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My dear Dr.Murty,

I have carefully gone through the paper "Genetics of yield and fibre quality in an inter-varietal cross in Gossypium hirsutum L." by Drs. S.S.Bains, A.B.Joshi and yourself sent with your D.O.No.9574 of 25th November, 1971.

I feel that the paper is rather lengthy and could be condensed. For instance, you may perhaps delete the results obtained using Mather (1949) model as this is known to be less satisfactory and more satisfactory models have been used in this study. The paper also needs to be better organised, see for instance p. 11 of the manuscript. Kindly check the captions of the tables. For instance, Table 5 & 6.

Standard for comparison

Another point which needs clarification is the statement of p. 10 (last para) regarding the superiority of design II in obtaining desirable combination. Is this superiority, a function of the design, or the larger number of crosses involved in design II in the present study as opposed to the fewer crosses in design I. Perhaps by having a larger number of half sub sets, design I could also give a number of desirable segregate. If it is the advantage of the greater number of genotypes used in design II, cannot this be reached in design I by reducing the number of female to which each male is mated.

Irrelevant here as [illegible]

While there is no doubt that design II is superior to design I for genetic analysis, is it equally superior for breeding programme also?

I shall be grateful if you can kindly condense the paper in the light of the above suggestion and return it as early as convenient.

With kind regards,

Yours sincerely,

SRamanujam
(S.RAMANUJAM)

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GENETICS OF YIELD AND FIBRE QUALITY IN AN INTER-VARIETAL CROSS IN *GOSSYPIUM HIRSUTUM* L.

By

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A major cause limiting advance under selection in allogamous and partially allogamous populations is the presence of linkage disequilibrium and the mimic k ing of overdominance by repulsion-phase linkages (Moll and Robinson, 1967). The role of th~~is~~ese phenomenon a can be examined only in generations subsequent to F_2. Such estimates ~~should~~ also need to be related to changes in the association of characters from F_2 to the subsequent generations, where intermating is practised to dissipate the effects of linkage disequilibrium. Limited information is available on fibre quality characters in interspecific crosses of Gossypium with such matings in biparental progenies (Ramey and Miller, 1966); but no information is available on intra-specific materials. In view of the above considerations, the present study ~~is~~ was undertaken using different ⊗ ~~to analyse the above phenomena for~~ for yield of seed cotton, boll weight, number of bolls per plant, ginning percentage, seed index, lint index, fibre length, fibre fineness, fibre shape and fibre strength. ~~in a cross between H.14, a locally adapted type to North India, and GL.20, a Sudanese introduction which has superior fibre properties on the following lines:-~~

~~(1) Analysis of the nature of gene action using parents, F_1, B_1, B_2 and F_2 by the methodology of Hayman~~

⊗ designs of ~~an~~ intermating at the F_2 level in an inter-varietal cross in upland cotton for estimating the various genetic ~~para~~ parameters for

~~(1958) and variance component analysis of Mather (1949)~~

(2) ~~A comparison of the estimates of variance due to additive, dominance and interaction from design I, design II, and design III of matings of Comstock and Robinson (1952)~~

(3) ~~To compare their efficiency and to assess the changes in association between yield and fibre quality due to differences in the mating system as compared to their base populations and also to investigate the changes in the means of derived populations.~~

MATERIAL AND METHODS 1 & 5 cap

The two varieties CL.20 (P_1) and H.14 (P_2) as well as the F_2 seeds of the cross between them formed the initial material, grown in kharif 1968. H.14 is a standard variety of American cotton locally adapted ~~and~~ recommended for cultivation in the Northern region of India. It has a good yielding ability. This has a mean fibre length of 24.5 mm,, ~~records~~ [illegible] a ginning-out-turn of 34.4 per cent, ~~has 8.36~~ a Pressley ~~pressing~~ strength index, of 8.36, yields about 300 kg/ha.of lint and has wide adaptability. CL.20 is a Sudanese cotton variety introduced into this country in 1960. It is a strong-fibred (10.18 Pressley strength index), long linted cotton (26.48 mm), having 36.2 % ~~per cent~~ ginning-out-turn but poor in lint yield (about 180 kg/ha). The biparental crosses, using all the three methods of Comstock and Robinson (1952), were made in the F_2 population of this cross comprising ~~of~~ 500 plants.

The design I progenies were formed by designating a random sample of twelve F_2 plants as male parents and crossing each of these to four randomly chosen F_2 plants used as females. The plants used in the crossing programme were also selfed.

12 × 4 = 48

only one set?

48

In design II, eight F_2 plants were assigned to a set at random, four being designated as male parents and four as female parents. All the sixteen possible intercrosses were made among these F_2 plants and at the same time each was selfed to give an F_3 progeny. Ten of these sets were made by the use of different random samples of eight F_2 plants in each set.

Indicate no. of progs

~~8~~ × 10 = 160

160

In design III, fifteen F_2 plants were randomly chosen as male parents. Each male parent was backcrossed to each parental line to produce a pair of backcross progenies. The F_2 plants were selfed to give the corresponding F_3 progenies.

How many such crosses

30

The material sown in <u>kharif</u> 1969 in two replications in RCB design consisted of the two parents, F_1, F_2, B_1, B_2, F_3s obtained by selfing the corresponding o~~f design~~ I(F_3DI), F_3s of
F_2 plants used in the making of designs I ~~and~~, II and III.
design II (F_3DII), F_3s of design III (F_3DIII) and the and
the corresponding BIPs ~~in each of the above designs~~.
bipa~~rental progenies created after crossing F_2s i.e., progenies of design I (DI), progenies of design II (DII) and~~
as the [illegible] intermating F_2 segregants,
within each design. The [illegible] i.e., the [illegible] F_3's are
pro~~genies of design III (DIII)~~. designated as F_3 DI, F_3 DII and
and F_3 DIII and the corresponding
BIP's as DI, DII and DIII respectively

#
Ⓧ
The observations on yield ~~and~~ its components and the fibre quality characters were recorded according to the standard procedures used in this crop. Fibre length, strength and fineness were measured in terms of halo length, Pressley strength index, and micronaire value respectively.

