

Greenleaf Tabasco,
a New Tobacco Etch
Virus Resistant
Tabasco Pepper Variety
(*Capsicum frutescens* L.)

SUMMARY

A new tobacco etch virus (TEV) resistant Tabasco pepper variety (*Capsicum frutescens* L.) named Greenleaf Tabasco (Tabasco G) has been developed at the Auburn University Agricultural Experiment Station. TEV, which is widely distributed in the South on solanaceous host plants and transmitted by aphids, causes a serious wilt disease of the commercial Tabasco variety, threat-

ening its survival and consequently that of the Tabasco hot sauce industry. The new variety removes this threat from the industry. In addition, the new variety has resistance to ripe rot, a more concentrated fruit set, a darker red mature fruit color, a brighter yellow immature fruit color, and a higher pungency.

Two Indian pepper introductions of *C. chinense* Jacquin from Peru, P.I. 152225 and P.I. 159236, were the sources of these improvements.

ON THE COVER

Plant at top is the tobacco etch virus (TEV) resistant Greenleaf Tabasco. Center left is P. I. 152225 with orange red fruit. Center right is P. I. 159236 with glossy, dark chocolate colored fruit. Note that up to three fruits are set per axil in *Capsicum chinense* and up to two in *Capsicum frutescens*. Bottom left shows fruit of the TEV resistant Greenleaf Tabasco, at right is fruit of the TEV susceptible commercial Tabasco variety showing the typical ripe rot symptom on the third fruit from the right.

Greenleaf Tabasco, a New Tobacco Etch Virus Resistant Tabasco Pepper Variety (*Capsicum frutescens* L.)¹

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ACCOUNTS of the McIlhenny Company of Avery Island, Louisiana (7) and of the Trappey and Sons Company of New Iberia, Louisiana (15), indicate that seeds of a fiery hot Indian pepper were introduced into Louisiana, probably from the State of Tabasco in Mexico, about 1848.

The fine qualities of this pepper for making a vinegar extract, used as a condiment and as an aid to digestion, were soon recognized around New Orleans. The pepper itself was named Tabasco for the state from whence it came. However, it was not until after the Civil War that Edmund McIlhenny, a New Orleans banker and gourmet, perfected a superior hot sauce made from the fermented mash of red ripe Tabasco peppers. He obtained a patent for the process in 1870.

McIlhenny's Tabasco sauce, which is made on the family plantation on Avery

Island, soon became internationally famous. This salt dome island provides not only the Tabasco peppers but also the large quantity of salt needed for the fermentation process by which this sauce is made. The pepper mash with salt added is packed into 50-gallon Kentucky white oak barrels, covered with a layer of salt, and allowed to ferment for 3 years. The mash is then filtered, homogenized, diluted 1:3 with vinegar, and bottled (9, 10). Since 1946, the name "Tabasco" has been the permanent trademark for the hot sauce of the McIlhenny Company (8).

In addition to its culinary history, the Tabasco pepper has an interesting "virus" history that began at the Georgia Agricultural Experiment Station, Experiment, Georgia in 1945. There the Tabasco variety was included in a collection of peppers being screened by Greenleaf for resistance to the bacterial leaf spot disease for breeding a resistant

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³ This publication is a cooperative effort of the Departments of Horticulture of Auburn University and of Clemson University. Greenleaf developed the new Greenleaf Tabasco pepper variety; Martin made the chemical pungency tests; Lease made qualitative and quantitative determinations of the various fruit pigments; Sims determined juice yields; and Van Blaricomb determined fruit color.

pimiento. The Tabasco plants, however, died from an unknown wilt disease early in July, just as they were beginning to fruit. Of the many peppers in the collection, only Tabasco was thus affected. In 1946, the disease reappeared, killing all plants except the two which had been covered with insect-proof cloth cages. In 1947, Greenleaf moved to the Agricultural Experiment Station at Auburn, where the disease was also observed in the field. Prior to 1947, Weimer, formerly USDA plant pathologist at Experiment, Georgia, had suggested that the disease had the characteristics typical of a virus disease, thus focusing attention on this possibility.

In 1949, Perry (1) succeeded in transmitting the disease to two of four healthy Tabasco plants by leaf inoculation with extract from a wilted Tabasco plant without the use of carborundum. However, it was Holmes (4,5), of the Rockefeller Institute for Medical Research, who first identified the causal agent as tobacco etch virus (TEV). He obtained the virus from Alabama pepper samples sent him by Greenleaf (1) in 1950. In the field the virus is spread by aphids which accounts for the high percentage of infected plants. The unique wilt reaction of Tabasco has since proved to be diagnostic for TEV (3).

