

Comparison of the Fan Design with the Split Plot Design for Spacing Experiments

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ABSTRACT

Nelder's design FAN (Systematic design) was compared with the Split Plot design (SPL) for spacing treatments. The field experiments were conducted using cotton IAN 579-188 on the same field. The data on plant height, number of bolls per plant and cotton yield per plant were collected and used to assess bias in the estimate of treatment means. The results revealed that (i) the comparison FAN vs SPL showed an underestimation of the treatments means in FAN when area per plant was 900 sq.cm. and above and (ii) the rectangularity had some impact on the variables studied. Therefore, FAN design can not be used for spacing trial on a crop with monopodial growth habit like cotton IAN 579-188.

(Received on 1st Nov. 1982)

INTRODUCTION

Fan design has been developed by Nelder (1962) for spacing experiments. Design consisted of single row plots for each spacing treatment arranged in much compacted area in a sequence (Systematic pattern). The systematic arrangement gives biased estimates (Tedin, 1931; Fisher, 1935; Barbacki and Fisher, 1936; Greenberg, 1951; Salmon, 1955 and Patel, 1978). Such information, however, is not available for fan design.

The spacing trials need large area under each replication of conventional designs like randomized block design, split plot design etc. for testing a number of spacing treatments. Generally spacing trials are conducted in split plot design to ease agronomical operations. In the present investigation the relative utility of Fan design (FAN) was assessed in relation to Split plot

design (SPL). For this purpose investigation on cotton IAN 579-188 was undertaken during the years 1973-74 and 1974-75 at the College Agronomy Farm, Gujarat Agricultural University, Anand Campus, Anand.

Spacing treatments

Keeping in view the growth habit of the cotton IAN 579-188, the different spacings were considered which varied from 0.045 m² to 0.270 m² per plant in both the layouts. The parameters of FAN were worked out as suggested by Nelder (1962). There were 10 spacing treatments in FAN (Table 1).

For SPL, a set of combinations of 30 cm, 60 cm and 90 cm as inter row spacings (Main plots) and 15 cm, 22.5 cm and 30 cm as intra row spacings (sub plots) was chosen. The smallest and largest spacings in the FAN matched with the smallest and largest spac-

TABLE 1
Spacing details for FAN and SPL.

FAN		SPL	
Coded spacing, S_j	Area per plant sq.cm.	Coded spacing, Sp_j	Area per plant, sq. cm.
S_1	450	Sp_1	450
S_2	550	Sp_2	675
S_3	670	Sp_3	900
S_4	820	Sp_4	900
S_5	990	Sp_5	1350
S_6	1220	Sp_6	1800
S_7	1490	Sp_7	1350
S_8	1820	Sp_8	2025
S_9	2220	Sp_9	2700
S_{10}	2700	—	—

ings of the SPL. The net plot size was 3.6 m x 3.6 m. in SPL.

The number of replications during both the years were 12 and 6 for FAN and SPL respectively.

RESULTS AND DISCUSSION

The data on plant height as well as number of bolls per plant of five

randomly selected plants and cotton yield per plot were collected from both the layouts to assess relative utility of FAN in relation to SPL. There were eight observations ($P_{1.1}$ through $P_{1.8}$) on plant height during the first year and three observations ($P_{2.1}$, $P_{2.2}$ and $P_{2.3}$) during the second year of the study. The corresponding observations in SPL were used in estimating differences in plant height (FAN vs SPL).

Since the number of treatments (Table 1) were not the same in FAN and SPL and also the area per plant in some of the treatments in FAN and SPL did not match with one another, the difference in spacing treatment means (bias) was judged using graphical method.

Plant height

data for various spacing treatments in each period of observation for FAN and SPL are presented in Tables 2 and 3 respectively and are depicted in Figures 1 (1973-74) and 2 (1974-75).

TABLE 2
Spacingwise plant height, in cm, during each period of observation in FAN.