Ⓧ

RESULTS

L & S Caps

Anova for Generation Means

Sep. Rom

~~As mentioned earlier, in Materials and Methods, each generation was grown in two replications.~~ ~~The~~ Analysis of variance (Tables 1, 2a, 2b ~~etc~~) revealed highly significant differences between the generation means for all the characters studied.

The mean performance of the twelve different generations studied for characters like yield per plant, boll weight, number of bolls per plant, ginning percentage, seed index, lint index, fibre length, fibre fineness, fibre shape and fibre strength ~~was~~ is shown in Table 1. The F_1 was intermediate between the parents for all the characters. However, it was closer to the superior parent.

There was significant decrease in the F_2 mean as compared with the F_1 for yield, seed index and fibre shape. The decrease was very large for boll weight, fibre length and fibre strength. The F_2 was at par with the F_1 ~~and~~ for boll number, ginning percentage, lint index and fibre fineness.

The means of backcrosses were intermediate between the F_1 and the corresponding recurrent parent, for all characters.

~~The selfed progenies of the F_2 plants used in mating for design I, design II and design III correspond to the F_3s. These were designated as F_3DI, F_3DII and F_3DIII. to allow further comparisons of their performance with the corresponding crossed progenies in the respective matings.~~

The F_2 means were compared with the corresponding composite means of F_3DI, F_3DII and F_3DIII. The F_3 mean values were ~~significantly~~ lower than F_2 means for all characters, ~~but~~ the difference being statistically significant only for boll weight, seed index and fibre strength ~~boll weight, seed index and fibre strength. However, the means of F_3 were consistently lower than the F_2 means for all characters.~~

The composite mean of BIP's or within DI, DII and DIII ~~intercrosses, i.e., design I (DI), design II (DII) and design III (DIII),~~ were each ~~showed~~ signi-

larger than the respective
cant ~~increase over~~ F_2 means for boll weight and fibre
The with respect to limited
strength. ~~Limited and in~~significant increase ~~was~~
not
~~observed for~~ yield, boll number, ginning percentage
were ~~limited~~ small and non-significant.
and fibre shape. ~~A significant increase was observed~~
The composite means for BIPs
for yield, boll weight, ginning percentage, seed index,
fibre shape and fibre strength ~~in the~~ composite means
~~BIPs are larger than~~
of ~~intercrosses as compared with~~ the ~~composite~~ F_3 means.
were larger than the corresponding composite F_3 means.

BIPs averaged over all the
The means of ~~intercrossed~~ population, ~~in all the~~
were larger than
~~three designs~~, ~~showed~~ significant ~~increase over~~ their
corresponding F_3 means for yield, boll weight, ginning
percentage and fibre strength. In DI, there was also
significant increase over F_3DI mean for boll number, seed
index and fibre shape. Also, characters like seed index,
lint index, fibre length and fibre shape showed significant
increase in DII means as compared to the F_3DII means.

salient
~~The silent features of the data in Table 1 may~~
~~be summarised as follows:~~
It comes thus appear from Table 1 that:

means of BIP's
~~(1)~~ (1) The ~~intercrosses~~ were, in general, better
not only was straight ~~[illegible]~~ better than the F_2's also and in
than ~~F_2 and~~ corresponding F_3's and ~~had reached~~ ~~the level~~
even reached the F_1 levels.
~~of F_1 in~~ some cases. ~~Therefore, there is substantial~~
By
~~variation among the segregants which can be exploited for~~
~~Therefore~~, The intermating of segregants in the F_2 had ~~improved~~
~~inter-mating.~~
~~[illegible]~~ improved the mean performance of the resulting population, ~~and~~
along with the release of ~~some~~ more genetic variation.

Somewhat from F_1 to the subsequent generations
(2) Inbreeding depression was not ~~as~~ large, ~~as would~~ be
~~was expected.~~ ~~Therefore, there is a likelihood of~~
indicates the presence of that could be ~~[illegible]~~ used
considerable additive genetic variation a~~vailable~~ for
in the present material.
practically all the characters, ~~provided intermating is~~
~~practised to release the variation.~~

(3) Among the three mating systems, design II was better than the other two ~~on the~~ as judged by performance of the ~~available~~ progenies available in this study. A more valid comparison would have been possible if the number of ~~progenies were similar~~ in the three designs were comparable in number.

5 caps Rom.

Estimation of Main Effects and Interactions

Using the means of P_1, P_2, F_1, F_2, B_1 and B_2 generations, six genetic parameters, m, d, h, i, j and l were estimated (Table 3) using ~~applying~~ the methodology of Hayman (1958). ~~(Table 3)~~ The estimate m is the F_2 mean, d the additive and h the dominance components. The other three estimates are of the digenic epistatic interaction, i (additive x additive), j (additive x dominance), and l (dominance x dominance).

The additive effect ~~were~~ was significant (Table 3) for all the characters. ~~while~~ The dominance effects were significant for all the characters ~~others~~ except yield, lint index and fibre fineness. ~~Some of~~ The interactions were significant for a majority ~~eight~~ of the ten characters, ~~but~~ but none of them were significant ~~not~~ for yield and lint index.

The additive effect was the most predominant for yield, lint index and fibre fineness, while the additive x additive interaction was also equally important for boll weight, boll number, seed index, fibre shape and fibre strength. Dominance effects were predominant for boll weight, boll number, fibre length, fibre strength, ginning percentage, seed index and fibre shape. The additive and dominance components were in the same direction for boll weight, ginning percentage, seed index, fibre length, fibre shape and fibre strength, indicating the scope for exploiting the additive and non-additive components. Among the four fibre quality characters, the dominance component was higher than the additive component for ~~three of them~~ fibre length, strength and shape, indicating the need for maintaining heterozygosity for these characters. The role of additive x dominance and dominance x dominance effects was limited for practically all the yield and fibre quality characters. ~~was limited~~. These results ~~were in support of the differences~~ support the conclusion drawn earlier in this paper based on the differences in the generation means (Table 2). ~~given in Table 1~~.