Meanwhile, Younkin of the Campbell Soup Company, Riverton, N.J. reported in personal correspondence that P. I. 152225 from Peru, a variety of *Capsicum chinense* Jacquin, had remained free of symptoms following inoculation with TEV. Greenleaf (2) subsequently showed that this was not immunity but a high level of resistance. This was proved by a slow rate of virus increase in inoculated plants and by their tolerance of the virus. The "etch" wilt reaction of Tabasco was dominant in the F₁ hybrid (P.I. 152225 x Tabasco) and resistance was inherited as a monogenic recessive trait (2).

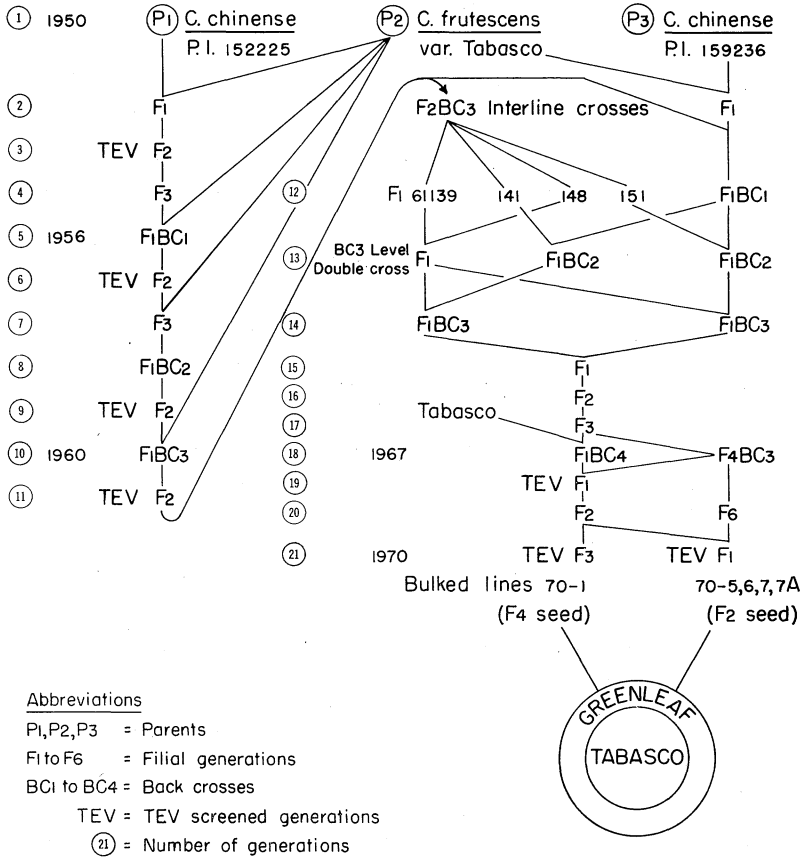
Holmes originally prompted the breeding effort by Greenleaf to develop a

TEV resistant Tabasco pepper. He anticipated that the disease would become important to the Tabasco industry in Louisiana, a prediction that has since come true. Joseph Montelaro, Louisiana State University Extension Service, wrote in May, 1959: "We are having a lot of trouble with the Tabasco variety. I know that the growers in the St. Martin area tell me that if something is not done that they will have to discontinue producing Tabasco pepper. You know that this is a big business in Louisiana." By this time, Greenleaf had begun to breed TEV resistant Tabasco type peppers at Auburn, but they were not yet commercially acceptable for fruit type. Now a highly desirable TEV resistant Tabasco variety, illustrated on Page 1, has been developed and is ready for release to the industry.

ORIGIN OF GREENLEAF TABASCO

Tabasco is probably the only commercially important pepper variety of the species *Capsicum frutescens* L. in the U.S. trade. Most other varieties are of *C. annuum* L. (12). In the breeding of Tabasco G, two strains of the Tabasco variety were used. In the first crosses a strain of the Reuter Seed Company of New Orleans was used and later one of the McIlhenny Company. Two TEV and ripe rot resistant Indian pepper cultivars from Peru, P.I. 152225 and P.I. 159236, both of *C. chinense* Jacquin (see illustration) contributed not only TEV and ripe rot resistance to the new Tabasco, but also improved fruit characteristics. This was possible because *C. chinense* crosses readily with *C. frutescens*, and no serious sterility barrier was encountered (13). Up to four backcrosses to Tabasco were made, with alternating selfed generations being screened for "etch" resistance after each backcross. Interline crosses were also made at the third backcross level to concentrate the genes for other desirable plant and fruit characteristics. The pedi-

PEDIGREE OF GREENLEAF TABASCO



gree of Tabasco G is presented in the figure.