S_j	1973-74								1974-75		
	$P_{1.1}$	$P_{1.2}$	$P_{1.3}$	$P_{1.4}$	$P_{1.5}$	$P_{1.6}$	$P_{1.7}$	$P_{1.8}$	$P_{2.1}$	$P_{2.2}$	$P_{2.3}$
S_1	68.2	76.5	79.1	81.7	81.8	82.7	83.8	86.6	82.5	99.3	104.9
S_2	68.2	75.0	76.7	78.4	79.7	80.8	81.6	84.3	82.3	100.5	108.3
S_3	65.4	74.9	77.5	79.4	81.6	85.2	85.4	86.4	78.7	91.8	97.3
S_4	67.1	76.6	78.1	80.0	82.3	82.3	83.6	86.6	81.6	95.0	101.1
S_5	65.4	75.5	79.7	81.8	83.6	84.7	85.9	89.7	75.2	88.6	96.2
S_6	64.7	76.1	78.3	81.0	83.2	83.8	84.5	87.1	72.5	84.7	92.2
S_7	68.1	79.1	83.4	86.1	88.6	90.1	90.2	94.1	69.3	85.2	91.0
S_8	67.3	79.6	85.0	87.7	90.4	90.7	92.3	95.6	70.1	86.8	94.8
S_9	65.8	81.2	84.7	87.8	91.3	91.5	91.9	97.2	68.5	85.2	92.2
S_{10}	64.3	78.8	84.2	88.1	90.4	91.8	93.0	96.6	63.2	80.3	88.6
Average	66.5	77.3	80.7	83.2	85.3	86.4	87.2	90.4	74.7	89.3	96.7

