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# Studies on the Inheritance of some Anthocyanin and Corolla Colour Characters in Asiatic Cotton

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**Introduction:** From a crop survey of the Peninsular Indian *arboreum* cottons in the Cocanadas (race *indicum*) zone, Balasubramanyan, Ramaswamy and Jagannatha Rao (1946) reported on the occurrence of three new genotypes not recorded earlier in this region. They were (a) Green stem/Ghost Spot – $R_2^{os}$ $R_2^{os}$; (b) Fully immature lint – *lm* and (c) Incomplete boll dehiscence – $de_b$ and the inheritance of these characters in a few combinations of crosses has since been reported by Balasubramanyan *et al* (1950).

The Green stem/Ghost Spot type was characterised by the complete absence of anthocyanin pigment in all plant parts and by the presence of a white patch in the place usually occupied by the red spot in the petal. The corolla colour of the new type was yellow and hence the white patch designated as 'Ghost' (Hutchinson, 1932) was easily visible. The inheritance of this Green stem/Ghost spot complex in relation to different anthocyanin and corolla colour factors, in five inter-racial crosses in *G. arboreum* involving Sun-red and Deep-red; Yellow corolla, Pale-yellow and White corolla genotypes is reported in this paper.

**Previous Work:** (i) *Anthocyanin organisation:* The anthocyanin genetics of cotton has been the subject of detailed study by Hutchinson (1932) and Silow and Yu (1942). Yu (1932); Yu and Hsi (1934); Hutchinson and Ghose (1937); Ramiah and Bholanath (1944) and Balasubramanyan *et al* (1950) have also reported on the occurrence of newer members of the anthocyanin multiple allelmorph series in Asiatic cottons or established homology of new mutants with known genes. A survey of anthocyanin organisation in cotton has also been recently made by Ramiah (1945).

In Asiatic cottons, the distribution of anthocyanin pigment in the vegetative parts of the plant and on the flower petal is known to be controlled by the $R_2$ series of multiple allelmorphs, of which at least twenty members have now been established (Stephens and Cassidy, 1946). The extent and intensity of pigmentation of the plant body and the presence or absence of petal spot constitute the two main attributes of the anthocyanin system.

In such diverse organs and locations as stem, petiole, leaf pulvinus, leaf veins, leaf lamina, bracts, calyx, bolls, anther, filaments, petal, lamina and petal edge, anthocyanin finds expression and on the basis of vegetative anthocyanin, three groups viz. 'Green', 'Dilute red' or 'Sun-red' and 'Deep red' can be made out. With regard to the other attribute viz., the presence or absence of petal spot, three phenotypes are recognised viz. 'Red spot', Ghost spot' and 'Spotless'. 'Ghost' has a white spot in the place usually occupied by red spot in the petal, while in the case of 'Spotless', no spot is present. Excepting in the case of 'Ghost', which occurs only in the 'Green' class, Red spot' and 'Spotless' forms exist in all the three classes of vegetative anthocyanin viz. 'Green', 'Dilute red' and 'Deep red'.

(ii) *Corolla Colour Genetics:* Three main Corolla Colour types occur in Asiatic cottons viz., Yellow, Pale Yellow and White. Hutchinson (1931) showed that the inheritance of corolla colour in Asiatic cottons was controlled by a multiple allelomorph series at the $Y_a$ locus (Gene symbol. after Hutchinson and Silow, 1939). Subsequent additions to this series were the 'Chinese Pale' at the $Y_b$ locus and 'Anomalum Pale' at the $Y_c$ locus (Silow, 1941). Bholanath (1942) let in confirmatory evidence for the complementary nature of $Y_a$ and $Y_b$ Loci for production of Yellow corolla.

Recently, Stephens (1954) has reviewed the position and summed up the situation as follows:

| | *Type* | *Genotype* | *Phenotype* | *Distribution* |
|---|---|---|---|---|
| 1. | Yellow | Ya Yb Yc | Yellow | *G. arboreum* and *G. herbaceum* |
| 2. | Common pale | $Y_a^p$ Yb Yc | Uniformly pale | *G. arboreum* only |
| 3. | Chinese pale | Ya $Y_b^p$ Yc | Pale, with intensification around throat of Corolla | Chinese strains of *G. arboreum* only |
| 4. | Anomalum pale | Ya Yb $Y_c^p$ | Uniformly pale | *G. anomalum* |
| 5. | White | Ya Yb Yc | White | *G. arboreum* |

**Material and Methods:** The present studies relate to crosses of the Cocanadas Green stem/Ghost spot, Yellow corolla type with 1) Sun-red spot, Yellow corolla; 2) Sun-red/Red spot, Pale yellow Corolla; 3) Sun-red/Red spot, White corolla; Deep red/Spotted, red on Yellow corolla; and 5) Deep red/Spotted, red on white corolla types in *Gossypium arboreum*. The characteristics of the parents used in the study are furnished in table 1.