Estimation of Variance Components on the Basis of Generation Variances

Sam Rao

Using the error variances, separately from the non-segregating generations, F_2, B_1 and B_2 generations, least square estimates of additive (D), dominance (H) and environmental (E) components were obtained for all the ten characters based on the methodology of Mather (1949) ~~(Table 4)~~. The additive component (D) was highly significant for all the characters (Table 4) except fibre shape while the estimate of ~~variance~~ non-additive component (H) was significant for only six characters, three of them being quality characters. The additive component (D) was much larger than dominance components (H) for yield, boll weight, boll number, ginning percentage, seed index, fibre length and fibre fineness. Among the four quality characters the dominance component was larger than the additive component for fibre shape and fibre strength. However, there is scope for improvement by selection for these characters also due to the availability of sufficient additive genetic variation, except ~~for~~ fibre shape. The predominance of additive variance for yield and yield components is encouraging.

omit

Since the dominance variance is confounded with the interaction variances also, ~~the~~ estimates of additive and dominance variances from the biparental matings may throw more information on the average of dominance.

Biparental Progenies

~~Stated~~ under
~~As discussed in the Materials and Methods all~~ All the three approaches ~~mating~~ mating designs ~~of~~ (DI, DII and DIII) of ~~of~~ Comstock and Robinson (1952) were ~~applie~~d used for estimating the variance components for yield and its components (~~of~~ Table 3) and fibre characteristics (Table 4). ~~in the F$_2$ population. The material thus created was designated as Design I, (DI), Design II (DII), and Design III (DIII). The results of analysis of the progenies for DI, DII and DIII are given in Tables 5, and 6 respectively, for all the characters studied.~~

Comparing the [illegible] 2a, b, c will give the [illegible] σ^2_A [illegible] σ^2_D [illegible] σ^2_{AA}.

The ~~d~~differences between progenies were pronounced for ~~almost~~ most of the yield and fibre ~~almost all the~~ characters in Design I (~~Table 2a~~) and Design II (~~Table 2b~~) and relatively ~~relatively much~~ less pronounced in Design III (~~Table 2c~~). The estimates of error variances were also different in all the three designs for the same character. However, none of the designs was consistently better than the other in the size of error variance.

The least square estimates of the genetic parameters (σ^2_A, σ^2_D, and σ^2_{AA}) based on the ~~pooled~~ data ~~from three~~ in Design III ~~The comparative statement regarding the estimates three designs~~ were obtained using the method of Hatter (1949) and are ~~of additive variance (σ^2A), dominance variance (σ^2D)~~ are presented in Table 5. A comparison of the estimates of σ^2_A ~~and~~ σ^2_D and average degree of dominance with DI, DII and DIII ~~was also given in Tables 5/6.~~ is given in Table 6. (X) A & ⊗ D

(X) ~~When considered along with the means,~~ (Tables) the relative size of additive variance (σ^2A) as compared to dominance variance (σ^2D) was higher in design II than in designs I and III for all the characters except lint index. This difference between the designs can only be explained on the basis of dissipation of ~~superior~~ spurious dominance. There-

(X) The direct estimates of σ^2_A and σ^2_D from the analysis of the progenies of ~~DI~~ all the three designs are given in Table 6. Also the estimates of average degree of dominance are given [illegible]

Not clear

fore, design II appeared to provide a more realistic estimate of the fixable variation. Considering all the three designs, In this case, the results indicated predominant additive gene action for yield, boll weight, boll number, ginning percentage, seed index, fibre length and fibre fineness. However, the dominance component was higher for lint index, fibre shape and fibre strength. These results were comparable with the additive variance component (D) and dominance variance component (H) from Table 3.

A detailed ~~An further~~ analysis of the progenies in design II ~~had~~ permitted the estimation of additive x additive variance ($\sigma^2 AA$) ~~(Table 5)~~. It is interesting to note that ~~This component~~ representing additive x additive variance ($\sigma^2 AA$) (Table 5) was significant for boll number and lint index for which the additive component was not significant. Since, additive x additive variance ($\sigma^2 AA$) is also available for selection, there is scope for improvement in boll number and lint index by selection. These results had also indicated the availability of considerable additive variance ($\sigma^2 A$) for fibre length and fibre fineness. ~~which was not~~ can be ~~detected in the~~ ~~from the analysis of progenies~~ other analysis.

⊗ A

note

⊕ B

to go to page 8

or place matter ⊕ A and B

The design II proved to be superior to the other two, both in the estimation of genetic parameters and releasing additive genetic variation which was previously not available due to linkage as was evident ~~by~~ from the mean performance of the characters in the design II (Table1). This was corroborated by changes in association between characters in the biparental progenies (Table and), as compared to the corresponding segregating generations(Tables and).

?

From a comparison of Tables and , It was found that in the biparental progenies of design I there was a change in the additive genetic association in the favourable direction between seed index and fibre shape and between seed index and fibre strength. Genotypic correlation between seed index and fibre length was also highly significant and positive. In the biparental progenies there was also possibility of simultaneous increase in yield and fibre fineness; boll weight and boll number; boll weight and fibre shape ; and ginning percentage and seed index.