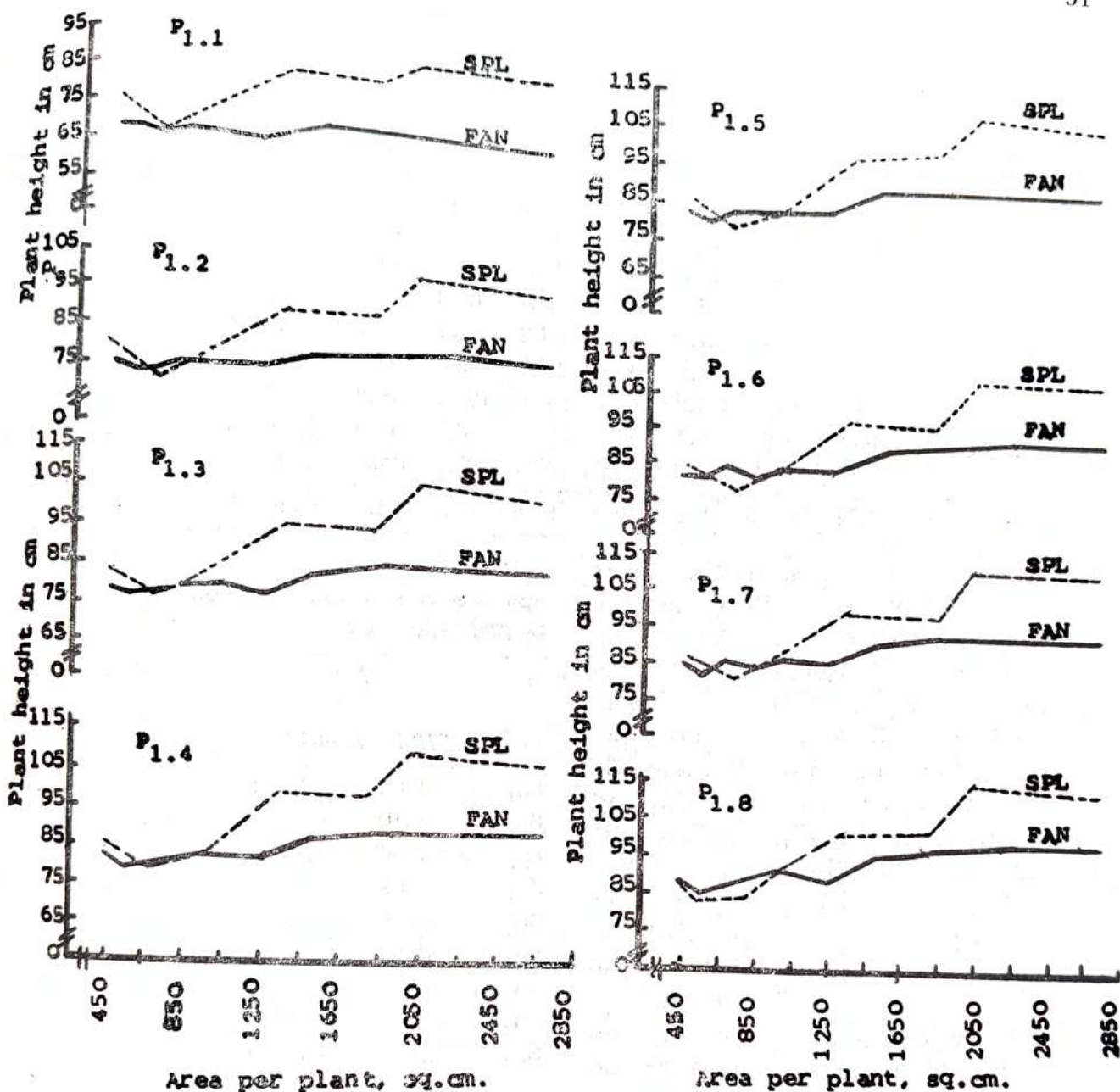


Figure 1: AVERAGE PLANT HEIGHT IN VARIOUS SPACINGS IN SPL AND FAN DURING P_{1.1} THROUGH P_{1.8}.

The results presented in Tables 2 and 3 reveal that the spacing treatments with area 900 sq. cm and above had greater plant height in SPL than the height in FAN. The plant height (Table 3) was less in Sp₃ than that in Sp₄, both having the same area (900 sq. cm) per plant but differing in rectangularity (1:1 in Sp₃ and 4:1 in Sp₄). Likewise Sp₅ had smaller plant height in each period of observation during both the years compared with that in Sp₇,

both having same area per plant but differing in rectangularity, 8:3 in Sp₅ and 6:1 in Sp₇. The results, therefore, indicate that the rectangularity i.e. inter and intra row spacing had some impact on the plant height of cotton IAN 579-188. Such information can not be obtained for FAN as it has constant and almost square rectangularity.

The difference in plant height in the corresponding spacing of FAN and SPL are indicative of bias in the estimates.

TABLE 3

Spacingwise plant height, in cm, during each period of observation in SPL.

Sp_j	19.3-74								1974-75		
	$P_{1'1}$	$P_{1'2}$	$P_{1'3}$	$P_{1'4}$	$P_{1'5}$	$P_{1'6}$	$P_{1'7}$	$P_{1'8}$	$P_{2'1}$	$P_{2'2}$	$P_{2'3}$
Sp_1	76.6	81.2	82.7	83.9	84.9	85.2	86.2	88.1	71.7	88.6	89.6
Sp_2	67.4	73.8	77.4	78.1	78.8	80.1	80.8	81.1	73.2	91.9	94.2
Sp_3	71.2	76.3	77.8	79.2	80.2	81.3	81.5	84.1	72.4	92.6	93.6
Sp_4	73.6	79.6	81.7	83.2	84.1	84.8	87.9	90.8	82.6	100.5	100.9
Sp_5	75.9	84.4	87.9	89.7	91.2	91.5	93.1	94.7	74.1	94.0	95.8
Sp_6	80.0	90.5	94.5	96.8	99.5	97.3	97.4	101.2	77.0	94.6	94.8
Sp_7	88.5	98.3	101.8	103.4	104.9	105.3	106.2	107.4	86.4	111.0	111.5
Sp_8	85.0	100.3	106.3	108.4	110.2	110.3	111.3	113.9	79.8	102.4	102.7
Sp_9	82.5	97.1	102.8	105.2	107.4	107.4	108.5	110.5	72.4	97.2	98.3
Average	77.9	86.8	90.3	91.7	93.5	93.7	94.8	96.9	76.6	97.0	97.9

The smallest and largest spacings were common in SPL and FAN i.e. Sp_1 matched with S_1 and Sp_9 matched with S_{10} . Two more spacings; Sp_2 with S_3 and Sp_6 with S_8 nearly matched (about 1% difference) in terms of area per plant. The matching pairs Sp_1 and S_1 , Sp_2 and S_3 , Sp_6 and S_8 and Sp_9 and S_{10} have been coded as $S'_{1'}$, $S'_{2'}$, $S'_{3'}$ and $S'_{4'}$ respectively. The differences in plant height (FAN vs SPL) in these spacings ranged from -10.92% to 1.78% in $S'_{1'}$, -0.79% to 4.31% in $S'_{2'}$, -15.88% to -5.55% in $S'_{3'}$ and -22.10% to -12.56% in $S'_{4'}$ during first year. The corresponding difference observed during second year were 12.13% to 17.50% in $S'_{1'}$, 0.16 to 7.51% in $S'_{2'}$, -9.02% to 0.5-1% in $S'_{3'}$ and -17.35% to -9.90% in $S'_{4'}$. The trend in difference in plant height (FAN vs SPL) in $S'_{2'}$, $S'_{3'}$ and $S'_{4'}$ was consistent in both the years. But $S'_{1'}$ had inconsistent trend in two years which may be due to seasonal fluctuations.

