633·51 : 551·577 (543)

A comparative study of rainfall and cotton crop under Crop-Weather Scheme at Akola and Nagpur

P. S. SREENIVASAN and J. R. BANERJEE

Meteorological Office, Poona

(*Received 25 June 1956*)

1. Introduction

With the inauguration of Crop-Weather Scheme relating to cotton by the Indian Central Cotton Committee, systematic data on crop and weather are being collected in a network of crop-weather stations in India. Akola and Nagpur are two stations in Madhya Pradesh where such information are recorded since 1949. Akola (Lat. 20° 42′N, Long. 77° 02′E) has a mean elevation of 925 feet. Nagpur (Lat. 21° 09′N, Long. 79° 12′E, Elevation 1054 ft) is about 140 miles east of Akola. Both the stations are situated in the black cotton soil of Deccan trap of Central India. The annual rainfall of Akola district is about 34″ of which nearly 28″ of rain is received in the four month period of June to September and 3·8″ in October to December. Nagpur district receives nearly 49″ of rainfall, that is, 15″ more than the rainfall at Akola Out of this 49″ of rainfall more than 43″ of rain is received in the period of 4 months, June to September, and 3·5″ in the period October to December, which is somewhat less than the rainfall in Akola.

As the very name of the tract suggests, cotton is the main crop in this black cotton soil of Deccan trap. The crop is usually sown in the first week of July on receipt of the early rains of the S.W. Monsoon when there is sufficient moisture in the soil for good germination. The sowing is done by drilling in rows which are one and a half feet apart. Usually the kapas are harvested in three pickings at both the stations. At Akola the last picking comes off by the middle of January to end of March while at Nagpur, it is carried out by the end of December to third week of January.

2. Material and method

The data discussed in this paper were collected under the Co-ordinated Crop-Weather Scheme. The details of the layout of crop-weather fields, the sampling technique for recording growth observations, the meteorological instruments and the times of observations are given in the Technical Circular No. 50 of the Agrimet. Division (1953). In brief, two varieties of cotton are grown at each station with six replications. On scheduled dates of observation, six random samples (each sample is 8-foot length of row, made up of two parallel 4-foot lengths in adjacent rows) are selected in each plot. Observations are taken at daily intervals for germination and flower count and at weekly intervals for periodical growth observations namely, number of plants per sample, height and number of fruiting branches on the end plants of the ultimate units of the sample.

The two cotton varieties under crop-weather study at Akola and Nagpur are H-420 and Local Jadi.

3. Results

In the first instance, the behaviour of the crop at these two stations was studied by the analysis of variance method. The differential behaviour of the crop was then examined taking into consideration the rainfall during the various phases of the crop.

3·1. *Analysis of variance*

For the present study six years' data are made use of. The two varieties are the same at both the stations. Hence the apportionment of the variance and degrees of freedom for the main effect, first order interaction and the error will be as follows—

Due to	Degrees of freedom
(a) Between stations	1
(b) Between varieties	1
(c) Between years	5
(d_1) Interaction between stations and varieties	1
(d_2) Interaction between stations and years	5
(d_3) Interaction between varieties and years	5
(e) Error	5
Total	23

3.1.1. *Germination percentage and number of plants per sample when the crop is two months old*

Tables 1(a), 1(b) and 1(c) give the germination percentage under field conditions, the number of plants per sample when the crop is two months old and the analysis of variance for these two crops attributes respectively. At Nagpur, in the year 1949-50 gap filling was done and in the year 1951-52 and 1954-55 thinning operation was carried out. At Akola, gap filling was done in the years 1951-52, 1952-53 and 1953-54 and thinning in 1950-51 and 1954-55.

