

THE INHERITANCE OF VIRESCENT YELLOW AND RED PLANT COLORS IN COTTON¹

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PREVIOUS WORK ON CHLOROPHYLL DEFICIENCIES

Deficiencies in the amount of chlorophyll in the cotton plant have been reported in relatively few instances. BALLS (1908) made a cross between an upland cotton with light green leaves and a dark green Egyptian cotton. He states that in the F₂ generation, plants with light green leaves and plants with dark green leaves appeared in a 3:1 ratio. STROMAN and MAHONEY (1925) recovered two chlorophyll deficient types in the F₂ generation from crosses between upland and Egyptian cottons (*Gossypium hirsutum* × *G. barbadense*). The first type, yellow seedlings, was due to 2 recessive genes, the segregating plants producing 15 green:1 yellow seedling. The second type was a pattern seedling character in which certain irregular areas devoid of chlorophyll on the cotyledon leaves were surrounded by normal green pigment. These pattern characters were inherited as recessives. In some cases two, in others three, pairs of genes were concerned. HARLAND (1932) also recovered from several different interspecific crosses various types which were partially deficient in chlorophyll. HORLACHER and KILLOUGH (1931) induced in upland cotton (*G. hirsutum*) by radiations a type that produces yellow seedlings lacking in chlorophyll. This yellow is lethal and a simple recessive to green, heterozygous plants producing 3 green: 1 yellow seedling. The yellow seedlings die after using up the stored food material of the seed. In all such chlorophyll deficient types which have been observed by the authors, the deficient portions are yellow due to the presence of carotinoid² pigments and the absence of green chlorophyll. No portion of a cotton plant devoid of carotinoid pigments was observed. The yellow seedling character mentioned above is not to be confused with the virescent yellow mature plant color discussed in this paper.

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² The authors wish to express their appreciation to Dr. R. G. REEVES, Professor of Biology, for conducting chemical and microchemical tests which show that the yellow pigment in the cotton plant is due to the two carotinoid pigments, carotin and xanthophyll.

HISTORY AND DESCRIPTION OF VIRESCENT YELLOW

The authors are indebted to Mr. R. E. KARPEN for the stock of virescent yellow cotton, which was found growing on the TEXAS AGRICULTURAL EXPERIMENT STATION, Substation No. 7, Spur, Texas, in 1925. Only two plants of this kind appeared among thousands of normal green cotton plants growing in a large field of Mebane cotton. From the nature of its discovery, it would appear probable that its origin was the result of a recent mutation. The senior author has grown numerous progenies from the original material which have always bred true for the virescent yellow plant color.

The seedlings and young plants of virescent yellow cotton have a greenish yellow appearance due to a partial deficiency of chlorophyll. The yellow carotinoid pigments are not completely masked by the green chlorophyll that is present, thus giving the plants their characteristic appearance. As these plants grow older the chlorophyll increases in amount to such an extent that at maturity virescent yellow plants are less striking in appearance and not as readily distinguishable from the normal green plants. Frost gives to the virescent yellow plants a yellowish cast in the autumn.

VIRESCENT YELLOW \times GREEN

In crosses we have made between virescent yellow and normal green cotton, the plants of the F_1 generation are all green. The F_2 generation segregated into 602 green:196 virescent yellow, a deviation of only 3.5 ± 8.26 from a 3:1 ratio. The genes concerned have been designated V , green, and v , virescent yellow.

RED LEAF COTTON

The occurrence and heredity of anthocyanin pigments in the cotton plant have been studied by several investigators. There are two general types of distribution of this pigment.

The first type is the red plant color which is produced by the anthocyanin and distributed throughout the stem and leaves making the entire plant red. This type has been described in *G. hirsutum* by McLENDON (1912), THADANI (1921), WARE (1927, 1929), and CARVER (1929). It has also been described by LEAKE (1911) in *G. arboreum*. It is usually called red leaf cotton.

The second type is the red leaf spot which is confined to the leaf pulvinus. This spot is due to the development of anthocyanin in the epidermal and sub-epidermal cells of the petiole at the point where it divides into the leaf-veins. This type has been described by BALLS (1908, 1910) in *G. barbadense*. This red spot on the leaf is characteristic of all the so-called green

varieties of *G. hirsutum*, and of many other species of *Gossypium*. In this paper this type is classed as green leaf cotton.

The red plant color produced by the complete distribution of anthocyanin throughout the plant has been found to be a simple dominant to green plant color by each of the investigators mentioned. BALLS reports that the red leaf spot is also a simple dominant to green.

The anthocyanin pigment in red leaf cotton is distributed over the entire plant, but develops in greater quantities in those parts which are directly exposed to the rays of the sun. Less anthocyanin develops on the under sides of the branches, petioles, and leaves than on the upper sides. When these surfaces are turned over and held in position so that the sun's rays strike these under surfaces directly, they also develop as much red color as is normally characteristic of the upper surfaces. The effect of light on the development of anthocyanin pigment is further shown by the fact that plants of the red leaf strain grown in the greenhouse during the winter develop very small amounts of red pigment, giving to the plants only a slightly reddish cast on a green background, whereas plants of the same genotype grown in the field in the summer are solid red in appearance, except for the greenish underparts noted above.