TABLE I

*Characteristics of parents used in the study*

| S. No. | Type | Botanical classification | Authocyanin | Corolla Colour | Genotype |
|---|---|---|---|---|---|
| 1. | CST 3 | *G. arboreum* race *indicum* | Green stem/Ghost | Yellow | $R_2^{OS}$ $R_2^{OS}$ Ya Ya |
| 2. | Burma C 19 | *G. arboreum* race *burmanicum* | Sun-red Spotted | Yellow | $R_2^{AS}$ $R_2^{AS}$ Ya Ya |
| 3. | Cernuum | *G. arboreum* race *cernuum* | Sun-red Spotted | Pale Yellow | $R_2^{AS}$ $R_2^{AS}$ $Ya^{P}$ $Ya^{P}$ |
| 4. | N. R. 5 | *G. arboreum* race *bengalense* | Sun-red Spotted | White | $R_2^{AS}$ $R_2^{AS}$ Ya Ya |
| 5. | Sanguineum 119 | *G. arboreum* race *bengalense* | Full-red Spotted | Red on Yellow | $R_2^{RS}$ $R_2^{RS}$ Ya Ya |
| 6. | Sanguineum major | *G. arboreum* race *bengalense* | Full-red Spotted | Red on White | $R_2^{RS}$ $R_2^{RS}$ Ya Ya |

The following five combinations of crosses were effected and observations made on the $F_1$, back crosses and $F_2$ populations.

1. CST. 3 x Burma C 19 ... (*indicum* x *burmanicum*)
2. CST. 3 x Cernuum ... (*indicum* x *cernuum*)
3. CST. 3 x N. R. 5 ... (*indicum* x *bengalense*)
4. CST. 3 x Sanguineum 119 ... (*indicum* x *bengalense*)
5. CST. 3 x Sanguineum major (*indicum* x *bengalense*)

Phenotypic classification in respect of pigmentation of plant parts and corolla colour in the yellow x pale yellow and yellow x white crosses, was made on the basis of visual scoring. In the case of crosses involving interaction of the deep red (anthocyanin genotype on corolla colour expression, colour plates of Hutchinson (1932) were utilised for grading. Freshly opened flowers were used for classification of corolla colour and petal grading was done with flowers on the plant, in the early period of the day before fading set in.

In analysing the results of segregation, the *Chi* square test was applied to test the goodness of fit to expected ratios and probability determined.

In dealing with the interaction of anthocyanin and corolla colour genotypes, the $R_2^{os}$ segregants have been left out since only in the $R_2^{RS}$ back ground is the expression of the corolla colour gene modified.

**Results and Discussion:** The data relating to the inheritance of anthocyanin, inheritance of corolla colour, anthocyanin—corolla colour combined assortment and interaction of genotypes on the expression of corolla colour are presented below and discussed under the respective heads.

(i) *Inheritance of anthocyanin:* The anthocyanin system in Asiatic cottons has two main attributes viz., the pigmentation of plant parts and the presence of petal spot. The results of segregation in the five crosses involving the Green stem/Ghost spot type on the one hand with three Sun-red/Red spotted and two Full red/Red spotted types are furnished in Table 2.