TABLE 1 (a)

Mean germination percentage under field condition

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	50	60	13	37	37·5
1950-51	52	37	35	48	43·0
1951-52	33	13	83	83	53·0
1952-53	31	37	47	51	41·5
1953-54	32	34	43	71	45·0
1954-55	65	50	58	64	59·3
Mean of all years	44	39	47	59	47·0

Variety mean Local : 45 H-420 : 49

Station mean Akola : 41 Nagpur : 53

Year	54-55	51-52	53-54	50-51	52-53	49-50	C.D.
Mean values	59·3	53·0	45·0	43·0	41·5	37·5	7·72

C. D.—Critical difference

TABLE 1(b)

Mean number of plants per sample of 8′ length of row

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	8·8	9·9	11·9	15·0	11·4
1950-51	9·0	8·9	15·6	17·0	12·6
1951-52	9·1	9·1	16·9	17·1	13·1
1952-53	9·5	9·7	13·8	16·9	12·5
1953-54	8·4	8·9	11·7	13·7	10·7
1954-55	10·2	8·2	12·3	13·1	10·9
Mean of all years	9·2	9·1	13·7	15·5	11·9

Variety mean Local : 11·5 H-420 : 12·3

Station mean Akola : 9·1 Nagpur : 14·6

Year	51-52	50-51	52-53	49-50	54-55	53-54	C.D.
Mean values	13·1	12·6	12·5	11·4	10·9	10·7	0·69

TABLE 1(c)

Analysis of variance for (a) germination percentage and (b) number of plants

Due to	Degrees of freedom	Variance for	
		Germination %	Number of plants
(a) Station	1	805·1†	177·6†
(b) Varieties	1	77·1	4·4†
(c) Years	5	228·3*	3·8†
(d_1) Stations × varieties	1	477·0*	5·0†
(d_2) Stations × years	5	903·3†	3·5†
(d_3) Varieties × years	5	116·6	1·0
(e) Error	5	29·8	0·24

*Significance at 5 per cent level

†Significance at 1 per cent level

From Table 1(a) it is observed that—

(*i*) On an average the germination percentage under field condition at Nagpur is better than at Akola,

(*ii*) The varieties behave differently at these two stations, H-420 giving better germination at Nagpur whereas Local has germinated better at Akola and

(*iii*) On an average, year 1954-55 has given good germination.

Table 1(b) brings out the following—

(*i*) Greater number of plants per unit area is retained at Nagpur after thinning, than at Akola,

(*ii*) Number of plants at Nagpur fluctuates to a greater extent from year to year than at Akola and

(*iii*) On an average more plants of the variety H-420 is retained at Nagpur whereas practically the same number of plants for both the varieties remains at Akola after thinning.

Table 1(c) giving the analysis of variance for germination percentage and number of plants per sample, indicates the magnitude of variation attributable to the various main and first order interactions. These variances have been tested against the error variance by the variance ratio method for 5 per cent and 1 per cent level of significance and indicated by * or †. Also from the error variances, the critical difference given in Tables 1(a) and 1(b) have been computed.

3.1.2. *Height, number of sympodial branches and flowers*

Tables 2(a), 2(b), 2(c) and 2(d) give (*a*) the mean final height of the end plants of the sample in centimetres, (*b*) the mean maximum number of sympodials in the end plants of the sample, (*c*) the mean of the highest number of flowers per sample for a day and (*d*) the analysis of variance for these three crop attributes, respectively.

Table 2 (a) indicates that—

(*i*) The mean height of the crop is higher at Akola than that at Nagpur. This may be due to less density of crop at Akola.

(*ii*) In a station, the height attained by the two varieties is more or less the same.

(*iii*) The height attained by the crop in the year 1954-55 is very low. This value for the year 1949-50 is also rather low. In the rest of the years, the height attained is more or less the same.

From Table 2(b) it is seen that—

(*i*) The number of sympodial branches produced by the crop at Akola is more than that at Nagpur,

(*ii*) Both the varieties have put forth more or less the same number of branches and

(*iii*) The crop has produced maximum number of branches in the year 1953-54 and minimum number in 1949-50. The years as arranged in the descending order of branch production are not the same as for height values.

