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lesions were found on the secondary roots, but it is doubtful if the grubs were the primary cause of the root deterioration or of the lesions since similar lesions will develop on roots of plants grown in the greenhouse in unsterilized soil even when no insects are present. The development of necrotic areas on tap roots of Ladino white clover in New Hampshire has been reported recently by Kilpatrick and Dunn.[4] They found no clear-cut relationship between fungi and insects, although the two were associated. Deterioration of the tap roots of Ladino white clover was also studied by Westbrooks and Tesar.[5]

Another type of injury appeared on the upper surface of stolons of plants which had been defoliated from one cause or another and seemed to be due to frost injury, or sunburn, or both. Plants which survived best had stolons half covered by soil and shaded by leaves. To simulate this shading, halves of some of the better plants (25 in all) including wild white clover as well as Ladino were mulched with sugar cane bagasse November 25, 1958. In March 1959, these mulched areas had fewer dead stolons than the corresponding unmulched portions of the plants, but by midsummer there was no difference.

In 1959 fifty plants were transplanted from the greenhouse in May into the same area of the field where the original lot of plants had been grown. All these plants had well-developed tap roots. By July, lesions were found to some extent on all thickened roots, both the tap roots and the thickened roots somewhat like tap roots that develop at the nodes. No insects were found in the soil around the plants but some of the roots looked chewed. These plants were compared with first-year seedlings grown from seed planted directly in the field. The seedling plants had similar but less robust root systems. There were more nodules on the fibrous roots and the thickened roots were smaller in diameter, but all thickened roots on the seedling plants had lesions to a greater or lesser degree. Even as young as these plants were, a few of the stolons were dying or already dead.

By July 31, the transplanted plants were going fast. Those that had shown anthocyanin color from leaf hopper injury earlier were now almost dead. Other plants showed the various blotches, yellow and white patches and twisted leaves of virus disease. Again, as had been observed in other years, the plants showing severe leaf hopper damage were compact in comparison with the others and were dead by October 31.

In each of the populations of white clover studied some plants were more vigorous and more persistent. This hardly seems to be chance as all of the plants had equal opportunity to become injured by diseases and insects but there was no correlation between plant type and survival. Some of the plants that had a wide spreading habit of growth with long internodes and infrequent rooting at the nodes survived as well or better than some of the dense compact plants. On the other hand, plants of both habits of growth died the first winter.

The evidence suggests that a complex of disease factors probably complicated by damage from insects is the primary cause of loss of stands of Ladino white clover. There do seem to be differences in resistance to leaf hoppers and to some of the leaf spot organisms but not to the complex of soil borne root rotting organisms. Until productive strains resistant to these organisms are found, it is doubtful if Ladino white clover will regain the place it did hold among forage crops in New England.

[4] Kilpatrick, R. A., and Dunn, G. M. Fungi and insects associated with deterioration of white clover tap roots. Crop Sci. 1: 147–149, 1961.

[5] Westbrooks, Fred E., and Tesar, Milo B. Tap root survival of Ladino clover. Agron. J. 47:403–410, 1955.

INHERITANCE OF VEINS-FUSED MUTANT IN AMERICAN UPLAND COTTON, *Gossypium hirsutum* L.[1]

R. J. Kohel and C. F. Lewis[2]

AN ABNORMAL plant phenotype was observed by H. W. Webb, of Coker's Pedigreed Seed Company, in a fourth-year increase block of American Upland cotton, *Gossypium hirsutum* L. Several aberrant plants were found in the material which indicated they might have arisen from a mutation in the interval between the original progeny row and the fourth year of increase. The prominent feature of the abnormal plants was irregular fusing of the leaf veins; therefore, this aberrant phenotype was named "veins-fused."

Seeds from abnormal plants were sent to Texas Agricultural Experiment Station for genetic evaluation. The purpose of this paper is to report results of a study of the inheritance of the veins-fused character.