TABLE II

*Inheritance of anthocyanin (Petal spot)*

| S. No. | Nature of cross and germination | | No. of plants with | | Total | Monogenic segregation | |
|---|---|---|---|---|---|---|---|
| | | | Pigmented/ Red spot | Green stem/ Ghost spot | | *Chi*$^2$ | Value of P. between |
| 1. | CST. 3 x BC 19 | $F_1$ | 33 | .. | 33 | .. | .. |
| | Back cross with CST.3 | | 49 | 44 | 93 | 0·269 | 0·50 — 0·70 |
| | Back cross with BC. 19 | | 102 | .. | 102 | .. | .. |
| | $F_2$ Total of 6 families | | 276 | 84 | 360 | 0·266 | 0·50 — 0·70 |
| 2. | CST. 3 x Cernuum | $F_1$ | 32 | .. | 32 | .. | .. |
| | Back cross with CST. 3 | | 58 | 52 | 110 | 0·328 | 0·50 — 0·70 |
| | Back cross with Cernuum | | 98 | .. | 98 | .. | .. |
| | $F_2$ Total of 4 families | | 299 | 99 | 398 | 0·003 | 0·95 — 0·98 |
| 3. | CST. 3 x N. R. 5 | $F_1$ | 37 | .. | 37 | .. | .. |
| | Back cross with CST. 3 | | 35 | 34 | 69 | 0·014 | 0·80 — 0·90 |
| | Back cross with N. R. 5 | | 26 | .. | 26 | .. | .. |
| | $F_2$ Total of 7 families | | 199 | 73 | 272 | 0·491 | 0 30 — 0·50 |
| 4. | CST. 3 x Sanguineum 119 | $F_1$ | 20 | .. | 20 | .. | .. |
| | Back cross with CST. 3 | | 66 | 50 | 116 | 2·206 | 0·10 — 0·20 |
| | Back cross with Sanguineum | | 55 | .. | 55 | .. | .. |
| | $F_2$ Total of 3 families | | 191 | 68 | 259 | 0·217 | 0·50 — 0·70 |
| 5. | CST. 3 x Sanguineum major | $F_1$ | 8 | .. | 8 | .. | .. |
| | Back cross with CST. 3 | | 79 | 97 | 176 | 1·840 | 0·10 — 0·20 |
| | Back cross with Sanguineum major | | 52 | .. | 52 | .. | .. |
| | $F_2$ Total of 3 families | | 232 | 80 | 312 | 0·068 | 0·70 — 0·80 |

*Cross 1:* CST. 3 x Burma C. 19 (*indicum* x *burmanicum*)
Green stem/Ghost x Sun-red/Red spot.

The $F_1$ was observed to be Sun-red/Red spot and in the back-cross with the recessive parent, Green stem/Ghost, segregation was obtained in the ratio of 1:1 for the two phenotypes. The segregation in $F_2$ also accorded well with expectations on the basis of monogenic inheritance.

*Cross 2:* CST. 3 x Cernuum (*indicum* x *cernuum*)
Green stem/Ghost x Sun-red/Red spot.

In this cross also, Sun-red/Red spot was dominant over Green stem/Ghost and the segregation in backcrosses and $F_2$ conformed to monogenic inheritance.

*Cross 3:* CST. 3 x N. R. 5 (*indicum* x *bengalense*)
Green stem/Ghost x Sun-red/Red spot.

The $F_1$ was again Sun-red/Red spot and a good fit for 3:1 segregation of Spot: Ghost in $F_2$ and 1:1 segregation in the back cross with the recessive parent CST. 3 was obtained.

Thus, in all the above three inter-racial crosses within *G. arboreum*, the Cocanadas Green stem/Ghost has proved to be a simple recessive to the Sun-red/Spotted types, confirming previous behaviour of the Green stem/Ghost ($R_2^{os}$) allele in other crosses with the Sun-red spotted ($R_2^{AS}$) allele.

*Cross 4:* CST. 3 x Sanguineum 119 (*indicum* x *bengalense*)
Green stem/Ghost x Full red/Red spot.

The Sanguineum 119 parent carries the $R_2^{RS}$ allele, the deepest member of the anthocyanin series and this was dominant over the Green stem/Ghost $R_2^{os}$ genotype in the $F_1$. In the back cross with recessive parent, the segregation gave a good fit to 1:1 ratio for the two phenotypes, while in the $F_2$, Spot and Ghost were inherited in the ration of 3:1.

*Cross 5:* CST. 3 x Sanguineum major (*indicum* x *bengalense*)
Green stem/Ghost x Full red/Red spot.

The Sanguineum major parent also carries the $R_2^{RS}$ allele, but differs from the Sanguineum 119 parent only in respect of its corolla colour genotype.

The behaviour of the $F_1$, back crosses and $F_2$ in this cross was similar to that of Sanguineum 119 cross in respect of anthocyanin inheritance.

The Cocanadas Green stem/Ghost which carries the $R_2^{os}$ allele of the anthocyanin multiple allelomorph series has thus confirmed its behaviour, as a simple recessive to the $R_2^{AS}$ and $R_2^{RS}$ alleles in the inter-racial crosses studied now.

(ii) *Inheritance of Corolla colour:* The CST. 3 Green stem/Ghost type possesses Yellow corolla and the inheritance of the same in crosses with Yellow corolla (Burma C 19); Pale yellow corolla (Cernuum); White corolla (NR5); Red on Yellow corolla (Sanguineum 119) and Red on White corolla (Sanguineum major) types is summarised in table 3.

*Cross 1:* CST. 3 x Burma C. 19 (*indicum* x *burmanicum*)
Yellow x Yellow.