In design II (~~Table~~) a remarkable change was observed in the association of characters as compared to the straight F_3 generation (Table). Improvement in yield alone would lead to improvement in ginning percentage, lint index, fibre length and fibre shape. Boll weight and fibre shape can be increased together. Other useful additive genetic correlations were found between boll number and ginning percentage, boll number and lint index, boll number and fibre shape. Also, along with increase in boll number and ginning percentage there was increase in fibre strength. Ginning percentage and fibre fineness were also positively correlated. Increase in lint index would result in increased fibre length, fibre shape and finer fibre.

While comparing the efficiency of biparental design I and design II it was seen that design II was undoubtedly better than design I in obtaining several desirable combinations and changing unfavourable associations to favourable associations.

Analysis of Variance of F_3 Progenies

The F_2 plants used in the crossing programme in different designs were selfed and their F_3 progenies were grown separately. ~~The analysis was presented in Tables 12, 13 and 14.~~ Except boll weight and fibre fineness in F_3DI and yield and boll number in F_3DII, F_3 progenies showed highly significant variation between themselves in all the three designs for all the characters.

DISCUSSION

Does the discussion start here?

The present study, using different designs of mating, ~~which was undertaken for the first time in this country,~~ on the genetics of a set of quality characters, viz., fibre length, fineness, shape and strength and yield components such as boll number and boll weight had brought out the following interesting results:

Was this not seen in earlier studies also?

Considerable genetic variation was observed within this material for all the quality characters - fibre length, fineness, shape and strength - and yield and its components - boll weight, boll number, ginning percentage, seed index and lint index although the difference between the two parents were not as pronounced for these characters. This can be due to the diversity of origin of the two parents. The magnitude of additive variation was large inspite of the predominance of dominance components, for both the yield and quality characters, indicating possibility of improvement for both yield and fibre properties.

Secondly, the role of non-allelic interactions mimicking dominance was brought out for boll weight, boll number, ginning percentage, seed index, fibre length, fibre shape, fineness and fibre strength (Tables 5 & 6). Thus, the biparental matings revealed the presence of additive x additive interactions which would also be available for selection (~~Table~~). The bias due to the over-estimation of dominance was brought out by changes in the average degree of dominance in the bi-parentals as compared to the straight F_3's.

Thirdly, the unfavourable associations between yield and quality components and among the quality components were found to be due to linkage which could be broken in BIPs. The changes in association between these characters in the BIPs as compared to F_3's have confirmed the above conclusion. The role of linkage in such association in limiting advance under selection was brought out for the first time in this study.

Fourthly, the improvement of a population would depend upon the precision of ~~estimates of~~ the estimates of the fixable component of genetic variation, the release of such variation in appropriate matings and a change of the association to the better by breaking the unfavourable linkages (Moll and Robinson, 1967). This was found to be true for all the quality characters and yield components. Among the different designs adopted, design II was found to be the most efficient in the estimation of parameters and in the release of variation for selection.

Fifthly, a comparison of different methods of analysis for estimating the genetic parameters revealed that the bi-parental matings gave a more realistic picture than th~~e estimates of variance components using~~ Mather's (1949) methodology involving F_2, B_1, B_2 along with the nonsegregating generations.

Finally, the analysis of generation means clearly brought out the predominant role of additive effects being cancelled by the interaction components or the dominance effects, thus, limiting beterosis. However, the magnitude of fixable effects was found to be reasonable to warrant selection.

Estimates of Heritability

The heritability estimates in narrow sense were calculated in all the three designs following the methodology of Hanson (1963). The present study indicated low estimates of heritability for yield, boll weight, boll number, ginning percentage, seed index and lint index and quality characters like fibre length, fineness, shape and strength. Earlier reports and the present estimates were as given below:

Heritability estimates of some characters in Upland cotton

Characters	Present study			Previous reports
	DI	DII	DIII	
Yield per plant	-	0.08	0.24	0.10 to 0.15 (Manning,1956) 0.64 (Al-Rawi and Kohel,1969)
Boll Weight	0.12	0.11	0.68	0.73 (Al-Rawi and Kohel,1969)
Boll Number	-	0.03	0.89	0.36 (Al-Rawi and Kohel,1969)
Ginning percentage	0.49	0.25	0.83	0.77 (Ferrer-Monge,1959) 0.45 (Al-Rawi and Kohel,1969)
Seed index	0.20	0.21	0.85	0.59 (Ferrer-Monge, 1959) 0.48 (Al-Rawi and Kohel,1969)

Lint index	0.27	0.05	0.77	0.73 (Ferrer-Monge, 1959) 0.45(Murray and Verhalen, 1969)
Fibre length	0.89	0.21	0.72	0.39 to 0.49 (Kamel and Ismail,1966); 0.00 to 0.20(Murray and Verhalen, 1969) 0.61 in F_1 and 0.49 in F_2 (Verhalen and Murray, 1969) 0.23 (Al-Rawi and Kohel,1970
Fibre fineness	0.44	0.51	0.06	0.30 (Niles, 1950), 0.60 to 0.77 (Kamel and Ismail,1966) 0.00 to 0.46 (Murray and Verhalen, 1969), 0.25 in F_1 and 0.19 in F_2(Verhalen and Murray, 1969), 0.08 (Al-Rawi and Kohel, 1970)
Fibre shape	0.18	0.24	0.61	--
Fibre strength	-	0.18	0.79	0.00 to 0.19 (Murray and Verhalen, 1969), 0.57 in F_1 and 0.52 in F_2 (Verhalen and Murray,1969), 0.86 (Al-Rawi and Kohel, 1970).

It might be considered that the present estimates using ~~in~~ design II represented a more realistic picture since the estimates of $o\ ^{2}D$ in design III were negative and when considered along with error variance, contributed to the inflated values of heritability. The estimates in design II were also lower or equal to the estimates in design I. Thus the amount of additive variation in this cross was not very high inspite of the diverse origin of the parents.

