OCCURRENCE OF THE DWARF-RED CHARACTER IN UPLAND COTTON [1]

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INTRODUCTION

Red coloration in the cotton plant, due to an increase in the anthocyanin pigmentation, is a genetic character that has received wide study. For literature on the inheritance of this character the reader is referred to Carver (*1*),[3] Harland (*2, 6*), Hutchinson (*8, 10*), McLendon (*14*), and Ware (*15, 17*). Hutchinson and Silow (*11*) have listed a multiple allelomorphic series of six types of anthocyanin pigmentation in the Asiatic cottons. A similar allelomorphic series has been established by Harland (*6*) for cottons of the New World group. This latter series, however, does not include any red-plant types occurring in upland cotton, to which belong most of the types studied by investigators (*1, 13, 14, 15, 17*) in this country. Harland (*6*) states that *Gossypium hirsutum* (upland) red R_1 (*11*) is a duplicate gene to the anthocyanin allelomorphic series R_2 of the New World cottons. Hutchinson, Silow, and Stephens (*12*) have recently reported that the anthocyanin pigmentation of each of the wild species of *G. thurberia, G. armourianum,* and *G. aridum* belongs to the R_1 series of *G. hirsutum.* The only members of this series previously reported are red plant and normal green plant.

The dwarf character in cotton appears very infrequently as compared to the red-plant character. Harland (*3, 4, 6*) reported the occurrence of "crinkled dwarf" in sea-island cotton. He stated that this mutant is much smaller than and fully recessive to normal sea-island cotton. Crinkled dwarf was thought to occur only in sea-island cotton but has now been reported by Hutchinson and Ghose (*9*) in *Gossypium hirsutum* L. (upland cotton). In this species also the crinkled-dwarf character behaves as a complete recessive to normal. Horlacher and Killough (*7*) produced dwarf cotton plants by means of X-ray treatment of the dry seeds. As yet no inheritance studies have been reported for this type of dwarfing.

In the present paper a new type of red-plant color, together with a new type of dwarfing, in Acala cotton is described, and the results of a study of the inheritance of this character, herein designated as "dwarf-red," are presented.

DESCRIPTION OF THE DWARF-RED CHARACTER

The dwarf-red mutation of Acala cotton originated as a red chimera on a plant of normal height. It was discovered in a planting of

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[3] Italic numbers in parentheses refer to Literature Cited, p. 481.

foundation seed at the United States Cotton Field Station, Shafter, Calif. When first observed the mutant plant was 10 inches high, and the first red leaf was about one-half normal size. As the plant developed, the somatic variation proved to be a deep-red band comprising about one-third of the circumference of the main axis. The plant finally grew to a height of about 4 feet. As the height increased, the band of red spiraled around the axis, producing a red fruiting branch wherever it happened to coincide with a node. All nodes on the plant not intersected by the band of red produced normal green vegetation. Attempts to obtain self-pollinated seed from the red portion of the plant were unsuccessful. However, open-pollinated seed from the red fruiting branches was planted the second year to produce a progeny of 17 plants. Twelve of these plants were red throughout and the remaining five were green. The green plants had the appearance of normal Acala in every respect. The occurrence of green plants indicates that all seed produced by the chimera did not possess the factor for the dwarf-red character. The red plants varied considerably in height, but all were much shorter than the normal Acala plants. The variation in height of the red plants is further evidence of the heterozygous nature of the seed produced by the dwarf-red chimera. As will be shown later, the heterozygous dwarf-red is intermediate in height between the homozygous dwarf-red and the normal green. Self-pollinated seed was obtained from all plants of the second year except a very dwarf-red one.

The progenies of eight plants were grown the third year. Three of these progenies were from green plants and were comprised of normal green plants. The other five progenies originated from self-pollinated red plants of the second year. All segregated into three distinct types, dwarf-red, normal green, and a type intermediate in both height and red color. Of these five segregating progenies, three gave an indication of a 1 : 2 : 1 ratio. The data for this segregation are presented in table 1.

TABLE 1.—*Third-year segregation of plant lines originating from a dwarf-red chimera*

Progeny	Dwarf red	Intermediate	Normal green	χ^2	P
RA-3	5	13	7	0.36	0.80+
RA-5	3	11	10	4.25	.10+
RA-10	4	13	8	1.32	.50+
RA-11	2	10	12	9.00	.01+
RA-12	2	9	12	9.78	.01−
Total	16	56	49		

The monohybrid ratio obtained for three progenies is not of great significance, owing to the small numbers involved. The fact that these progenies even approached a monohybrid ratio would show that the seed produced by the chimera was heterozygous, or cross-pollinated with normal green cotton, or both. The deficiency of dwarf-red individuals would indicate that many were too weak to survive. This fact is borne out by observation, as many of this type that did survive were too weak to produce bolls. However, after the

dwarf-red was reduced to homozygosity and crossed with normal green Acala, differential viability did not occur apparently in the recovered dwarf-red segregates of the F_2. This will be noted subsequently.