Table 2(c), giving the highest number of flowers per sample of 8-foot length of row, shows that there is no appreciable difference in the number of flowers at the two stations and between the two varieties. However there is significant difference in this number from year to year. The order in which the years are ranked is practically the same as that for the crop height.

Table 2(d) gives the analysis of variance for the above discussed three crop characters. In addition to the inferences already drawn, this table shows that for height and number of sympodials of the crop, there is a differential response of the crop for the station and year as shown by the highly significant variance for the interaction between stations and years.

3.1.3. *Yield of Kapas, ginning percentage and halo length*

The cotton crop is usually picked in this tract in three instalments. For the purpose of analysis of variance the total yield of kapas from all the pickings and the mean ginning percentage and halo lengths for these pickings are taken into consideration.

TABLE 2 (a)

Mean final height in cm of end plants of the sample

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	66	54	88	87	73·7
1950-51	71	81	87	93	83·0
1951-52	95	95	75	68	83·3
1952-53	101	95	80	71	86·7
1953-54	94	90	76	73	83·3
1954-55	75	69	61	63	67·0
Mean of all years	84	81	78	76	79·5

Variety mean Local : 81 H-420 : 79

Station mean Akola : 83 Nagpur : 77

Year	52-53	51-52	53-54	50-51	49-50	54-55	C.D.
Mean values	86·7	83·3	83·3	83·0	73·7	67·0	5·09

C.D.—Critical difference

TABLE 2 (b)

Mean maximum number of sympodial per end plant

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	3·3	1·9	7·6	7·8	5·1
1950-51	11·0	11·3	8·4	8·9	9·9
1951-52	11·0	11·8	13·9	12·4	12·3
1952-53	12·0	10·6	10·1	8·7	10·1
1953-54	10·1	18·2	14·0	13·2	16·1
1954-55	16·5	16·1	10·1	9·4	13·0
Mean of all years	12·1	11·7	10·7	10·1	11·1

Variety mean Local : 11·4 H-420 : 10·9

Station mean Akola: 11·9 Nagpur : 10·4

Year	53-54	54-55	51-52	52-53	50-51	49-50	C.D.
Mean values	16·1	13·0	12·3	10·1	9·9	5·1	0·89

TABLE 2 (c)

Mean of highest number of flowers per sample

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	4·3	3·9	4·2	6·0	4·6
1950-51	5·2	7·2	4·9	5·6	5·7
1951-52	6·1	7·5	8·1	7·7	7·3
1952-53	6·6	5·9	7·1	6·9	6·6
1953-54	5·7	5·7	7·4	6·1	6·2
1954-55	4·1	3·5	3·4	3·3	3·6
Mean of all years	5·3	5·6	5·9	5·9	5·7

Variety mean Local : 5·6 H-420 : 5·7

Station mean Akola : 5·5 Nagpur : 5·9

Year	51-52	52-53	53-54	50-51	49-50	54-55	C.D.
Mean values	7·3	6·6	6·2	5·7	4·6	3·6	0·98

TABLE 2 (d)

Analysis of variance for (a) height, (b) number of sympodials and (c) number of flowers

Due to	Degrees of freedom	Variance for		
		Height	No. of sympodials	No. of flowers
(a) Stations	1	170·7*	14·6†	1·1
(b) Varieties	1	37·5	1·9	0·2
(c) Years	5	225·8†	54·2†	7·5†
(d_1) Stations × varieties	1	1·5	0	0·1
(d_2) Stations × years	5	449·3†	18·7†	0·9
(d_3) Varieties × years	5	39·7	0·4	0·7
(e) Error	5	12·9	0·4	0·48

*Significance at 5 per cent level

†Significance at 1 per cent level

The absolute values of

(*i*) the yield of kapas in pounds per acre,

(*ii*) the ginning percentage and

(*iii*) halo length in millimetres

are given in Tables 3(a), 3(b) and 3(c) respectively while the analysis of variance for these three crop characters are given in Table 3(d).