Regarding quality characters, the heritability estimates appeared to be slightly higher as compared to those of the yield components. The estimates of Verhalen and Murray (1969) were higher for fibre strength in F_1 (0.57) and F_2 (0.52) population of a 10x10 diallel in Upland cotton. But Murray and Verhalen (1969) in their experiment I reported heritability of 0.19 in narrow sense for fibre strength in one of the seasons. The later estimate was closer to the estimate obtained in the present study in design II. In experiment I, the heritability estimates obtained by Murray and Verhalen (1969) for fibre length in the year 1962 and for fineness in 1961 were comparable to the estimates obtained in the present investigation in design II.

The high proportion of additive to non-additive genetic variance for fibre length and fibre fineness as compared to the corresponding values for yield components and a reasonable size of additive variance for shape and strength were indicative of possibility of simultaneous improvement for these characters in the present cross.

Comparison of Systems of Mating

Among the three designs employed in the present study the estimates of additive variance in design II, were intermediate between that of design I and design III. On the other hand, the magnitude of dominance and error variances in design I and design III were responsible for higher heritability estimates than those obtained in design II. The mean performance of the progenies indicated that the estimates from design II were more realistic for all the characters. As mentioned by Moll and Robinson (1967) and Miller and Rawlings (1967) the estimates of additive component from advanced generations would be more reliable than those from the corresponding F_2 generations. Linkage disequilibrium and repulsion-phase linkages which mimic overdominance could result in biased ? | estimates in the F_2 generation. These effects causing bias could be dissipated in BIPs and through random mating. The consistency of the estimates of additive components for all the characters in design II confirmed ~~the findings~~ (?) ~~of above authors~~ that design II was the most effective mode for estimation of the components of genetic variation and to create populations of utility in breeding.

The real test of the utility of design II in breaking the undesirable linkages should be the improvement of the mean performance of the progeny and changes in the association between characters to the better as compared to the F_3. This was found to be true for both yield and quality characters. (Table).

Changes in Association between Characters in Different Systems of Mating

Contrary to the previous reports of Miller and Rawlings (1967b) of adverse correlated response between yield and quality, it was found that considerable improvement in association between characters had taken place in progenies from design II. The same authors (1967a) had reported reduction in the unfavourable correlation between yield and fibre strength by nearly half after six generations of intermating. This must have taken place due to breaking of the initial linkages and thereby overcoming the adverse correlated response in the absence of intermating. Feaster and Turcotte (1968) found that yield was not correlated with ginning percentage or its components and was positively associated with fibre length. In design II of the present study, along with the improvement of yield, there was increase in ginning percentage., fibre shape and fibre length. Simultaneous improvement in fibre strength and boll number and ginning percentage and fibre strength was also observed. Therefore, it could be concluded that the earlier reports of unfavourable associations between quality and quantity in cotton might be due to intense selection for uniformity without changes in the initial undesirable linkages. The small sample size which was associated with intense selection must have further narrowed the response. The intermating in the early segregating generations by simulating random mating was essential in the improvement of any population of Upland cotton or interspecific hybrids involving hirsutum.

In design I also, some undesirable linkages were broken and new combinations formed but the extent was much more enhanced in design II, for example, as compared to design I the major desirable changes in association between characters in design II were between yield and ginning percentage; yield and lint index; yield and fibre shape; boll number and fibre strength and ginning percentage and fibre strength. Advantage of design II would also lie in the greater range of genotypes involved in the mating as compared to design I and design III, thereby preserving genetic variation in the population and reducing the chances of genetic drift and unfavourable correlated response. The additive x additive interaction was also partitioned in design II (Tables 5&6). The confounding of these fixable types of interactions with o ^{2}D could not permit their detection in designs other than design II. Such an analysis of separating o ^{2}AA had not been done so far in cotton. The large size of o ^{2}AA for yield, boll, weight, boll number, seed index and lint index indicated that improvement in these traits was feasible by utilizing the additive x additive interaction also. The high value of o ^{2}AA as compared to o ^{2}A for fibre strength

~~was~~ [illegible] also ~~encouraging~~ of interest although such interactions were negligible for other quality characters. The predominance of additive variation for fibre fineness and the useful role of $o\ ^{2}AA$ in fibre strength along with the above information on the nature of gene action for yield and its components confirmed the utility of this design of mating in creating populations for the simultaneous improvement of yield and quality, not possible in straight F_3's or backcrosses conventionally used in cotton breeding.

Another system of mating which may be of potential use for breaking linkages and dissipating the effects of linkage dis-equilibrium is disruptive selection. A comparison of this method with that of design II in the same population will be of interest. Finally, it may be mentioned that the existing cotton breeding procedures based on single plant selection instead of population performance need to be modified for the improvement of quality coupled with yield even in the highly domesticated species like Upland cotton. The predicted estimates of gain should be related to the realised gain particularly for quality characters to avoid genetic slippage due to unfavourable inter-environmental correlations in successive generations of selection.

REFERENCES

Al-Rawi, K.M. and Kohel, R.J. (1969). Diallel analysis of yield and other agronomic characters in Gossypium hirsutum L. Crop Sci., 9: 779-783.

Al-Rawi, K.M. and Kohel, R.J. (1970). Gene action in the inheritance of fibre properties in intervarietal diallel crosses of Upland cotton. Crop Sci., 10 : 82 -85.

Comstock, R.E. and Robinson, H.F. (1952). Estimation of average dominance of genes. Heterosis. 496-516. Ames, Iowa State College Press.

Feaster, C.V. Turcotte, E.L. (1968). Association of colour, yield, and quality of lint in Pima cotton. Crop Sci., 8 : 197-199.

Ferror-Monge, J.A. (1959). Inheritance of yield components in an interspecific hybrid of cotton. Diss. Abstr., 19 : p. 1525. (From P.B.A., 1959, 29, p. 813).

Hanson, W.D. (1963). Heritability. In Statistical Genetics and Plant Breeding. Publication 982 N.A.S. and N.R.C. Washington D.C. : 125 - 140.