It is clear from the results that the FAN design gives underestimation of plant height when area per plant was 900 sq.cm and above. This is supported by the results presented in Figures 1 and 2 also.

TABLE 4

Spacing-wise number of bolls per plant in SPL and FAN.

Sp_j	SPL		S_j	FAN	
	1973-74	1974-75		1973-74	1974-75
Sp_1	8.80	7.16	S_1	6.73	4.82
Sp_2	6.10	6.64	S_2	6.07	4.32
Sp_3	8.66	7.40	S_3	6.33	3.80
Sp_4	9.67	8.04	S_4	7.40	4.37
Sp_5	10.93	8.68	S_5	7.38	4.63
Sp_6	15.36	11.24	S_6	9.53	5.37
Sp_7	15.43	7.72	S_7	12.75	5.80
Sp_8	19.26	9.40	S_8	13.07	7.18
Sp_9	22.46	10.60	S_9	15.40	8.48
—	—	—	S_{10}	18.32	9.95
Average	12.74	8.54	—	9.88	5.67

Number of bolls per plant for various spacings in FAN and SPL are presented in Table 4 and are graphically presented in Figure 3.

The examination of the results (Table 4) reveals that in general, the number of bolls per plant in FAN was less than that in SPL during both the years. Like plant height, rectangularity played a vital role in the performance of the attribute in the spacing trials. The com-

