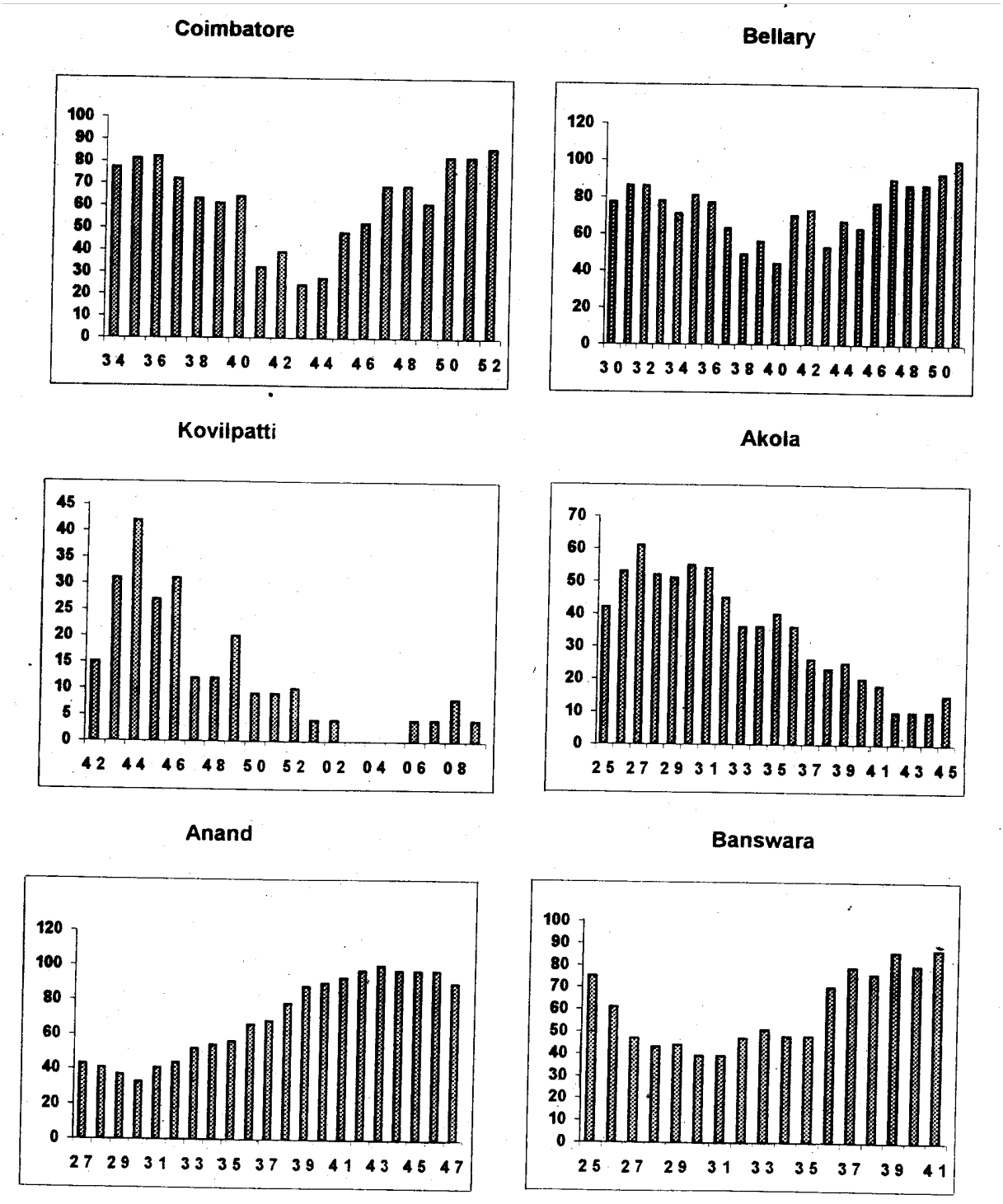

Fig. 5. Probability of occurrence (%) of dry week during crop growth stages at different stations

boll formation stage ranged from 7.2 to 16.9 cm. Thus there was a high degree of variability of irrigation requirements at both the stations from vegetative to boll formation stages. Total irrigation requirements were more for crop grown at Kovilpatti (41.0 to 59.6 cm) than that at Coimbatore (16.9-36.4 cm). Chandra Mohan *et al.* (1967) conducted field experiments on MCU-1 cotton for two years during kharif season at Bhavanisagar in Tamil Nadu. Irrigation was given based on 20% depletion of available soil moisture. The authors reported that about

60.0-65.0-cm water was required by the crop for its normal growth when rainfall received in the study years were 30.5 and 51.0 cm respectively. In Tamilnadu, irrigation at 50% depletion of available soil moisture was found to be optimum for winter Combodia cotton on red sandy loam soil at Bhavanisagar (Ali *et al*. 1974). The authors found that total irrigation requirement was of the order of 67.5 to 77.0 cm applied in 9 to 13 irrigations depending upon the rainfall.