Hayman, B.I. (1958b). Separation of epistatic from additive and dominance variation in generation means. Heredity, 12 : 371-391.

Kamel, S.A. and Ismail, A.A. (1966). Inheritance of fibre length and fineness of Egyptian cotton. Emp. Cott. Grow. Rev. 43 : 207 - 217.

Manning, H.L. (1956). Yield improvement from a selection index technique. Heredity, 10 : 303-332.

Mather, K. (1949). Biometrical genetics. The study of continuous variation. Dover Public., Inc. U.S.A. pp. 158.

Miller, P.A. and Rawlings, J.O. (1967a). Break-up of initial linkage blocks through inter-mating in a cotton population. Crop Sci., 7 : 199-204.

Miller, P.A. and Rawlings, J.O. (1967b). Selection for increased lint yield and correlated responses in Upland cotton. Crop Sci. ,7 : 637 - 640.

Moll, R.H. and Robinson, H.F. (1967). Quantitative genetic investigations of yield of maize. Der Zuchter, 37 : 192-199.

Murray, J.C. and Verhalen, L.M. (1969). Crop Sci., 9 : 752-755.

Table 1 : Mean performance of different generations of material for all characters studied

Characters	Mean performance of generations						C.D.	
	P_1	P_2	F_1	F_2	B_1	B_2	5%	1%
Yield per plant (gm)	35.56	51.52	46.34	42.05	40.10	48.03	3.35	4.72
Boll weight (gm)	4.99	3.03	4.68	3.98	4.88	3.60	0.15	0.22
Number of bolls per plant	18.03	30.60	26.63	24.08	23.90	28.20	3.24	4.57
Ginning percentage	38.15	33.53	36.75	35.81	37.84	34.55	0.99	1.30
Seed index (gm)	10.00	8.30	9.41	9.15	9.69	8.92	0.20	0.28
Lint index (gm)	5.55	4.50	5.01	4.88	5.29	4.67	0.18	0.25
Fibre length (mm)	26.66	24.13	25.47	25.00	25.96	24.62	0.31	0.44
Fibre fineness (micronaire units)	3.73	4.44	4.00	4.10	4.01	4.29	0.11	0.16
Fibre shape (D)	2.13	1.44	1.90	1.72	1.95	1.64	0.13	0.19
Fibre strength (Pressley strength index)	10.04	8.00	8.86	8.50	9.58	8.53	0.11	0.16
	F_3DI	F_3DII	F_3DIII	DI	DII	DIII		
Yield per plant(Gm)	40.05	39.55	39.50	45.05	46.75	43.00	3.35	4.72
Boll weight (gm)	3.85	3.70	3.56	4.63	4.55	4.40	0.15	0.22
Number of bolls per plant	22.50	23.00	22.15	25.78	26.00	25.05	3.24	4.57
Ginning percentage	35.01	34.85	34.75	36.30	36.41	36.10	0.99	1.30
Seed index (gm)	8.98	8.80	8.95	9.25	9.10	9.08	0.20	0.28
Lint index (gm)	4.75	4.68	4.70	4.90	4.95	4.78	0.18	0.25
Fibre length (mm)	24.85	24.70	24.73	24.98	25.10	24.80	0.31	0.44
Fibre fineness (micronaire units)	4.20	4.25	4.15	4.18	4.22	4.05	0.11	0.16
Fibre shape (D)	1.62	1.58	1.65	1.78	1.85	1.68	0.13	0.19
Fibre strength (pressley strength index)	8.40	8.35	8.38	8.75	8,68	8.55	0.11	0.16

Combine Tables 2 ~~& 9~~ by a E's with 2 Tables 3 & 4 / with design

Anova for Progenies in DI, DII and DIII ~~designs~~. for yield and its components.

Table 2a : Estimates of genetic components of variance and average degree of dominance ~~from~~ for Design I ~~Exp~~ experiment

Source	D.F.	Yield/ Plant	Boll Weight	Boll Numbers	Ginning percentage	Seed index
		ANALYSIS OF VARIANCE				
		Mean sum of squares				
Sets	2	1057.425	0.934	76.886	36.125	0.881
Replications in sets	3	214.090	0.099	12.270	3.400	0.983
Males in sets	9	**1053.681	*0.289	**106.369	**16.908	**1.588
Females in sets	36	**177 .103	0.215	**23.445	**6.688	**0.972
Error	45	67.627	0.128	11.823	1.906	0.436
$\hat{\sigma}^{*2}_A$		438.288 ±224.560	0.026 ±0.068	41.464 ±32.868	5.112 ±3.688	0.308 ±0.356
$\hat{\sigma}^{*2}_D$		-219.336 ±240.732	0.140 ±0.128	-18.220 ±25.740	4.452 ±4.864	0.764 ±0.600
$\sqrt{\hat{\sigma}^{*2}_D/\hat{\sigma}^{*2}_A}$		-	1.922	-	0.933	1.574

Source	D.F.	Lint index	Fibre length	Fibre fineness	Fibre shape	Fibre strength
Sets	2	0.372	8.207	0.328	0.173	0.884
Replications in sets	3	0.031	0.682	0.024	0.031	0.163
Males in sets	9	**0.854	**12.939	**0.319	**0.160	0.282
Females in sets	36	**0.445	**3.096	**0.139	**0.095	*0.410
Error	45	0.137	0.712	0.065	0.014	0.139
$\hat{\sigma}^{*2}_A$		0.204 ±0.188	4.920 ±2.780	0.092 ±0.068	0.032 ±0.036	-0.064 ±0.032
$\hat{\sigma}^{*2}_D$		0.412 ±0.284	-0.152 ±3.136	0.052 ±0.096	*0.128 ±0.052	**0.604 ±0.196
$\sqrt{\hat{\sigma}^{*2}_D/\hat{\sigma}^{*2}_A}$		1.420	-	0.751	2.00	-