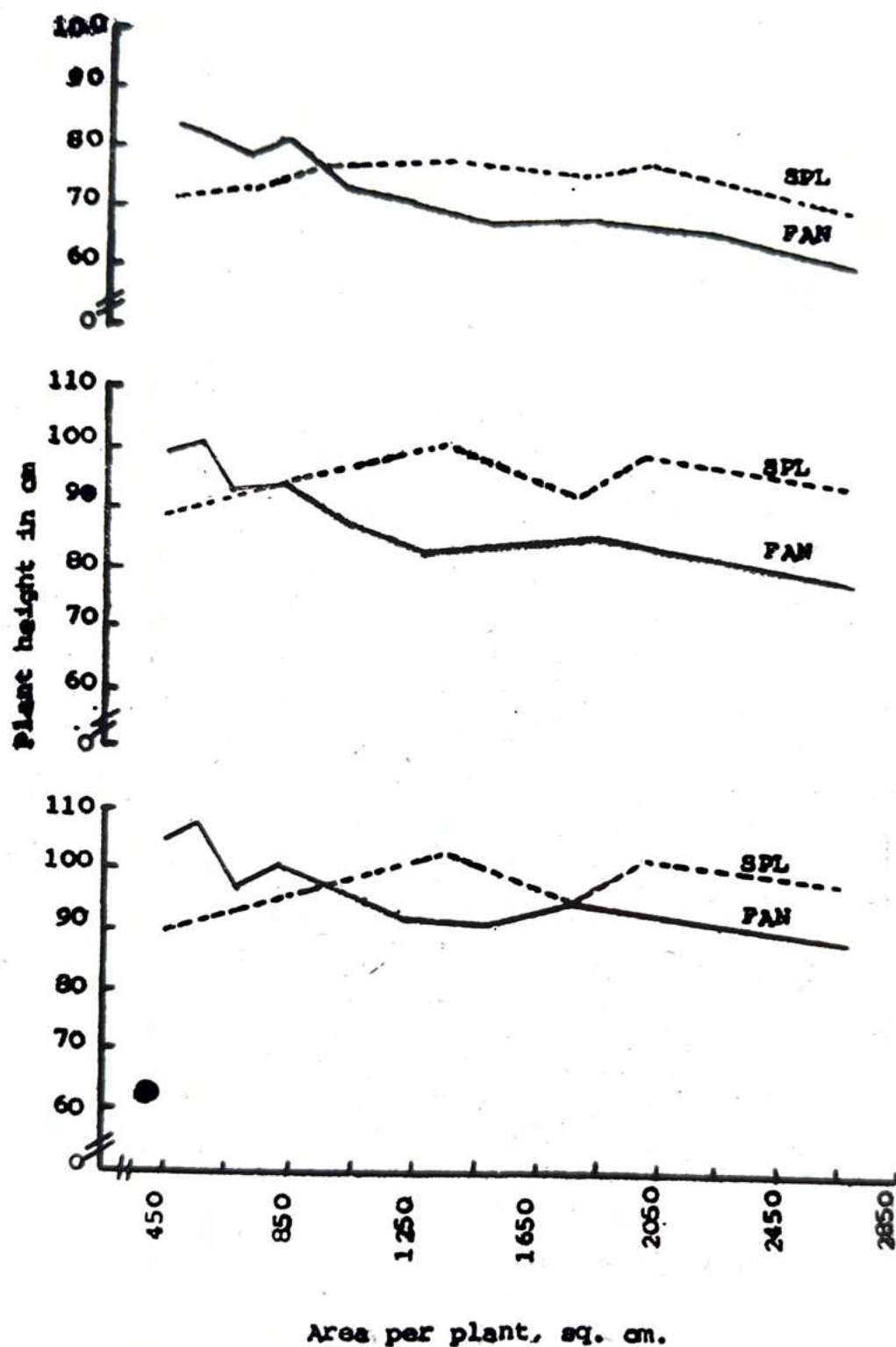


FIGURE 2: AVERAGE PLANT HEIGHT IN VARIOUS SPACINGS IN SPL AND FAN DURING $P_{2.1}$ (UPPER), $P_{2.2}$ (MIDDLE) AND $P_{2.3}$ (LOWER).