CHARACTERISTICS AND PERFORMANCE

Plant Habit and Productivity. Two distinct growth habit types, based on the kind of branching, occur in the original Tabasco variety. The more desirable type produces plants with a flat

top, bearing erect fruits well exposed for picking. The other type bears fruits in racemes with drooping branches. Plants of the first type are usually taller, and when in full fruit present a stunning appearance. The flat top habit seems difficult to stabilize genetically. Tabasco G, like the original variety, is a mixture of both plant types.

TABLE 1. COMPARATIVE PRODUCTIVITY OF SINGLE PLANT SELECTIONS OF TABASCO AND TABASCO G IN 1969

Variety and line		Total fruit	Total fruit weight	Ripe fruit	Ripe fruit weight	Per cent ripe fruit	Av. fruit weight
		No.	G.	No.	G.	Pct.	G.
Tabasco.....	69-13	500	503				1.0060
	69-13	840	860				1.0238
	69-13	1,712 ¹	1,606	852	740	46.1	0.9381
Tabasco G.....	69-2	2,041	1,910				1.0060
	69-11	2,103 ¹	2,142	1,328	1,438	67.1	1.0185

¹ Best single plant selections of each variety in the field.

Several observers independently agreed that Tabasco G seemed more productive than the original variety. This was verified by counting and weighing the fruit of several of the better plants of each. In 1969, the best Tabasco G selection had 23 per cent more fruits than the best Tabasco selection and 33 per cent more fruit weight, Table 1. The heavier fruit set of Tabasco G is probably a result of a greater fruit density per unit length of stem.

Fruit Abscission. Easy abscission of the fruit is a characteristic of economic importance because it facilitates picking. This trait is genetically dominant over hard abscission (11) but various intermediate degrees occur in the original Tabasco variety. Despite rigorous selection for this trait, Tabasco G is still variable in abscission but probably no more so than Tabasco itself. Ease of abscission improves with fruit maturity and comparisons between plants or varie-

ties must be made with fruits of comparable maturity.

Fruit Size, Weight, and Shape. The two varieties are similar in fruit size and weight, Table 2. In three years' comparisons there was little difference in fruit length, but Tabasco G fruits were significantly broader, Table 2. Over the years Tabasco G was selected for a broadly conical fruit shape with a rounded, smooth styler tip in preference to slender fruits with sharper tips that would tend to catch on processing screens.

Maturity. Tabasco and Tabasco G are late maturing varieties that are adapted only to areas having a long growing season. When sown in peat pots early in February and transplanted to the field in the middle of April, harvesting of ripe fruit can begin in the middle of August. Harvest of immature fruit in the yellow-green stage could start 2-3 weeks earlier. The plants con-

TABLE 2. COMPARATIVE SIZE AND WEIGHT OF MATURE FRUITS OF TABASCO AND OF TABASCO G

Variety and year		Fruit	Av. fruit length	Av. fruit width	Fruit	Av. fruit weight
		No.	mm ¹	mm ²	No.	G ³
Tabasco.....	1967	150	30.42 b	7.88 b	1,484	0.8430
Tabasco.....	1968	107	30.09 b	8.14 b		
Tabasco.....	1969	100	31.76 a	8.22 b	500	1.2080
Tabasco G.....	1967	200	30.46 b	9.03 a	836	1.0963
Tabasco G.....	1968	108	29.46 b	8.66 a		
Tabasco G.....	1969	200	29.57 b	8.82 a	1,500	1.1955

^{1,2} Comparisons should be by years. Values followed by different letters differ significantly at $P < 0.01$.

³ Figures are means of bulk weights. A larger fruited strain of Tabasco was used in 1968 and 1969 than in 1967.