Dwarf-red Acala in the homozygous condition averages 19 inches in height as contrasted with 48 inches for normal green and 32 inches for the heterozygote. Dwarfness is characterized by a decrease in the length of the internodes, as well as a decrease in the number of nodes. The homozygous dwarf-red Acala averages 23 nodes, the heterozygous dwarf-red 30 nodes, and the normal green 35 nodes per plant.

The coloring of dwarf-red Acala differs from that in other red-plant types of upland cotton. Ware (*15*, *16*, *17*) studied the Winesap variety of cotton and found that this variety in the homozygous condition is a deep red throughout the entire plant, stem, foliage, flowers, and bolls. In contrast to the Winesap variety, dwarf-red Acala has pale cream-colored flowers comparable to those of normal green Acala. In addition, the bolls of dwarf-red Acala are green as contrasted with the red bolls of other red-plant types of cotton. This latter observation caused R. A. Silow, who visited the Shafter, Calif., station in 1939, to express the opinion that dwarf-red Acala represents a distinctly new type of red-plant coloration in upland cotton.

The association between dwarfing and red-plant color is apparently complete; in over 1,200 homozygous red plants no exception to this rule was found. In the heterozygous condition both the color and height of plant are uniformly intermediate between the dwarf-red and normal green plants. This evident association between red-plant and dwarfism suggests linkage or pleiotropism. To date, few cases of linkage of this sort of association have been authenticated in cotton.

Chlorophyll determinations of the leaves of dwarf-red Acala, normal green Acala, as well as several other varieties of red-plant cotton, show that all have a very similar chlorophyll content. Other varieties of red-plant cotton have grown to normal height in the station nursery. This observation would largely dispel any conclusion that dwarfing was due to any local conditions of soil or climate.

INHERITANCE OF THE DWARF-RED CHARACTER IN THE CROSS DWARF-RED×NORMAL GREEN ACALA

Homozygous dwarf-red Acala when crossed with normal green produced in the F_1 generation a progeny that was uniformly intermediate in both color and height of plant between the two parental types. As mentioned above, the "crinkled dwarfs" reported by Harland (*4*, *5*) and Hutchinson and Ghose (*9*) were entirely recessive in the F_1 or heterozygous condition. However, the intermediate red coloration in the dwarf-red heterozygote agrees with such studies previously reported (*1*, *6*, *8*, *14*, *15*, *17*). The F_2 generation segregated into the monohybrid ratio of 1:2:1. Table 2 presents the data of this segregation along with χ^2 for goodness of fit to a 1:2:1 ratio. Corresponding P values indicate a satisfactory agreement between the theoretical 1:2:1 ratio and observation.

TABLE 2.—*Segregation of the F_2 generation in the cross between dwarf-red Acala and normal green Acala*

Progeny	Dwarf red	Intermediate	Normal green	χ^2	P
93	88	155	99	3.70	0.20−
10-20	6	12	6	.00	1.00
10-21	6	15	3	2.25	.30+
21-1	19	28	19	1.52	.50−
21-11	28	47	26	.56	.80−
20-15	14	32	14	.27	.90−
20-22	18	42	17	.66	.70+
20-24	20	32	16	.71	.70+
20-1	20	41	20	.01	.99+
20-10	18	38	15	.61	.70+
20-13	36	44	23	5.47	.05+
6-2	8	16	9	.09	.95+
Total	281	502	267		

A backcross of the heterozygous dwarf-red to either parental type produces in the following generation a monohybrid ratio of 1 heterozygote to 1 parental type. Table 3 reports the results of the backcross between a heterozygous dwarf-red and normal green. Chi-square and the corresponding P values indicate a very satisfactory agreement between the observed and the theoretical 1 : 1 ratio. The backcross to the other parental type, dwarf-red, resulted in 23 intermediate red plants and 25 normal dwarf-red plants. As will be readily seen, this also is a very satisfactory agreement with the theoretical 1 : 1 ratio.

TABLE 3.—*Segregation of the backcross generation in the cross between the F_1 and the normal green Acala*

Progeny	Intermediate red	Normal green	χ^2	P
3-2	26	32	0.62	0.50−
4-2	17	16	.03	.90−
51	13	10	.39	.50+
40	9	7	.25	.70−
Total	65	65		

SUMMARY

The mutation of Acala cotton herein designated as "dwarf-red" originated as a chimera on an otherwise normal green plant.

Seeds produced by the chimera were heterozygous for the dwarf-red character.

A new type of red-plant color in upland cotton is described.

A new type of dwarfing in cotton is described which is not recessive in the heterozygous condition.

Dwarfing in this type is closely associated with red-plant color. Possibly both expressions are controlled by the same factor.

Dwarf-red Acala when crossed with normal green Acala produced an F_2 generation that was intermediate in both color and plant height between the parental types.

The F_2 generation of the cross between dwarf-red Acala and normal green Acala segregated into the 1:2:1 ratio, inducing a simple monohybrid.

Likewise the backcross generations obtained from the crosses made between the F_1 or the heterozygous dwarf-red and the parental

types verified the monohybrid condition, both segregating into the 1:1 ratio.

Indications are that dwarf-red is controlled by a single factor.

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