*, ** Significant at 5% and 1% level

~~*Significant at 5% level of significance~~

~~**Significant at 1% level of significance~~

Contd

Table 2b: Estimates of genetic components of variance and average degree of dominance from Design II

Source	D.F.	ANALYSIS OF VARIANCE				
		Yield /plant	Boll weight	Boll number	Ginning percentage	Seed index
		Mean sum of squares				
Sets	9	936.674	0.847	116.743	47.975	3.266
Replications in sets	10	313.237	0.238	24.882	5.385	2.170
Males in sets	30	136.750	**0.501	16.381	**12.304	**1.086
Females in sets	30	192.140	0.384	*36.302	**10.962	**1.393
Males x females in sets	90	122.439	0;307	23 .129	**6.237	**0.687
Error	150	139.217	0.268	23.290	2.934	0.471
$\hat{\sigma}^2 A$		10.501 ±17.832	0.034 ±0.046	0.804 ±2.898	1.338 ±1.212	0.138 ±0.130
$\hat{\sigma}^2 D$	-13	-13,639 ±14.999	0.002 ±0.036	-0.481 ±2.508	1.000 ±0.780	0.038 ±0.087
$\sqrt{\hat{\sigma}^2 D/\hat{\sigma}^2 A}$		-	0.244	-	0.863	0.524

Source	D.F.	Lint index	Fibre length	Fibre fineness	Fibre shape	Fibre strength
Sets	9	1.041	11.277	0.704	0.119	8.327
Replications in sets	10	0.208	2.477	0.227	0.039	0.229
Males in sets	30	**0.596	**3.732	**0.261	**0.081	**0.974
Females in sets	30	**0.529	**3.420	**0.271	**0.279	**0.713
Males x females in sets	90	**0.483	1.268	0.075	**0.108	**0.574
Error	150	0.120	1.158	0.059	0.029	0.096
$\hat{\sigma}^2 A$		0.018 ±0.060	0.294 ±0.246	0.046 ±0.026	0.018 ±0.018	0.068 ±0.086
$\hat{\sigma}^2 D$		**0.172 ±0.047	-0.092 ±0.168	-9.015 ±0.015	*0.029 ±0.012	**0.203 ±0.061
$\sqrt{\hat{\sigma}^2 D/\hat{\sigma}^2 A}$		3.00	-	-	1.269	1.745

* Significant at 5% level of significance
**Significant at 1% level of significance

Table 2c : Estimates of genetic components of variance and average degree of dominance from Design III

Source	D.F.	ANALYSIS OF VARIANCE				
		Yield /plant	Boll weight	Boll number	Ginning percentage	Seed index
		Meannsum of squares				
Sets	2	16.381	0.099	99.300	11.380	0.349
Replications in sets	3	148.332	0.663	17.282	0.080	0.006
Inbred lines in sets	3	2337.480	3.535	610.748	49.150	9.594
F_2 parents in sets	12	138.939	*0.151	**85.444	**4.872	**0.897
F_2 parents x inbred lines	12	111.058	0.031	6.880	0.800	**0.237
Error	27	104.983	0.058	10.603	0.824	0.055
$\hat{\sigma}^2_A$		33.956 ±59.311	0.092 ±0.059	*74.840 ±32.414	*4.048 ±1.854	*0.840 ±0;339
$\hat{\sigma}^2_D$		3.038 ±25.110	-0.014 ±0.009	-1.366 ±1.904	-0.013 ±0.186	*0.091 ±0.045
$\sqrt{2\hat{\sigma}^2_D/\hat{\sigma}^2_A}$		0.423	-	-	-	0.465

		Lint index	Fibre length	Fibre fineness	Fibre shape	Fibre strength
Sets	2	0.929	4.600	0.032	0.042	1.242
Replications in sets	3	0.205	0.649	0.027	0.039	0.039
Inbred lines in sets	3	7.037	28.781	1.186	0.965	6.141
F_2parents in sets	12	**0.377	**2.432	0.033	**0.050	**0.523
F_2 parents x inbred lines	12	0.127	0.553	0.030	0.029	0.105
Error	27	0.062	0.771	0.032	0.015	0.107
$\hat{\sigma}^2_A$		0.316 ±0.283	1.656 ±0;941	0.002 ±0.015	0.034 ±0.019	*0.408 ±0.200
$\hat{\sigma}^2_D$		0.033 ±0.025	-0.112 ±0.146	-0.001 ±0.007	0.007 ±0.006	0.001 ±0.024
$\sqrt{2\hat{\sigma}^2_D/\hat{\sigma}^2_A}$		0.457	-	-	0.661	-

*Significant at 5% level of significance
**Significant at 1% level of significance

Table 2 : Estimates of genetic parameters from the generation means on the basis of six parameter model

Genetic parameters	CHARACTERS				
	Yield per plant	Boll weight	Boll number	Ginning percentage	Seed index
m	42.05 ±1.90	3.98 ±0.08	24.08 ±0.86	35.81 ±0.19	9.15 ±0.07
d	-7.93** ±2.09	1.28** ±0.08	-4.30** ±0.88	3.29** ±0.24	0.77** ±0.08
h	10.86 ±8.75	1.71** ±0.37	10.19** ±3.90	2.45** ±0.91	0.88** ±0.32
i	8.06 ±8.68	1.04** ±0.37	7.88* ±3.86	1.54 ±0.89	0.62* ± 0.31
j	0.05 ±1.07	0.30** ±3.04	1.97** ±0.46	0.98** ±0.12	-0.07 ±0.04
l	-4.56 ±11.73	-0.62 ±0.48	-10.19* ±5.09	-1.14 ±1.25	-5.72** ±0.43