TABLE 3 (a)

Total yield of kapas in lbs per acre

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	366	226	490	628	427
1950-51	786	840	865	985	869
1951-52	1403	1257	1103	1004	1192
1952-53	1081	943	975	906	976
1953-54	861	800	1115	1110	971
1954-55	733	545	736	737	688
Mean of all years	872	769	881	895	854

Variety mean Local : 877 H-420 : 832

Station mean Akola : 821 Nagpur : 888

Year	51-52	52-53	53-54	50-51	54-55	49-50	C.D.
Mean values	1192	976	971	869	688	427	66·7

TABLE 3 (b)

Mean ginning percentage

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	32·4	33·3	33·5	32·4	32·9
1950-51	32·9	33·5	32·9	32·0	32·8
1951-52	32·9	33·4	32·6	31·8	32·7
1952-53	33·5	33·8	32·7	31·7	32·9
1953-54	34·2	34·1	32·6	33·3	33·3
1954-55	33·2	33·5	34·0	33·1	33·5
Mean of all years	33·2	33·6	33·1	32·4	33·1

Variety mean Local : 33·1 H-420 : 33·0

Station mean Akola : 33·4 Nagpur : 32·7

Year	54-55	53-54	49-50	52-53	50-51	51-52	C.D.
Mean values	33·5	33·3	32·9	32·9	32·8	32·7	0·66

TABLE 3 (c)

Mean halo length in millimetres

	Akola		Nagpur		Mean for the year
	Local	H-420	Local	H-420	
1949-50	16·2	20·0	18·3	21·1	18·9
1950-51	15·2	19·8	19·1	22·2	19·1
1951-52	15·5	20·1	16·3	23·5	18.9
1952-53	17·9	20·2	19·0	22·1	19·8
1953-54	16·5	20·4	19·5	23·0	19·9
1954-55	17·6	19·6	20·5	23·0	20·2
Mean of all years	16·5	20·0	18·8	22·5	19·4

Variety mean Local : 17·7 H-420 : 21·3

Station mean Akola : 18·3 Nagpur : 20·7

Year	54-55	53-54	52-53	50-51	49-50	51-52	C.D.
Mean values	20·2	19·9	19·8	19·1	18·9	18·9	1·77

C.D.—Critical difference

TABLE 3 (d)

Analysis of variance for (a) yield of kapas (b) ginning percentage and (c) halo length

Due to	Degrees of freedom	Variance for		
		Kapas	Ginning %	Halo length
(a) Stations	1	27,540*	2·7*	34·1†
(b) Varieties	1	11,837	0·1	78·5†
(c) Years	5	282,074†	0·5	1·3
(d_1) Stations × varieties	1	20,710*	1·8	0·1
(d_2) Stations × years	5	44,954†	0·5	0·6
(d_3) Varieties × years	5	6,257	0·1	1·6
(e) Error	5	2,231	0·22	1·56

*Significance at 5 per cent level

†Significance at 1 per cent level

From Table 3(a) it is seen that—

(*i*) On an average, Nagpur has yielded more kapas than Akola,

(*ii*) At Akola Local Jadi which is a mixture, has yielded more than H-420 variety and

(*iii*) The yield of kapas is maximum in the year 1951-52 and minimum in the year 1949-50.

The ginning percentage given in Table 3(b) shows that cotton at Akola gives greater percentage than at Nagpur whereas halo length given in Table 3(c) indicates the reverse result which is in agreement with the general observations namely 'greater the ginning percentage less the staple length'.

The variety H-420 has yielded higher halo length than Local Jadi.

Table 3(d) which gives the analysis of variance for all the three above discussed crop characters indicates that in addition to the differential response of station to varieties, the yield response of kapas from year to year is not similar at these two stations.

These differential responses of varieties to the two localities with respect to yield and halo length of kapas may be attributable to the interaction of climatic and soil characteristics.