When red leaf cotton is placed in an alkaline solution the anthocyanin pigment turns blue. The red color is restored when the tissue is placed in an acid solution.

RED LEAF \times GREEN

Our crosses between red leaf cotton and green leaf cotton, which has the red leaf spot, have confirmed the interpretation of the inheritance of these two characters given by the investigators mentioned above. The F_1 generation from this cross was red, but of a lighter shade than the red leaf parent. The F_2 generation consisted of 357 red:122 green, a deviation of only 2.25 ± 6.39 from a 3:1 ratio.

The homozygous red (RR) plants can usually be separated phenotypically from the heterozygous red (Rr) plants. In general the RR plants are dark red and the Rr plants are light red. The genotype of any red leaf plant cannot, however, be determined definitely without a progeny test.

VIRESCENT YELLOW \times RED LEAF

Virescent yellow cotton was crossed with red leaf cotton. The plants of the F_1 generation were light red. In the F_2 generation red leaf and virescent yellow plants were produced, as also were green plants and a new type which has been named bronze. These types appeared in the proportions shown in table 1.

TABLE 1
F₂ population from Virescent Yellow × Red Leaf Cotton.

	RED LEAF	BRONZE	GREEN	VIRESCENT YELLOW
Observed	256	101	94	28
Calculated, 9:3:3:1	269.44	89.81	89.81	29.94
o-c	-13.44	11.19	4.19	-1.94

p = .50

It is apparent from table 1 that two pairs of genes which are inherited independently are concerned in this cross. The genotype of the original red leaf parent was *RRVV*, that of the virescent yellow *rrvv*. The green segregates were *rrVV* or *rrVv*. The bronze segregates were due to the action of the red leaf gene *R* on virescent yellow and were of the genotypes *RRvv*, which is dark bronze, and *Rrvv* which is light bronze. All four pigments, anthocyanin, chlorophyll, xanthophyll, and carotin, are present in bronze plants and combine in such proportions as to produce this color type. Mature bronze plants are practically indistinguishable from red leaf plants. In general, the *F₂* red leaf plants can be divided phenotypically into dark red and light red, and the *F₂* bronze plants can be divided phenotypically into dark bronze and light bronze. However, in neither case can the separation of the genotype be made with absolute certainty without resort to the breeding test. *F₃* progeny were grown from self-fertilized bolls of 40 different *F₂* plants with the results given in table 2.

TABLE 2
Breeding behavior of selfed F₂ segregates.

<i>F₂</i> PHENOTYPE	<i>F₂</i> GENOTYPE	NO. OF <i>F₂</i> PLANTS	PHENOTYPIC CLASSES IN <i>F₃</i>					
			DARK RED	LIGHT RED	DARK BRONZE	LIGHT BRONZE	GREEN	VIRESCENT YELLOW
dark red	<i>RRVV</i>	3	66					
dark red	<i>RRVv</i>	2	30		5			
light red	<i>RrVV</i>	1	5	21			12	1 (?)
light red	<i>RrVv</i>	11	38	92	17	34	45	12
dark bronze	<i>RRvv</i>	2			50			
light bronze	<i>Rrvv</i>	8			33	85		43
green	<i>rrVV</i>	0						
green	<i>rrVv</i>	10					174	64
virescent yellow	<i>rrvv</i>	3						35

In each case the breeding behavior of the F_2 genotype is according to expectation, with the exception of the one virescent yellow plant appearing among the progeny of the light red F_2 plant, which, according to the remainder of its progeny, must have been $RrVV$. It seems probable that this one off-type plant in the entire F_3 population of 862 was the result of mechanical mixture.

The F_3 population from selfing the light red plants heterozygous for both genes, $RrVv$, fits very closely the expected ratio of 3 dark red : 6 light red : 1 dark bronze : 2 light bronze : 3 green : 1 virescent yellow (table 3).

TABLE 3
F₃ population from RrVv Light Red F₂'s.

	DARK RED	LIGHT RED	DARK BRONZE	LIGHT BRONZE	GREEN	VIRESCENT YELLOW
Observed	38	92	17	34	45	12
Calculated, 3:6:1:2:3:1	44.62	89.25	14.87	29.75	44.62	14.87
o-c	-6.62	2.75	2.13	4.25	0.38	-2.87

$p = .77$

The different color types of cotton plants resulting from this dihybrid cross can more readily be distinguished when the plants are bearing their first few adult leaves than at any other time in the life of the plants. It is impossible to classify such plants with any degree of accuracy at later stages of growth. Neither is classification from the cotyledon leaves accurate.

SUMMARY

1. Virescent yellow cotton, a new type, is described. This cotton is greenish yellow when young. The chlorophyll gradually increases in amount so that at maturity these plants are not readily distinguishable from normal green plants. Virescent yellow is a simple recessive to green. The genes of this pair have been designated as V (green) and v (virescent yellow).

2. Red leaf cotton is produced by the distribution of anthocyanin pigment throughout the plant. Data are presented, confirming the results secured by others, which indicate that red leaf R is a simple dominant to green leaf r .

3. Genes R and V are inherited independently.

4. The combination of R with v produces a new type named bronze. Bronze is produced by the development of red anthocyanin pigment on a virescent yellow background.

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