Procedure and Results

In 1958, a small population from seeds of the original veins-fused plants was grown for observation. All plants in the population exhibited the veins-fused phenotype illustrated in Figure 1. The stunted growth and deformed leaves resembled effects produced by spraying plants with low concentrations of 2,4-D. Leaves of veins-fused plants, as contrasted with normal leaves (Figure 2), were thicker and had more numerous veins or veinlets which fused irregularly. This fusion caused folding and rolling of the leaves and loss of their normal shape.

To study the inheritance of veins-fused, aberrant plants were crossed reciprocally with an inbred line (D&PL-14). Small F_1 populations of the crosses were grown in the winter greenhouse, 1958–59, and all plants appeared normal. These F_1's were self-pollinated to provide seeds for an F_2 population.

In 1959, an S_1 population of the mutants, the reciprocal F_1's of the mutant and D&PL-14 cross, and the F_2's were grown in the field. Segregation was readily apparent in the F_2 populations, and plants were classified as mutant or normal. As the plants matured, 1 to 3 leaves on previously normal-appearing plants developed a partial-mutant expression. Further examination of the F_1's revealed that under field conditions all the F_1's exhibited the intermediate mutant expression. The F_2 populations were reclassified as normal, intermediate and mutant. Data from the 1959 field plantings are presented in Table 1.

No reciprocal differences were observed among the F_1's, and they were uniformly of the intermediate phenotype. The intermediate phenotype was assumed to be the heterozygous class, and the F_2 data were tested for deviations from the 1:2:1 segregation of a single factor. The observed

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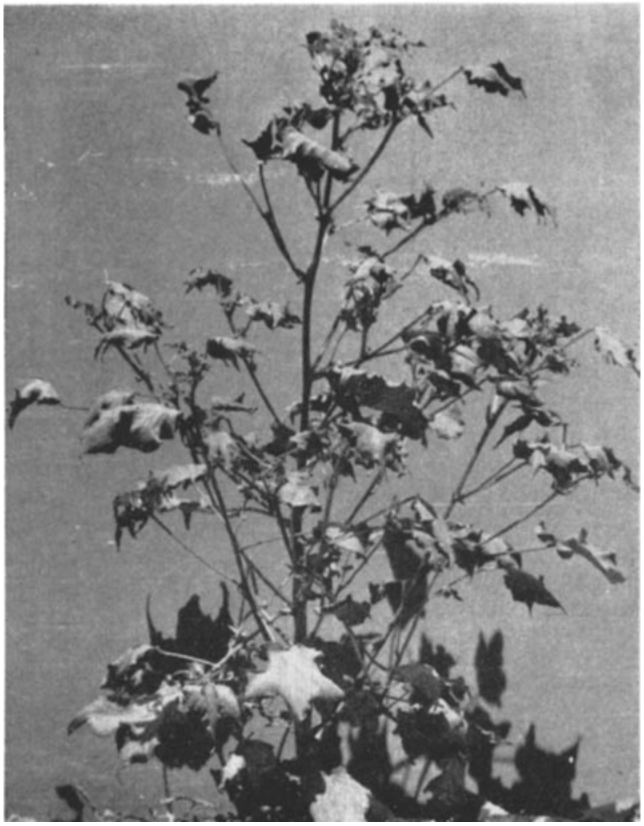

Figure 1—A representative veins-fused mutant plant of American Upland cotton.

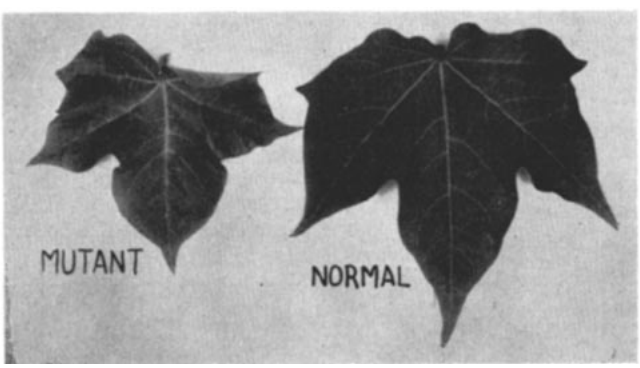

Figure 2—Homozygous and heterozygous mutant leaves compared with a normal American Upland cotton leaf.

segregations did not deviate significantly from that expected for a single factor.