In this cross between two Yellow corolla types, the $F_1$ was Yellow and in the back crosses and $F_2$, all the plants possessed Yellow corolla, thus confirming that both the parents carried the $Y_a$ allele.

*Cross 2:* CST. 3 x Cernuum (*indicum* x *cernuum*)
Yellow x Pale Yellow.

In the $F_1$, yellow corolla colour was dominant over pale yellow and in the back cross with CST. 3, all the plants were yellow. In the other back cross viz., with the recessive Pale yellow parent, 1 : 1 segregation for the two phenotypes was obtained. The $F_2$ segregated in the ratio of 3 : 1 for yellow and pale yellow corolla types, respectively.

The cernuum parent is known to carry the $Y_a^P$ allele and its behaviour as a simple recessive to $Y_a$ carried by the CST. 3 parent is confirmed.

*Cross 3:* CST. 3 x N. R. 5 (*indicum* x *bengalense*)
Yellow x White.

In the $F_1$, all plants possessed yellow corolla and in the back cross with CST. 3 all the plants were yellow. In the other back cross with the recessive white corolla parent, the segregation for yellow and white corolla plants gave a good fit to 1 : 1 expectation. In the $F_2$, the proportion of plants in the two phenotypes conformed to a 3 : 1 segregation.

The N. R. 5 parent is known to carry the $y_a$ allele and the behaviour of the same as a simple recessive to $Y_a$ of the CST. 3 parent is confirmed.

TABLE III

*Inheritance of Corolla Colour*

| S. No. | Nature of cross and generation | No. of plants with corolla | | | Total | Monogenic segregation | |
|---|---|---|---|---|---|---|---|
| | | Yellow | Pale Yellow | White | | $X^2$ | Value of P. between |
| 1. | CST. 3 x BC. 19 | $F_1$ 33 | .. | .. | 33 | .. | .. |
| | Back cross with CST. 3 | 93 | .. | .. | 93 | .. | .. |
| | Back cross with BC. 19 | 102 | .. | .. | 102 | .. | .. |
| | $F_2$ Total of 6 families | 360 | .. | .. | 360 | .. | .. |
| 2. | CST. 3 x Cernuum | $F_1$ 32 | .. | .. | 32 | .. | .. |
| | Back cross with CST. 3 | 110 | .. | .. | 110 | .. | .. |
| | Back cross with cernuum | 56 | 42 | .. | 98 | 2·000 | 0·10 — 0·20 |
| | $F_2$ Total of 4 families | 304 | 94 | .. | 398 | 0·404 | 0·50 — 0·70 |
| 3. | CST. 3 x N. R. 5 | $F_1$ 37 | .. | .. | 37 | .. | .. |
| | Back cross with CST. 3 | 69 | .. | .. | 69 | .. | .. |
| | Back cross with N. R. 5 | 16 | .. | 10 | 26 | 1·384 | 0·20 — 0·30 |
| | $F_2$ Total of 7 families | 205 | .. | 67 | 272 | 0·020 | 0·80 — 0·90 |

| S. No. | Nature of cross and generation | No. of plants with corolla | | | | Total | $X^2$ | Value of P. between |
|---|---|---|---|---|---|---|---|---|
| | | Red on yellow | Yellow | Red on white | White | | | |
| 4. | CST. 3 x Sanguineum major | $F_1$ 20 | .. | .. | .. | 20 | .. | .. |
| | Back cross with CST. 3 | 66 | 50 | .. | .. | 116 | 2·206 | 0·10 — 0·20 |
| | Back cross with Sanguineum 119 | 55 | .. | .. | .. | 55 | .. | .. |
| | $F_2$ Total of 3 families | 191 | 68 | .. | .. | 259 | 0·217 | 0·50 — 0·70 |
| 5. | CST. 3 x Sanguineum major | 8 | .. | .. | .. | 8 | .. | .. |
| | Back cross with CST. 3 | 79 | 97 | .. | .. | 176 | 1·840 | 0·10 — 0·20 |
| | Back cross with Sanguineum major | 31 | .. | 21 | .. | 52 | 1·024 | 0·10 — 0·20 |
| | $F_2$ Total of 3 families | 176 | 68 | 56 | 12 | 312 | 4·536 | 0·20 — 0·30 |

*Cross 4:* CST. 3 x Sanguineum 119 (*indicum* x *bengalense*)
Yellow x Red on Yellow.