3.2. *Rainfall versus crop attributes and yield*

The rainfall and the number of rainy days during the various phases of crop-growth namely, germination, elongation, development of sympodial branches, period of flowering and also the presowing rainfall, have been found out for these two stations for the six years. These are presented in a histogram along with the crop attributes.

3.2.1. *Presowing rainfall and germination percentage*

Fig. 1 gives presowing rainfall for six weeks before sowing and germination percentage (both the varieties put together). In the figure, on the left hand side, the germination and the rainfall are drawn for each year in the form of a histogram. Values given on the top of this histogram for rainfall indicate the number of rainy days. The figure also gives on the right hand side, the number of plants per sample eight weeks after sowing along with the rainfall and the number of rainy days during this period. It appears that (*i*) The presowing rainfall and number of rainy days have little influence on germination. Hence, moisture in the soil does not seem to be the limiting factor of germination. (*ii*) Germination is somewhat better at Nagpur than at Akola except for 1949-50. Also, when the germination percentage falls below 40, gap filling is resorted to. On the other hand, if it is more than 55, thinning of the crop is done. (In the year 1950-51, the seed rate at Akola was 29½ lbs per acre instead of 18 lbs, and hence in spite of rather low germination percentage thinning of crop was carried out). (*iii*) On an average the rainfall at Nagpur for the period of eight weeks after sowing is about 50 per cent more than that at Akola. The number of rainy days is also slightly more at Nagpur than at Akola. (*iv*) As the stand in the crop is adjusted by thinning or by filling up the gaps, the mean number of plants per sample in Akola is more or less steady but varies slightly at Nagpur. At Nagpur greater number of plants per unit length is retained than at Akola and this is perhaps due to more favourable conditions at Nagpur namely, more rains and better germination. Due to this thinning and filling up operation, the mean number of plants per sample appears to be independent of germination percentage.

3.2.2. *Elongation, sympodial branch developments, flowering and rainfall during these periods*

In the lower half of Fig. 2, the rainfall and number of rainy days during the period of (*a*) rapid elongation, (*b*) sympodial (fruiting) branch development and (*c*) flower opening are given. In the upper half of this figure, the maximum height in cm, maximum number of sympodial on end plant and maximum number of flowers per day are drawn for the two stations separately.