From the 1959 data, we hypothesized that segregation for veins-fused was at a single locus and that homozygous mutant alleles produced the extreme mutant phenotype and the heterozygote a less pronounced but detectable mutant phenotype. To test this hypothesis, F_3 progenies, along with backcrosses of F_1's to the mutant parent ($F^1{}_0$) and to the D&PL-14 parent ($F^2{}_0$) were grown in 1960; the backcrosses were designated $BC^1{}_1$ and $BC^2{}_1$, respectively.

The BC_1 and F_3 data and corresponding chi-square tests were summarized. The 6 F_3 families from 3 mutant and 3 normal F_2's did not segregate and were true-breeding mutant and normal, respectively. The 5 F_3 families from

Table 1—Classification of S_1, F_1, and F_2 cotton plants grown in the field, 1959.

Population	Number of plants				χ^2	P
	Normal	Inter-mediate	Mutant	Total		
S_1 (mutant)			30	30		
F_1 (mutant × D&PL-14)		15		15		
F_1 (D&PF-14 × mutant)		15		15		
F_2 (mutant × D&PL-14)	42	74	37	153	0.49	.8 -.7
F_2 (D&PL-14 × mutant)	33	80	38	151	0.87	.7 -.5
Pooled F_2	75	154	75	304	0.05	.98-.95
Heterogeneity					1.31	.7 -.5

suspected heterozygotes segregated into normal, intermediate, and mutant phenotypic classes. These classes did not deviate significantly from the expected 1:2:1 segregation ratio of a single factor. The 6 $BC^1{}_1$ families segregated intermediates and mutants and the 6 $BC^2{}_1$ families segregated normals and intermediates. In both backcross populations the segregation did not deviate significantly from the expected 1:1 segregation of a single factor.

Discussion and Summary

The data presented for S_1, F_1, F_2, F_3, and BC_1 populations indicate that veins-fused is controlled by segregation at a single locus. When plants are homozygous for the mutant allele, the mutant phenotype is expressed, but when they are heterozygous for the mutant allele, an intermediate phenotype is produced.

In the material studied, all three levels of the mutant gene could be distinguished phenotypically. When veins-fused was crossed to a multiple-marker line for dominant genes, however, approximately half of the F_1 showed the intermediate mutant expression and the remainder were normal in appearance. In the F_2, expression of the intermediate phenotype was again incomplete, and the mutant had to be scored as a complete recessive.

Since the above results have established the monofactorial inheritance of a new mutant in cotton, it was desirable to assign the mutant character a genetic symbol. Corresponding to the proposed name veins-fused, the genetic symbol *vf* is proposed for the mutant character. The mutant genotype would be *vf vf* and the normal genotype would be *Vf Vf*.

A SIMPLE METHOD OF HOT WATER EMASCULATION OF SORGHUM[1]

J. E. Freeman, P. W. Watkins, H. H. Hadley, and R. H. Hageman[2]

BULK emasculation of sorghum flowers with hot water was first reported in 1933 by Stephens and Quinby.[3] The effectiveness of hot water as an agent for killing pollen was recognized by other plant breeders who have since employed various modifications of the methods suggested by Stephens and Quinby on several species of grasses.

One of the greatest disadvantages of hot water emasculation of sorghum has been the difficulty of constructing a suitable emasculation apparatus. An attempt was made at the University of Illinois in the summer of 1959 to develop

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[3] Stephens, J. C., and Quinby, J. R. Bulk emasculation of sorghum flowers. J. Am. Soc. Agron. 25:233–234. 1933.