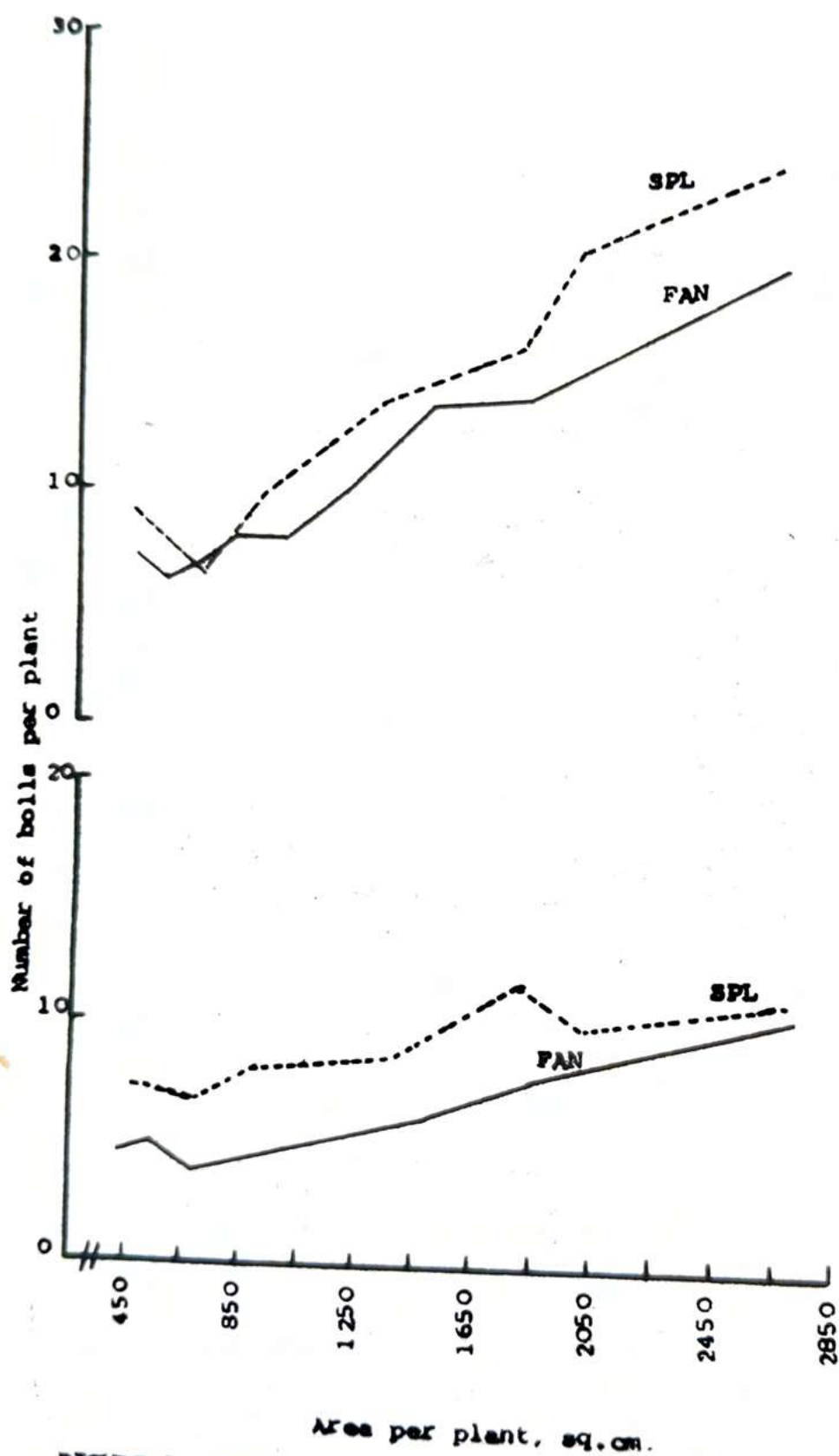


FIGURE 3: AVERAGE NUMBER OF BOLLS PER PLANT IN VARIOUS spacings in SPL and FAN during 1973-74 (UPPER) AND 1974-75 (LOWER).