The corolla colour genotype of the Sanguineum 119 parent is $Y_a$, but due to the inter-action of the anthocyanin allele $R_2^{RS}$, the phenotypic expression is 'Red on Yellow'. In the $F_1$, the corolla colour was 'Red on Yellow' due to dominance of $R_2^{RS}$ over $R_2^{OS}$ (CST. 3 parent). In the back cross with CST. 3, segregation was obtained in the ratio of 1:1 for Red on Yellow: Yellow corolla plants. In the other back cross viz., with Sanguineum 119, all the plants possessed 'Red on Yellow' corolla. The segregation in $F_2$ conformed to 3:1 expectations for 'Red on Yellow': Yellow corolla plants.

Although this cross represents one between two types both carrying $Y_a$, due to the differences in their anthocyanin genotypes viz., $R_2^{RS}$ and $R_2^{OS}$, phenotypic segregation for corolla colour was obtained and the same was identical with that of anthocyanin segregation. The intensity of anthocyanin expression on the yellow corolla background was also studied in the different $R_2^{RS}$ segregants as per standard grades and these results are presented and discussed in a separate section.

*Cross 5:* CST. x Sanguineum major (*indicum* x *bengalense*)
Yellow x Red on White.

The Sanguineum major parent carries the recessive $y_a$ allele for corolla colour and the phenotypic expression of this white corolla gene is 'Red on White' in the background of $R_2^{RS}$, the anthocyanin allele carried by Sanguineum major.

The $F_1$ was 'Red on Yellow' due to the $Y_a$ allele inherited from the CST. 3 parent. In the backcross with this parent, segregation for the $F_1$ and parental phenotypes was obtained in the ratio of 1:1. In the backcross with the other parent viz., Sanguineum major, segregation for the $F_1$ and the parental phenotypes gave a good fit to 1:1 segregation. In the $F_2$, the phenotypic classes were 'Red on Yellow', Yellow, 'Red on White' and White corolla and and the segregation conformed to expectations on a 9:3; 3:1 hypothesis.

Although this cross represents one between two alleles viz., $Y_a$ and $y_a$, so far as corolla colour is concerned, four phenotypic classes have been obtained in the $F_2$ due to the interaction of the

$R_2^{RS}$ anthocyanin allele on corolla colour expression. The grades of corolla colour segregation in this cross is dealt with in a subsequent section of this paper.

(iii) *Corolla Colour — Anthocyanin combined assortment:* The crosses involved in the present study include three anthocyanin genotypes in the $R_2$ series of multiple allelomorphs and three corolla colour genotypes in the $Y_a$ series of alleles.

The data relating to corolla colour—anthocyanin combined assortment in the five crosses studied are presented below.

*Cross 1:* CST. 3 x Burma C. 19 (*indicum* x *burmanicum*)
Yellow corolla/Green stem — Ghost x Yellow corolla/Sun-red, spotted.

Since both the parents carry the Yellow corolla gene $Y_a$, there was a segregation only in respect of anthocyanin, the results of which have been presented earlier.

*Cross 2:* CST. 3 x Cernuum (*indicum* x *cernuum*)
Yellow corolla/Green stem—Ghost x Pale yellow corolla/Sun-red, spotted.

This represents a cross between $Y_a\ Y_a\ R_2^{os}\ R_2^{os}$ and $Y_a^{\ P}\ Y_a^{\ P}\ R_2^{AS}\ R_2^{AS}$. The $F_1$ was phenotypically $Y_a\ R_2^{AS}$ (Yellow corolla/Sun-red, spotted) and the results of segregation in $F_2$ and back crosses are presented in table 4(a).

*Cross 2:* CST. 2 x cernuum: Yellow corolla/Green stem, Ghost x Pale yellow corolla/pigmented-red spot.

It would be seen that the results of combined assortment accord well with expectations on the basis of independent dihybrid segregation for corolla colour and anthocyanin.

*Cross 3:* CST. 3 x N. R. 5. (*Indicum* x *bengalense*)
Yellow corolla/Green stem-Ghost x White corolla Sun-red, spotted.

This is a cross between $Y_a\ Y_a\ R_2^{os}\ R_2^{os}$ and $Y_a\ Y_s\ R_2^{AS}\ R_2^{AS}$. The $F_1$ was phenotypically $Y_a\ R_2^{AS}$ (yellow corolla/Sun-red, spotted) and the combined segregation in back crosses and $F_2$ summarised in table 4(b) would show that there is independent assortment of the corolla colour and anthocyanin genes.

*Cross 3:* CST. 3 x N. R. 5 Yellow corolla/Green stem-Ghost x White corolla/pigmented red spot.