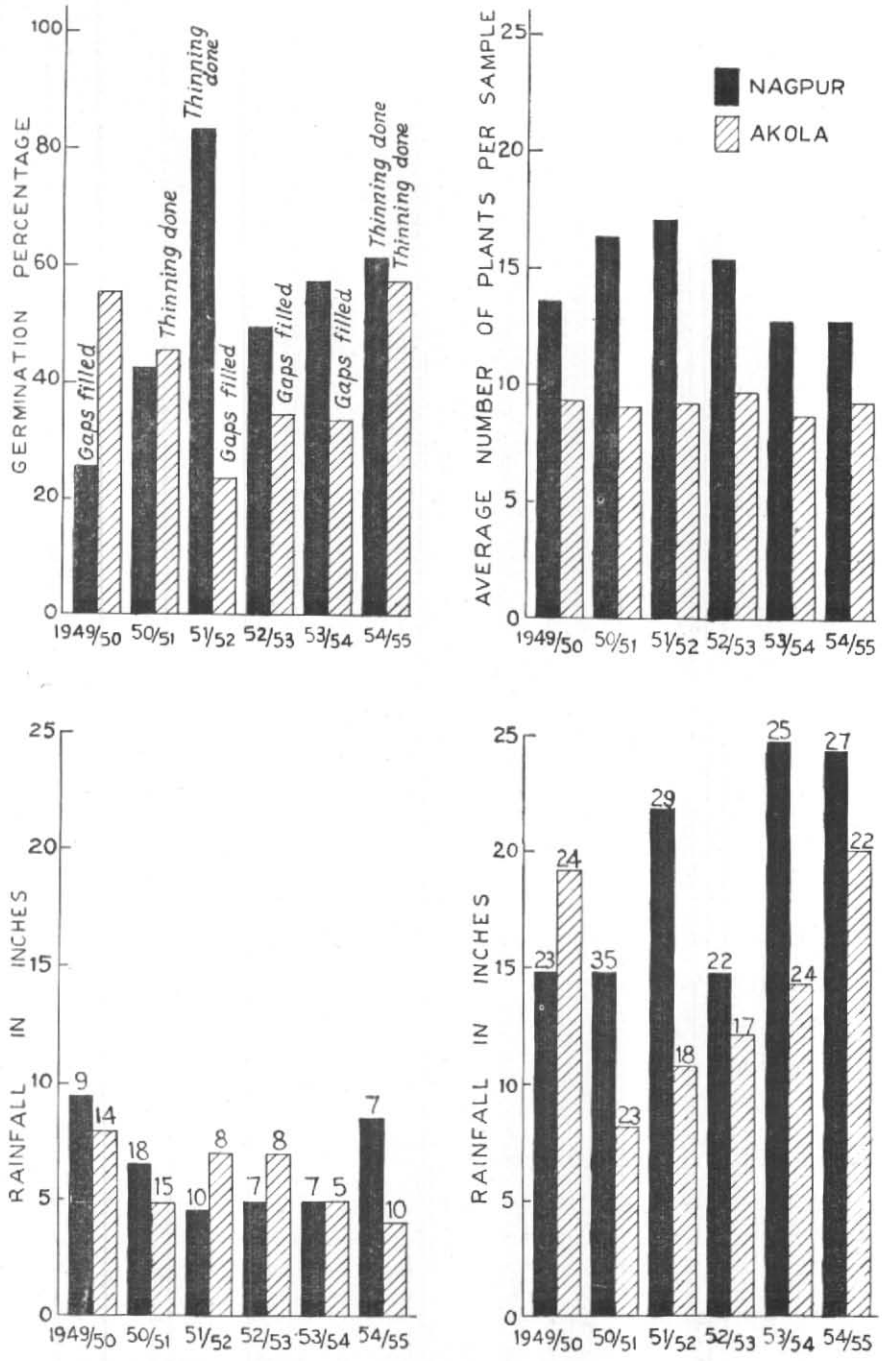

Fig. 1. Rainfall and germination

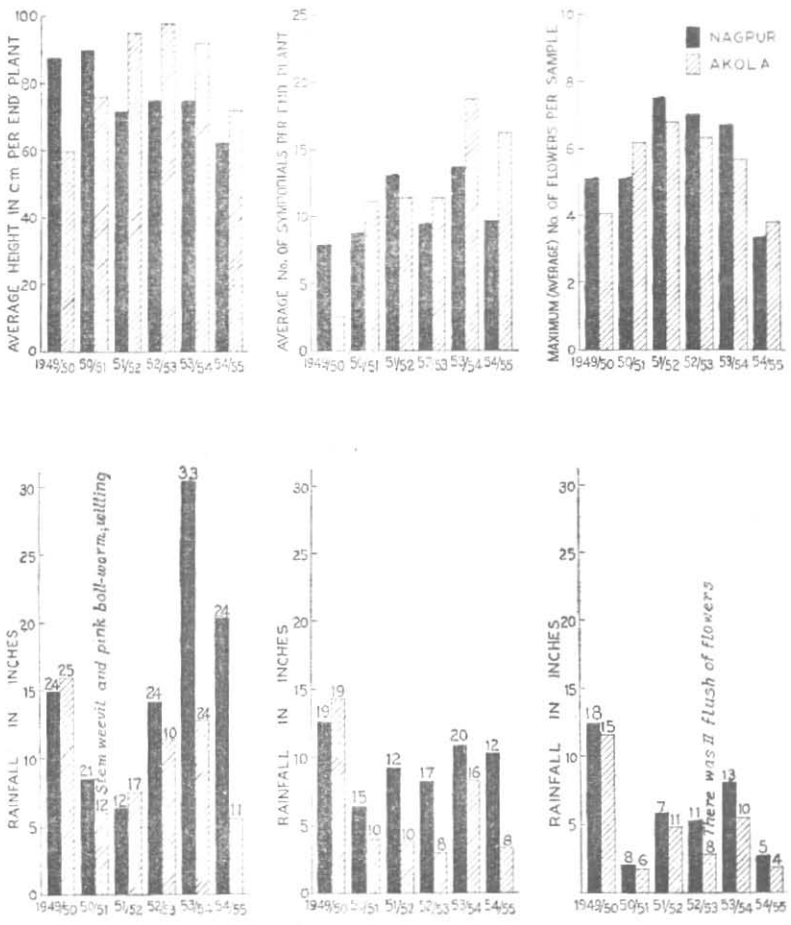

Fig. 2. Rainfall and (a) Elongation, (b) No. of Sympodials and (c) Maximum No. of Flowers

From the figure the following inferences may be drawn—

(*i*) The rainfall and number of rainy days during elongation period is much more in Nagpur than in Akola on the last two years. In the remaining four years the rainfall is more or less of the same order at both the stations. The rainfall at Nagpur is more fluctuating than at Akola.

(*ii*) There is not enough evidence to state that more rainfall or greater number of rainy days lead to better height. In general, the crop at Akola seems to be somewhat taller than at Nagpur.

(*iii*) During these six years, rainfall during the period of sympodial development is between 3″ to 15″ and number of rainy days is 8 to 20. More rain as in 1949-50 and greater number of rainy days as in Nagpur in 1953-54, seem to depress the branch formation. In this phase also, Nagpur receives more rain than Akola.

(*iv*) Fluctuations in the maximum number of sympodial branches is more in Akola than in Nagpur. Also cotton grown at Akola produces somewhat more number of sympodials than at Nagpur.

(*v*) Too much or too little rainfall and number of rainy days produce less number of flowers. The amount and distribution of rainfall received during this period are more or less similar at both the stations.

(*vi*) The maximum number of flowers at Nagpur in a year agrees well with that produced at Akola. This may again be due to similar amount and distribution of rainfall during flowering period as mentioned in the previous para.

3.2.3. *Yield of kapas*

Fig. 3 gives the histogram of yield of kapas along with a few essential remarks. It is seen that —

(*i*) Yield fluctuates to a greater extent at Akola than at Nagpur. This is attributable mostly to lesser and more precarious rainfall at Akola during the elongation and development of sympodial branches,

(*ii*) On an average, yield of kapas from cotton crop at Akola and Nagpur is of the same order, and

(*iii*) The variation in the yield from year to year is more or less in the same fashion at both the stations.