TABLE 3. FRUIT COLOR, JUICE COLOR, AND SOLUBLE SOLIDS OF TABASCO AND OF TABASCO G IN 1969

Variety and line		Fruit color ^a	Juice color ^b	Soluble solids
				<i>Pct.</i>
Tabasco.....	69-13	Blood Red No. 820	Capsicum Red No. 715/2	12.0
Tabasco G.....	69-3	Currant Red No. 821	Dutch Vermilion No. 717/1	10.6
Tabasco G.....	69-11	Currant Red No. 821	Dutch Vermilion No. 717/1	10.0

^{a,b} Colors are from the British Horticultural Color Chart. The fruit and juice colors of Tabasco were a considerably lighter red than those of Tabasco G.

tinue to fruit until killed by frost in late fall.

Fruit and Juice Color. Immature fruits of Tabasco G are a brighter yellow than those of Tabasco. This should improve the appearance of the whole-pack product known as vinegar sauce. Ripe fruit of Tabasco G are dark red and glossy as if waxed. They range in color from Currant Red No. 821 to Cardinal Red No. 822 in the British Horticultural Color Chart (6). Fruit of Tabasco lack this high gloss. Their color matches Blood Red No. 820, a considerably lighter shade of red, Table 3.

The juice colors of both varieties were of a lighter tone than the external fruit colors, but corresponded to the latter in their relative intensity. Juice of Tabasco G matched Dutch Vermilion No. 717/1

and Tabasco juice Capsicum Red No. 715/2, Table 3. Lease found that Tabasco G fruits had 39 per cent more extractable red pigments (capsanthin, capsorubin, and zeaxanthin) than did Tabasco fruits. Colorimetric values determined by Van Blaricom confirmed the darker red color of Tabasco G fruits, Table 4.

Percentage Dry Matter and Juice Yield. In the immature yellow-green stage fruits of Tabasco and of Tabasco G are firm and fibrous when crushed between the fingers, yielding little juice. However, as the fruit matures it gradually turns into a bag of juice. It is this property that makes Tabasco so uniquely suitable for hot sauce. Paradoxically the yellow-green fruit have a lower dry matter content than red ripe fruit, while orange fruit are intermediate in this re-

TABLE 4. MATURE FRUIT COLOR OF TABASCO AND TABASCO G

Variety and year	Colorimetric values with Gardner color difference meter ¹					Color ²	No.
	RI	a	b	a/b			
Tabasco.....	1967 ³	8.03	46.7	15.5	2.69	Blood red	820
	1969	9.30	34.7	19.3	1.80	Blood red	820
Tabasco G.....	1967	4.63	36.8	12.6	2.91	Cardinal red	822
	1969	8.00	38.2	17.5	2.18	Cardinal red	822
	1969	6.80	39.3	16.8	2.34	Cardinal red	822

¹ Color of fresh pepper, measured by a Gardner color difference meter with the following standard plate values: RI = 7.9; 'a' = 61.0; 'b' = 20.4.

RI indicates luminous reflectance. A lower reflectance index indicates a deeper, more intense color. Higher 'a' values indicate more redness. Higher 'b' values indicate more yellowness. A higher a/b ratio indicates a more attractive red color.

² Color names and numbers are from the British Horticultural Color Chart pp. 166, 168. Cardinal Red is a darker red color than Blood Red.

³ Comparisons should be by years.

TABLE 5. PERCENTAGE DRY MATTER OF BULK SAMPLES OF TABASCO AND TABASCO G FRUITS AT 3 STAGES OF MATURITY

Fruit color	Dry matter		Difference
	Tabasco	Tabasco G	
	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>
	Dried in forced air oven at 52 C—Auburn '67		
Red.....	31.0	22.9	26.0
Orange.....	27.3	21.0	23.1
Yellow-green.....	18.9	17.8	5.6
	Dried in vacuum oven at 69 C—Auburn '67		
Red.....	28.9	21.3	26.3
Orange.....	27.9	21.3	23.7
Yellow-green.....	20.9	16.4	21.5
	Dried in vacuum oven at 52 C—Clemson '67		
Red.....	34.4	23.5	31.7

spect. The water in the immature fruit appears to be physically bound whereas it is relatively free in the mature fruit. Mature fruit of Tabasco G had 26 per cent less dry matter than those of Tabasco, Table 5. The expected increase in juice yield from Tabasco G was not, however, realized in Sims' tests. This was probably because of the inability of the Carver press to extract as much juice as anticipated at the pressures used. This can be seen by the difference obtained when two pressures were used. For example, at 10,000 psi the juice yield from Tabasco was 53.5 per cent of the fresh fruit weight, whereas it was only 23.8 per cent at 5,000 psi. Nevertheless, the highest juice yield, 55 per cent, was from a Tabasco G sample, Table 6.