TABLE IV (a)

*Cross 2:* CST. 3 x Cernuum: Yellow corolla/Green stem Ghost x Pale-yellow corolla/Pigmented-Red spot

| Generation | No. of plants | | | | Total | $X^2$ | P. value between |
|---|---|---|---|---|---|---|---|
| | Yellow Red spot | Pale-Yellow Red spot | Yellow Ghost | Pale-yellow Ghost | | | |
| $F_1$ | 32 | .. | .. | .. | 32 | .. | .. |
| Back cross with CST. 3 | 58 | .. | 52 | .. | 110 | 0·328 | 0·50 — 0·70 |
| Back cross with Cernuum | 56 | 42 | .. | .. | 98 | 2·000 | 0·10 — 0·20 |
| $F_2$ Total of 4 families | 227 | 72 | 77 | 22 | 398 | 0·543 | 0·90 — 0·95 |

TABLE IV (b)

*Cross 3:* CST 3 x N. R. 5: Yellow corolla/Green stem-Ghost x White corolla/Pigmented Red spot

| Generation | No. of plants | | | | Total | $X^2$ | P. value between |
|---|---|---|---|---|---|---|---|
| | Yellow Red spot | White Red spot | Yellow Ghost | White Ghost | | | |
| $F_1$ | 37 | .. | .. | .. | 37 | .. | .. |
| Back cross with CST. 3 | 35 | .. | 34 | .. | 69 | 0·014 | 0·80 — 0·99 |
| Back cross with N. R. 5 | 16 | 10 | .. | .. | 26 | 1·384 | 0·20 — 0·30 |
| $F_2$ Total of 7 families | 148 | 51 | 57 | 16 | 272 | 0·928 | 0·80 — 0·90 |

*Cross 4:* CST. 3 Sanguineum 119 (*indicum* x *bengalense*) Yellow corolla/Green stem – Ghost x Red on Yellow/Full red-spotted.

This cross represents $Y_a\ Y_a\ R_2^{os}\ R_2^{os}$ x $Y_a\ Y_a\ R_2^{rs}\ R_2^{rs}$.

The parents differ only in their anthocyanin genotype and the segregation for this character has been presented earlier. In respect of corolla colour, both the parents carry the Yellow corolla gene $Y_a$, but the phenotypic expression of the same is greatly modified by the anthocyanin background and the grades of corolla colour in segregating populations vary in the heterozygous and homozygous phases of both the genes. These results are discussed in the subsequent section of this paper.

*Cross 5:* CST. 3 x Sanguineum major (*indicum* x *bengalense*) Yellow corolla/Green stem-Ghost x Red on White Full red-spotted.

This is a cross between $Y_a\ Y_a\ R_2^{os}\ R_2^{os}$ and $Y_a\ Y_a\ R_2^{rs}\ R_2^{os}$. The F1 was phenotypically Red on Yellow/Full red spotted ($Y_a\ Y_a\ R_2^{rs}\ R_2^{os}$) and in the $F_2$, independent dihybrid assortment was obtained in the ratio of 9 : 3 : 3 : 1 for the four phenotypes, Red on Yellow/Full red-spotted; Red on White/Full red-spotted; Yellow corolla/Green stem-Ghost and White corolla/Green stem-Ghost. The last-mentioned phenotype was confirmed to be so in further breeding tests, since Ghost spot will not be visible against White corolla background, but merely appear as spotless.

The combined assortment in $F_2$ and back crosses is summarised in table 4(c).

The corolla colour grading in respect of the $Y_a$ gene in its homozygous and heterozygous phases in the $R_2^{rs}$ background is discussed in the next section.

(iv) *Interaction of genotypes:* The inheritance of anthocyanin and corolla colour in the crosses involving the two Sanguineum parents which carry the highest member of the anthocyanin allelomorph series viz. $R_2^{rs}$ presents interesting data for study of the interaction of genotypes and the same is dealt with in this section. The phenotypic expression of the corolla colour genes $Y_a\ Y_a$ (Yellow) and $Y_a\ Y_a$ (White) in their homozygous and heterozygous states is modified by the anthocyanin genotype.

TABLE IV (c)

*Cross 5:* CST. 3 x Sanguineum Major: Yellow corolla/Green stem-Ghost x Red on White/Deep Red-spotted

| Generation | No. of plants | | | | Total | $X^2$ | P. value between |
|---|---|---|---|---|---|---|---|
| | Red on Yellow spot | Red on White spot | Yellow Ghost | White Ghost | | | |
| $F_1$ | 8 | .. | .. | .. | 8 | .. | .. |
| Back cross with CST. 3 | 79 | .. | 97 | .. | 176 | 1·840 | 0·10 — 0·20 |
| Back cross with Sanguineum major | 31 | 21 | .. | .. | 52 | 1·924 | 0·10 — 0·20 |
| $F_2$ Total of 3 families | 176 | 56 | 68 | 12 | 312 | 4·536 | 0·20 — 0·30 |

All *arboreums* homozygous for both $R_2^{RS}$ and $Y_a$ grade consistently at 10-11 (Silow and Yu 1942) and this is found to be the feature in the case of the Sanguineum 119 parent utllised in the present study. This phenotype may be designated as 'Red on Yellow' corolla.