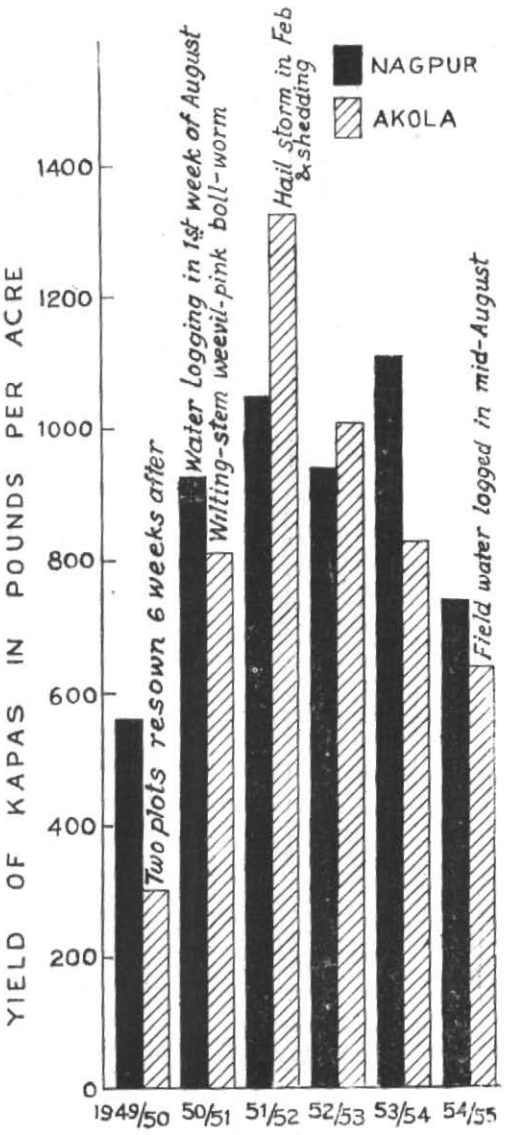

Fig. 3. Yield of Kapas (Cotton)

4. Discussions

In order to evaluate the effect of the multifarious weather factors on crop growth and yield, it is not only advisable but also essential to collect systematically for a long series of years, the crop data right from the time of sowing to harvest along with the weather data. Nevertheless, for preliminary studies, the replication in space may be treated as replication in time provided —

(*i*) the soils at these stations are comparable and

(*ii*) the varieties are the same or at least behave alike for a given set of climatic conditions. Akola in Berar and Nagpur in Madhya Pradesh are situated in black cotton soil of Deccan trap and are separated by about 140 miles. The two varieties under crop-weather study are also the same at both these places. Hence the two conditions stated above are fulfilled, thereby making it possible to treat the replication in space as equivalent to replication in time. The significant variation between stations for all crop characters and yield except maximum number of flowers, indicates that the crop behaviour at Nagpur is different from that grown at Akola. This differential behaviour cannot be attributed entirely to the difference in soil fertility. For, the variance due to the interaction between stations and years is highly significant for most of these crop characters. In other words, there is a differential response of the crop from year to year at these two stations and this can be attributed only to the difference in weather factors at these two stations. The variance due to years is of much higher order than the variance between stations for most of the crop characters, indicating thereby the greater influence of weather on the crop.

The aim of including two varieties in crop-weather study is to find out whether the response of the varieties to the weather factors is similar or not. From the variances due to the interaction between varieties and years given in Tables 1, 2 and 3, we may infer that the two varieties response alike to the weather factors. Even the variances between varieties namely, Local Jadi and H-420 are not significant for all crop characters except the number of plants which is controlled by seed rate and cultivation practices and the halo length.

Of all the weather conditions, rainfall is perhaps the most important. Hence in this paper an attempt has been made to present the rainfall and the number of rainy days during the various phases of the crop. From a study of these graphs, it appears that rainfall is not a limiting factor for germination and the elongation of the crop. However, it appears to influence the sympodial branch formation and maximum flower opening. Thus there are certain critical phases of the crop where weather plays a major influence. The weather changes the duration of various phases of the crop. Thus the elongation period is nearly 73 days in Nagpur while it is hardly 66 days in Akola. But the duration of sympodial branching is longer at Akola than at Nagpur, being 60 days and 52 days respectively. This difference is still greater in period of flower opening being 84 days in Akola and only 50 days in Nagpur. Since the varieties grown at these stations are the same, the reason for this difference in the various periods of the crop has to be looked into in weather factors alone. This can be done only when more data are collected.

5. Acknowledgements

The authors are deeply indebted to Shri S. P. Venkiteshwaran, Director of Agricultural Meteorology, for kindly going through the paper critically. Also, our thanks are due to the various authorities who were directly and indirectly responsible for collecting the data at these two stations.

REFERENCES

Fisher, R. A.	1950	*Statistical Methods for Research Workers*, Oliver and Boyd, London.
Fisher, R. A. and Yates, F.	1948	*Statistical Tables for Biological, Agricultural and Medical Research*, Oliver and Boyd, London.
India met. Dep.	1953	*Agrimet. Tech. Circ.* (revised), 50.
Snedecor, G. W.	1946	*Statistical Methods*, The Iowa State Coll. Press, Ames, Iowa.