Irrigation requirements for cotton (Var. DCH-32) grown in clay soil at Bellary in Karnataka state were calculated for 1994 and 1995. In both the years, there was no rain at the boll formation stage of the crop (Fig. 4). As a result irrigation requirements were appreciably high (32.1 cm) during this stage of the crop at this station. Though the station received rainfall during vegetative and flowering stages, irrigation requirements were much higher (17.4 to 22.0 cm) at flowering stage. Total irrigation requirements of the crop from seedling to boll formation ranged between 54.2 to 56.2 cm. Study on cotton at Siruguppa, Karnataka by Patil *et al*. (1969) showed that the maximum yield of cotton was obtained when the crop received two pre-flowering and four post flowering irrigation, amounting to 49.1 cm. Yadav (1972) reported that irrigation at 75% depletion of actual soil moisture at black cotton soil of Siruguppa was adequate and this required 8 irrigations with water of 73.0 cm.

At Akola irrigation requirements for different growth stages were computed for four years (1990- 93). The crop (Var. AHH-468) was sown in last week of June to middle of July. Except 1991 rainfall during seedling to vegetative phases was sufficient to replenish the soil moisture requirements of the crop (Fig. 4). However, irrigation requirements varied considerably in the range of 0 – 23.2 cm at flowering stage due to the variable rainfall. Rainfall of 19 cm, which received in 1993 during flowering stage, was found to be sufficient. At boll formation stage irrigation requirements ranged from 14.0 to 22.4 cm. Total irrigation water required by the crop during its entire life period was 15.0 to 29.5 cm.

Adequate rainfall during seedling and vegetative stages of crops at Anand (Var. H-6) and Banswara (Var. DIGVIJAY) was found to be adequate for the growth of the crop without any irrigation. Both at flowering and boll formation stages, the crop grown at Anand required more irrigation than at Banswara. Irrigation requirements at flowering and boll formation stages were 26.0 to 37.2 cm and 8.2 to 31.3 cm respectively for crop grown at Anand while the same was 3.3 to 10.4 cm and 4.1 to 9.3 cm respectively at Banswara.

Thus it was observed that more irrigation was required by the crop grown at Bellary (54.2-56.2), Anand (45.4-63.4 cm) and Kovilpatti (41.0-59.6 cm) while moderate irrigation was required for crops grown at Akola (15.0 - 47.3 cm) and Coimbatore (16.9-36.4 cm) during seedling to boll formation stages of the crop. Irrigation requirements of the crop grown at Banswara were relatively less and ranged from (7.4-19.1 cm).

Operational aspects of irrigation scheduling

From the foregoing discussion it may seen that though irrigation requirements for different varieties of cotton grown at different locations of the country vary considerably, the amount of rainfall at a particular stage of the crop along with its water holding capacity decides the quantum of irrigation to be applied for normal growth. It is a accepted fact that short range forecast may not always provide sufficient lead-time to take effective decision in water management; on the other hand with the available forecasting tool medium range forecast for rainfall can not be accurately made over the Indian region. Under such a circumstance, scheduling of irrigation based on probability of rainfall and dry and wet may be the realistic approach for economic and efficient irrigation scheduling of crop (Fig. 5).

In this study irrigation requirements of cotton at different growth stages were computed based on 70% rainfall probability (Fig. 4). It is seen that a light irrigation/no irrigation (0.5 to 1 cm) is required by the crop grown at Coimbatore, Kovilpatti, Bellary and Akola during seedling stage. At vegetative stage 5-6 cm of irrigation is adequate for the crop grown at Coimbatore, Bellary and Banswara while crop grown at Kovilpatti would require 8 cm of water. There is a substantial variation in the irrigation requirements for the different variety of crop at flowering stage. Maximum irrigation (40 cm) would be required by MCU-10 raised at Kovilpatti followed by irrigation amount of 36 cm at Anand, 20 cm at Bellary, 15 cm at Banswara, 10 cm at Coimbatore and 5 cm at Akola. At boll formation stage of the crop more irrigation (32 cm) would be required by the crop grown at Anand and irrigation requirements for crop grown at Akola, Kovilpatti, Coimbatore and Banswara are 22, 17, 15 and 10 cm respectively.

Thus it is seen that the crop requires maximum irrigation during flowering and boll formation stages. These two stages are the most critical stages of cotton as lack of adequate moisture in these stages result in premature flower drop, boll shedding, poor development of bolls, low ginning percentage and ultimately low yield of cotton (Dastur and Singh 1943; Khan 1951).