The CST. 3 x Sanguineum 119 $F_1$ heterozygous for both $R_2^{RS}$ and $Y_a$ graded at 7-8 and in the $F_2$, segregation was obtained in the ratio of 1 : 2 : 1 for parental: F1 grades of 'Red on Yellow'; Yellow corolla respectively.

In the backcross with $R_2^{os}$, all the $R_2^{RS}$ $R_2^{os}$ segregants graded at 7-8 as expected, while in the backcross with $R_2^{RS}$, a 1 : 1 segregation was obtained far parental and $F_1$ grades of 'Red on Yellow' corolla, which gave a good fit to the genotypic expectations. The relevant data are furnished in table 5.

*Cross 4:* CST. 3 x Sanguineum 119 (*indicum* x *bengalense*)
$R_2^{os}$ $R_2^{os}$ $Y_a$ $Y_a$ x $R_2^{RS}$ $R_2^{RS}$ $Y_a$ $Y_a$

The sanguineum 119 parent is homozygous for both $R_2^{RS}$ and $Y_a$; the $F_1$ is heterozygous for $R_2^{RS}$; in the back cross with CST. 3 ($R_2^{os}$ $R_2^{os}$ $Y_a$ $Y_a$), the phenotypically $R_2^{RS}$ segregants are all heterozygous for this gene (i. e.) like the $F_1$; in the back cross with Sanguineum 119 ($R_2^{RS}$ $R_2^{RS}$ $Y_a$ $Y_a$), the phenotypically $R_2^{RS}$ segregants are in the homozygous and heterozygous phases in the proportion of 1 : 1; in the $F_2$, the $R_2^{RS}$ segregants occur in the ratio of 2 : 1 in the heterozygous and homozygous phases respectively.

The data on petal pattern grades furnished in the table above accord well with these expectations.

The Sanguineum major parent carries the $R_2^{RS}$ and $Y_a$ alleles in their homozygous phase and the phenotypic expression of corolla colour in this parent may be designated as 'Red on White'. This parent graded at 1 and the $F_1$ CST. 3 x Sanguineum major which has a genetic constitution of $R_2^{RS}$ $R_2^{os}$ $Y_a$ $Y_a$ was found to posses grade 7 corolla colour.

The data pertaining to this cross are as follows.

*Cross 5:* CST. 3 x Sanguineum major (*indicum* x *bengalense*)
$R_2^{os}$ $R_2^{os}$ $Y_a$ $Y_a$ x $R_2^{RS}$ $R_2^{RS}$ $y_a$ $y_a$

The frequency arrays of petal pattern distribution of the $R_2^{RS}$ components in the different generations, as graded with Hutchinson's petal colour grades are furnished in table 6.

TABLE V

*Frequency array of petal pattern distribution*

| S. No. | Material | Hutchinson's $R_2^{RS}$ grades 7 | 8 | 9 | 10 | Total plants | $X^2$ | Value of P. between |
|---|---|---|---|---|---|---|---|---|
| 1. | Sanguineum 119 | .. | .. | .. | 13 | 13 | .. | .. |
| 2. | CST. 3 x Sanguineum 119 $F_1$ | 20 | .. | .. | .. | 20 | .. | .. |
| 3. | Back Cross with CST. 3 | 116 | .. | .. | .. | 116 | .. | .. |
| 4. | Back cross with Sanguineum 119 | 34 | .. | 25 | .. | 59 | 1·370 | 0·2 — 0·3 |
| 5. | $F_2$ Total of 3 families | 131 | .. | 77 | .. | 208 | 1·273 | 0·2 — 0·3 |

TABLE VI

*Frequency arrays of petal pattern distribution*

| S. No. | Material | Hutchinson's $R_3^{RS}$ grades 7 | 8 | 9 | 10 | 11 | Total plants | $X^2$ | Value of P. between |
|---|---|---|---|---|---|---|---|---|---|
| 1. | CST. 3 x Sanguineum major $F_1$ | 8 | ... | .. | .. | 8 | .. | ... | .. |
| 2. | Back cross with CST. 3 | 20 | 47 | 14 | .. | 81 | .. | .. | .. |
| 3. | Back cross with Sang. major | 10 | 10 | 1 | 4 | .. | 25 | .. | ... |
| 4. | $F_2$ Total of 3 families | 34 | 57 | 10 | 31 | 1 | 133 | 0·184 | 0·5 — 0·7 |

Only the $R_2^{rs}$ segregants are dealt with, since only in this genotypic background, the expression of the $Y_a$ gene is modified.