	Lint index	Fibre length	Fibre fineness	Fibre shape	Fibre strength
m	4.88 ±0.09	25.00 ±0.16	4.10 ±0.05	1.72 ±0.03	8.50 ±0.11
d	0.42** ±0.11	1.34** ±0.17	-0.28** 8±0.05	0.31** ±0.04	1.05** ±0.14
h	0.38 ±0.43	6.43** ±0.72	0.19 ±0.22	0.41** ±0.15	2.06** ±0.52
i	0.40 ±0.43	1.16 ±0.71	0.20 ±0.22	0.30* ±0.15	2.20** ±0.52
j	-0. 10 ± 0.06	0.27** ±0.09	0.07* ±0.03	-0.03 ±0.02	0.03 ±0.07
l	-0.25 ±0.61	-10.99** ±0.96	0.27 ±0.29	-0.11 ±0.21	2.68** ±0.75

*Significant at 5% level of significance
**Significant at 1% level of significance

omit

Table 4 : Components of variation and average degree of dominance on the basis of generation variances

Components	CHARACTERS				
	Yield /Plant	Boll weight	Boll number	Ginning percentage	Seed index
$\hat{D}$	395.214** ±47.569	0.922** ±0.113	100.010** ±4.304	3.164** ±0.315	0.356** ±0.110
$\hat{H}$	126.570 ±64.999	-0.229 ±0.155	-22.960** ±5.881	1.753** ±0.430	0.251 ±0.150
$\hat{E}$	23.748** ±6.141	0.076** ±0.015	7.680** ±0.555	0.598** ±0.041	0.073** ±0.014
$\sqrt{H/D}$	0.566	-	-	0.744	0.839

Components	Lint index	Fibre length	Fibre fineness	Fibre shape	Fibre strength
$\hat{D}$	0.622** ±0.065	2.770** ±0.129	0.280** ±0.029	0.034 ±0.024	0.490** ±0.047
$\hat{H}$	0.912** ±0.087	0.676** ±0.177	0.039 ±0.040	0.132** ±0.032	2.168** ±0.064
$\hat{E}$	0.073** ±0.008	0.170** ±0.017	0.018** ±0.004	0.017** ±0.003	0.570** ±0.006
$\sqrt{H/D}$	1.211	0.499	0.373	1.970	2.103

*Significant at 5% level of significance
**Significant at 1% level of significance

Least Square σ^2_A, σ^2_D and σ^2_{AA} ~~Genetic~~

Table 5 : Estimates of ~~genetic~~ components ~~of variance~~ and average degree of dominance from ^ ~~least square analysis of~~ ~~the Pooled Data of the Three Designs I~~, D II ~~and D III~~.

from the data in Design II

~~$\hat{\sigma}^2$m, $\hat{\sigma}^2$f and $\hat{\sigma}^2$mf (from DesignII)~~, $\hat{\sigma}^2F_3$(from ~~DesignI~~

and ~~Cov. DIIF3DII~~

Characters	$\hat{\sigma}^2_A$	$\hat{\sigma}^2_D$	$\hat{\sigma}^2_{AA}$	$\sqrt{\hat{\sigma}^2_D/\hat{\sigma}^2_A}$
Yield per plant	10.279 ± 20.990	4.686 ± 34.874	1.893 ± 29.170	0.675
Boll weight	-0.030 ± 0.067	-0.004 ± 0.109	0.206 ± 0.093	-
Boll number	1.630 ± 2.657	-3.813 ± 4.412	*7.471 ± 3.699	-
Ginning percentage	1.661 ± 2.508	7.209 ± 4.166	-0.343 ± 3.486	2.083
Seed index	0.107 ± 0.175	0.376 ± 0.290	0.218 ± 0.243	1.874
Lint index	0.017 ± 0.063	**0.699 ± 0.063	**0.073 ± 0.027	6.412
Fibre length	**0.948 ± 0.340	0.429 ± 0.565	-0.226 ± 0.473	0.672
Fibre fineness	**0.079 ± 0.027	0.045 ± 0.045	-0.041 ± 0.038	0.754
Fibre shape	0.025 ± 0.042	**0.182 ± 0.070	-0.025 ± 0.059	2.699
Fibre strength	0.028 ± 0.101	**0.877 ± 0.189	0.189 ± 0.141	5.599

*Significant at 5% level of significance
**Significant at 1% level of significance

Table ~~5~~ 6 : Compar~~ative study~~ of estimates of ~~additive~~ $\tilde{\sigma}_A$, $\tilde{\sigma}_D$ variance (~~$\hat{\sigma}^2 A$~~), domin~~ance~~ variance ($\hat{\sigma}^2 D$) and average degree of dominance in the ~~three~~ [illegible] designs. DI, DII and DIII

Characters	$\hat{\sigma}^2_A$			$\hat{\sigma}^2_D$			Average degree of dominance		
	DI	DII	DIII	DI	DII	DIII	DI	DII	DIII
Yield/plant	438.288	10.501	33.956	-219.336	-13.639	3.038	-	-	0.423
Boll weight	0.036	0.034	0.092	0.140	0.002	-0.014	1.922	0.244	-
Boll number	41.464	0.804	74.840*	-18.220	-0.481	-1.366	-	-	-
Ginning percentage	5.112	1.338	4.048*	4.452	1.000	-0.013	0.933	0.863	-
Seed index	0.308	0.138	0.840*	0.764	0.038	0.091	1.574	0.524	0.465
Lint index	0.204	0.018	0.316	0.412	0.172**	0.033	1.420	3.000	0.457
Fibre length	4.920	0.294	1.656	-0.152	-0.092	-0.112	-	-	-
Fibre fineness	0.092	0.046	0.002	0.052	-0.015	-0.001	0.751	-	-
Fibre shape	0.032	0.018	0.034	0.128*	0.029*	0.007	2.000	1.269	0.661
Fibre strength	-0.064	0.068	0.408*	0.604**	0.203**	0.001	-	1.745	-

*Significant at 5% level of significance

**Significant at 1% level of significance