Soluble Solids and Pungency. In 1968, soluble solids measurements were made with a hand refractometer on the juice of 30 individual ripe fruits of Tabasco and on 42 fruits of Tabasco G. The mean soluble solids of both varieties was 10.5 per cent, Table 6. In 1969, two bulk samples of Tabasco G had 10.6 per cent and 10.0 per cent soluble solids, respectively, and one bulk sample of Tabasco, 12.0 per cent. The difference in soluble solids between the two varieties probably has little practical significance, but the higher pungency of Tabasco G fruit shown in both the 1967 and 1969 tests by Martin, Table 6, has obvious economic importance for a hot sauce manufacturer (14,16).

TABLE 6. JUICE YIELD, SOLUBLE SOLIDS, AND PUNGENCY OF TABASCO AND TABASCO G FRUITS

Variety	Fruit maturity	Juice yield ^a		Soluble solids 1968	Pungency ^b	
		1967	1969		1967	1969
		<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>		
Tabasco.....	Red	23.8	53.5	10.5	7.5	7
	Orange	26.6				
	Yellow-green	26.7				
Tabasco G.....	Red		44.0			8
	Red	23.8	55.0	10.5	9.0	8
	Orange	26.2				
	Yellow-green	22.7				

^a A Carver laboratory press was used. In 1967, samples of 73.5 g were pressed at 5,000 psi. In 1969, samples of 100.0 g were pressed at 10,000 psi.

^b Chemical color test by Ting and Barron's methods. The color scale ranges from 1 = mildest to 10 = hottest.

Seed Weights. Seed weights of two Tabasco G lines were compared with those of two Tabasco strains. One of the latter was small fruited, the other large. Five 200-seed samples of each were weighed and the mean weight of 100 seeds of each calculated. The two Tabasco G seed lots weighed 0.7720 and 0.7760 g/100 seeds, respectively, averaging 58,603 seeds/lb. The Tabasco seeds were significantly heavier, weighing 0.8880 g and 0.9030 g/100 seeds for the smaller and larger fruited strain, respectively, and averaging 50,602 seeds/lb. Fruit size in Tabasco was thus independent of seed weight.

DISCUSSION

TEV Resistance. To maintain the TEV resistance of Tabasco G, this variety must be grown in isolation from the commercial Tabasco, as any outcrosses with the latter will be as highly susceptible to the "etch" wilt disease as Tabasco itself. Tabasco G breeds true for resistance to the disease. Field trials and controlled inoculation with TEV over the past 20 years have demonstrated the stability of this resistance. The fear of a virus buildup in the new variety that could threaten other more susceptible pepper varieties in the field has proved unfounded. Because Tabasco G has a lower rate of TEV multiplication in its tissues than do susceptible pepper varieties that respond to infection with the typical leaf mottling symptom (2), there would actually be less virus buildup in it. Furthermore, TEV is not seed transmitted. In the field most Tabasco G plants are vigorous and appear to be healthy and free from TEV mottling symptoms. The development in the field of heavily TEV inoculated seedling transplants into bushes bearing satisfactory crops supports this inference. The evidence is that the TEV resistance of Tabasco G is permanent and horizontal as defined by Van der Plank (17).

Ripe Rot Resistance. Ripe fruits of Ta-

basco are subject to a fruit rot that first shows as an orange discoloration on the red fruit, resembling sunscald, see figure. The causal organisms have not been identified. The fruit eventually shrivels into a dry shell varying from a straw color to a very dark red. Infected fruits could spoil the pepper mash, or in any case reduce its quality. Tabasco G derives its considerable resistance to ripe rot from its two *C. chinense* parents shown in figure.

Higher Pungency of Tabasco G. The higher pungency of Tabasco G fruits vs. Tabasco fruits was a bonus of interspecific hybridization. This result was most unexpected because the Tabasco variety itself was already known to be one of the most pungent of peppers and because the pungency of the two *C. chinense* parent cultivars was an unknown quantity.

Variability of Tabasco G. The variability of Tabasco G. in fruit size, shape and in plant type is moderate, but no greater than is commercially acceptable and genetically desirable to maintain the vigor and broad adaptability of the new variety.

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