The $F_1$ which is heterozygous for both $R_2^{rs}$ and $R_2^{os}$ graded at 7. The genotypes in the backcross with CST. 3 are 1) $R_2^{rs}$ $R_2^{os}$ $Y_a$ $Y_a$ and 2) $R_2^{rs}$ $R_2^{os}$ $Y_a$ $y_a$ and this population has graded 7 to 9 with no indication of any segregation. In the back cross with Sanguineum major, the genotypes are $R_2^{rs}$ $R_2^{rs}$ $Y_a$ $Y_a$ and $R_2^{rs}$ $R_2^{rs}$ $y_a$ $y_a$.

A large enough population in this back cross would possibly yield a 1 : 1 segregation for grades 7 and 8 : grades 9, 10 and 11.

In the $F_2$, the genotypes of the phenotype 'Red on Yellow' i. e. $R_2^{rs}$ component are :

| | *Frequency* | |
|---|---|---|
| (1) homozygous for $R_2^{rs}$ and homozygous for $Y_a$ | 1 | 3 |
| (2) homozygous for $R_2^{rs}$ and heterozygous for $Y_a$ | 2 | |
| (3) heterozygous for $R_2^{rs}$ and homozygous for $Y_a$ | 2 | 6 |
| (4) heterozygous for both $R_2^{rs}$ and $Y_a$ | 4 | |

Items 1 and 2 may be expected to grade 9-11, while items 3 and 4 will cover grades 7 and 8.

From the frequency distribution of this phenotype in the $F_2$ population, a close fit to 1 : 2 segregation is obtained in respect of the above classes.

The interaction of the $R_2^{rs}$ allele with the corolla colour genotypes may be summed up as follows :

(1) Homozygous $R_2^{rs}$ with homozygous $Y_a$ grades 10 and above.

(2) Homozygous $R_2^{rs}$ with heterozygous $Y_a$ grades not below 9.

(3) Heterozgous $R_2^{rs}$ with homozygous or heterozygous $Y_a$ grades 7 and 8.

(4) The influence of heterozygous $Y_a$ on the expression of $R_2^{rs}$ in corolla colour, is only slight and does not shift the grade below one, to that obtained in the homozygous phase.

**Summary :** The inheritance of the Cocanadas Green stem/Ghost spot type, spotted in Peninsular Indian *G. arboreum* race *indicum*, in five inter-racial crosses with Sun-red/spotted and Full red/Spotted ; yellow corolla, Pale yellow and White corolla genotypes is reported.

In anthocyanin inheritance, the Green stem/Ghost which carries the $R_2^{os}$ allele confirmed its behaviour as a simple recessive to the $R_2^{AS}$ (Sun-red/Spotted) and $R_2^{RS}$ (Full red/spotted) alleles of the anthocyanin multiple allelomorph series.

In respect of corolla colour, the Pale Yellow corolla ($Y_a^P$) of *Cernuum* and White corolla ($y_a$) of N. R. 5 behaved as simple recessive to Yellow corolla ($Y_a$) of the Green stem/Ghost parent. In the cross with Sanguineum 119 carrying Yellow corolla gene $Y_a$, phenotypic segregation for corolla colour was however obtained due to differences in their anthocyanin genotypes and the same was identical with that of anthocyanin segregation. In the cross with Sanguineum major carrying the White corolla gene $Y_a$, four phenotypic classes were obtained in the $F_2$ due to the interaction of the $R_2^{RS}$ anthocyanin allele on corolla colour expression and the segregation accorded well with the expectations.

Anthocyanin and corolla colour genes assorted independently in all the crosses studied.

The interaction of the $R_2^{RS}$ anthocyanin genotype on the expression of corolla colour was studied with reference to colour plates of Hutchinson (1932) in the two crosses involving $Y_a$ and $y_a$ alleles and the results have been discussed.

It was shown that while heterozygosity of the $R_2^{RS}$ allele brought down the grade of petal pattern, the influence of heterozygous $Y_a$ on the expression of $R_2^{RS}$ in corolla colour, was only slight and did not shift the grade below one, to that obtained in the homozygous phase.

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