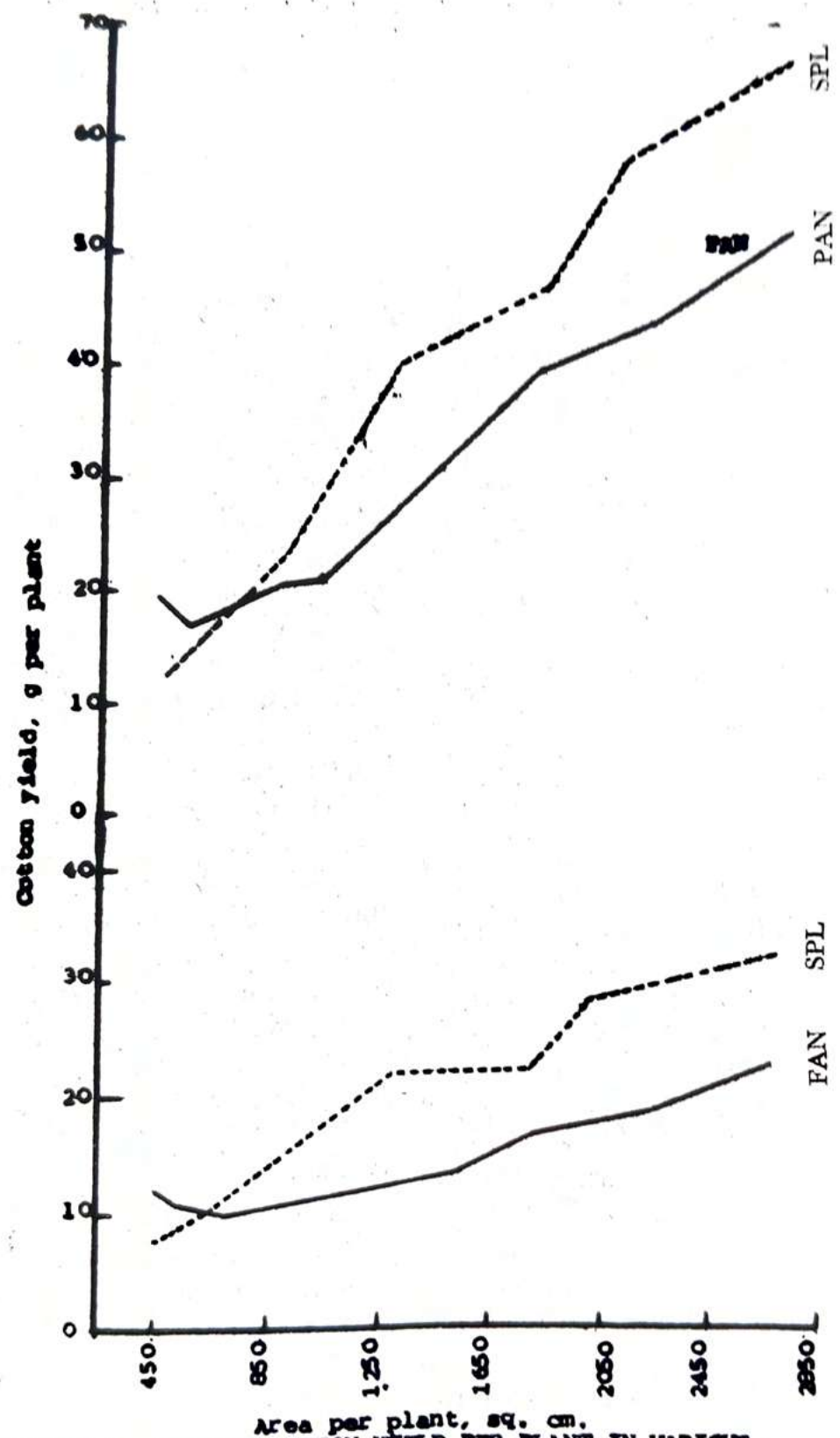


FIGURE 4. AVERAGE COTTON YIELD PER PLANT IN VARIOUS SPACINGS IN SPL AND FAN DURING 1973-74 (UPPER) AND 1974-74 (LOWER)

parison of common spacing treatments (FAN vs SPL) over seasons showed that the S'_1 , S'_2 , S'_3 and S'_4 had negative differences in the number of bolls per plant. It is also clear from Figure 3 that, except for one spacing S_3 in FAN, all other spacings in SPL had greater number of bolls per plant than the corresponding spacing in FAN. On the basis of two season's data it can be concluded that the estimates of the average number of bolls per plant in FAN are biased.

Cotton yield per plant for various spacing treatments in FAN and SPL are presented in Table 5 and are depicted in Figure 4.

TABLE 5

Spacingwise cotton yield, g per plant in SPL and FAN.

Sp_j	SPL		S_j	FAN	
	1973-74	1974-75		1973-74	1974-75
Sp_1	11.52	7.87	S_1	19.11	12.09
Sp_2	18.45	10.37	S_2	16.77	10.58
Sp_3	22.58	13.77	S_3	18.25	9.78
Sp_4	24.63	15.04	S_4	20.18	10.30
Sp_5	37.49	20.04	S_5	20.84	11.32
Sp_6	47.41	22.15	S_6	26.83	12.30
Sp_7	43.31	23.80	S_7	34.34	12.98
Sp_8	59.13	28.54	S_8	40.63	16.28
Sp_9	69.06	32.23	S_9	45.06	18.28
—	—	—	S_{10}	53.42	22.89
Average	37.06	19.63	—	29.54	13.68

The results presented in Table 5 reveal that the average cotton yield per plant in SPL was more than that in FAN. The cotton yield per plant increased with the increase in area per plant in SPL during both the years of study. In case of FAN the cotton yield per plant decreased from 19.11 in S_1 to 16.77 in S_2 during first year and from 12.09 in S_1 to 9.78 in S_3 during second year and thereafter it

increased with the increase in spacing. The spacings Sp_3 and Sp_4 (having same area of 900 sq.cm) and Sp_5 and Sp_7 (having same area of 1350 sq.cm) in SPL showed deviation in cotton yield per plant which may be attributed to rectangularity.

The differences in cotton yield per plant in the corresponding spacings of FAN and SPL are indicative of bias in the estimates. These differences for S'_1 , S'_2 , S'_3 and S'_4 were compared and found that the average cotton yield in S'_1 in FAN was more than that for the corresponding spacing in SPL in both the years. In case of S'_2 , S'_3 and S'_4 the average cotton yield per plant in SPL was more than in FAN. It is evident from the Figure 4 that the cotton yield per plant was more in SPL than that in FAN when the area per plant is 900 sq.cm and above. The results thus lead to the conclusion that the estimates of average cotton yield per plant in FAN are biased.

The results presented in Tables 2 through 5 revealed that the FAN, in general, gives underestimation of plant height, number of bolls per plant and cotton yield per plant. Tedin (1931), Barbacki and Fisher (1936), Yates (1939), Greenberg (1951) and Salmon (1955) had also reported bias in systematic arrangements.

The adjacent plots of FAN may have a border (marginal) effect on each other which is not possible to evaluate directly. Hence the alternative layouts were simulated and studied for obtaining estimates of border effect, if any. It was observed that there was no border effect and the FAN can be used for spacing experiments on crops with monopodial type of growth habit such as cotton IAN 579-188 (Patel, 1978).

The bias observed in treatment means in FAN was due to systematic arrangements

of single row plots. Therefore, a method for adjustment of bias need to be developed particularly for FAN design. The ractangularity plays vital role in crop geometry and therefore, it should be given due consideration in planning of the spacing experiments.

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