A number of references (Rajaratnam 1955, Kulkarni and Hayavaden 1968, Yadav 1972, Kalippa *et al.* 1974) where irrigation on cotton was recommended at fixed time interval. Such irrigation scheduling may not be always productive because the station may either get rainfall or there may be adequate available soil moisture due to the rainfall at the preceding days. In this context, scheduling of irrigation based on information on probability of occurrence of dry week and probability of rainfall different crop growth stages will be more judicious approach. Thus in a particular stage of the crop with special emphasis on critical growth stages, irrigation may be provided when the probability of occurrence of dryness is more. Light irrigation may be recommended at Coimbatore, Kovilpatti, Bellary and Akola on 34th & 36th week (PD = 77- 88%), 42nd week (PD = 85%), 31st - 32nd week (PD = 86%) and 25th week (PD = 58%) respectively. At vegetative stage 5 - 6 cm irrigation may be provided to the crop growth at Coimbatore, Bellary and Banswara on 37th week (PD = 72%), 35th week (PD = 81%) and 29th week (PD = 44%) respectively. During this stage 8 cm irrigation may be given to the crop grown at Kovilpatti on 47th to 50th week (PD = 80 - 91%). At flowering stage irrigation may be supplied for 6 weeks from 51st week to 4th week of the succeeding year at Kovilpatti (PD = 90 - 100%), 38th to 42nd week at Anand (PD = 78 - 97%), 41 & 42 and 46th week at Bellary (PD= 70 - 77%), 32 & 36 week at Banswara (PD = 47 - 70%), 47th - 48th week at Coimbatore (PD = 69%) and 37 & 39th week at Akola (PD = 74 - 77%). It has been observed that the PD values ranged from 76 - 100% during the boll formation stages of all the varieties of crop under study. Thus the irrigation may be applied any week at this stage of the crop. The periods of boll formation stages are 49 to 50th week, 5th to 9th week, 47th to 51st week, 40th to 45th week for crops grown at Coimbatore, Kovilpatti, Bellary, Akola, Anand and Banswara respectively.

Thus based on short and medium range weather forecast, information on probability of rainfall at 70 % levels, probability of getting dry week, the amount of irrigation required at 70% risk level could be provided for scheduling irrigation at different growth stages at different locations for maximizing productivity of the cotton crop. This would also help to prevent application of excess irrigation water and also soil degradation problem due to high water table caused by excess irrigation.

4. Conclusion

Irrigation requirements varied amongst the different varieties of the cotton cultivated in different stations. Major share of irrigation was required by the crop at flowering and boll formation stages of the crop. Irrigation requirement was maximum at Bellary (54.2 to 56.2 cm) followed by at Anand (45.4 to 63.4 cm), and Kovilpatti while moderate irrigation was required by the crop grown at Akola (15.0 to 47.3 cm) and Coimbatore (16.9 to 36.4 cm). It was minimum (7.4 -19.1cm) at Banswara. As the interannual variability of irrigation requirements was high for crops under study, formulation of specific irrigation scheduling based on 70% rainfall probability may be one of the realistic approaches for efficient and economic use of water for crop.

Thus based on the rainfall probability at 70% level and probability of occurrence of dry spells, following irrigation scheduling for each of the station are recommended for the crop.

(*i*) *Coimbatore*

(a) No irrigation / light irrigation (0.5 - 1 cm) at 34-36th week (20 Aug - 9 Sep) during seedling stage.

(b) 5-6 cm irrigation at 37th week (10 - 16 Sep) during vegetative stage.

(c) 10 cm irrigation at 47th & 48th week (19 Nov to 2 Dec) during flowering stage.

(d) 15 cm irrigation at 49th to 50th week (3 Dec - 16 Dec) during boll formation stage.

(*ii*) *Kovilpatti*

(a) No irrigation / light irrigation (0.5 - 1.0 cm) at 42nd week (15 - 21 Oct) during seedling stage.

(b) 8 cm irrigation at 47th to 50th week (19 Nov - 16 Dec) during vegetative stage.

(c) 40 cm irrigation at 51st to 4th week (17 Dec - 28 Jan) of the succeeding year during flowering stage.

(d) 17 cm irrigation at 5th to 9th week (29 Jan - 4 Mar) during boll formation stage.

(*iii*) *Bellary*

(a) Light irrigation (0.5 - 1.0 cm) at 31st to 32nd week (30 Jul – 12 Aug) during seedling stage.

(b) 5-6 cm irrigation at 35th week (27 Aug - 2 Sep) during vegetative stage.

(c) 20 cm irrigation at 41 – 42 and 46th week (8 Oct - 21 Oct and 12 - 18 Nov) during flowering stage.

(d) 21 cm irrigation at 47 - 51st week (19 Nov - 23 Dec) during boll formation stage.

(*iv*) *Akola*

(a) Light irrigation (0.5 - 1.0 cm) at 25th (18 - 24 Jun) and 29th week (16 - 22 Jul) corresponding to seedling and vegetative stages.

(b) 5 cm irrigation at 37 to 39th week (10 Sep - 30 Sep) during flowering stage.

(c) 22 cm irrigation at 40 - 45th week (1 Oct - 11 Nov) during boll formation stage.

(*v*) *Anand*

(a) No irrigation is required at seedling and vegetative stage.

(b) 36 cm irrigation at 38 to 42nd week (17 Sep - 21 Oct) during flowering stage.

(c) 32 cm irrigation at 43rd to 47th week (22 Oct - 25 Nov) during boll formation stage.

(*vi*) *Banswara*

(a) 5 - 6 cm irrigation at 29th week (16 - 22 July) during vegetative stage.

(b) 15 cm irrigation at 32 to 36th week (6 Aug - 9 Sep) during flowering stage.

(c) 10 cm irrigation at 37 - 41st week (10 Sep - 14 Oct) during boll formation stage.

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