VARIABILITY AND HERITABILITY OF BRONZE WILT RESISTANCE IN COTTON CULTIVARS

Alois A. Bell
USDA, ARS, SPARC
College Station, TX

Abstract

The effects of environment and genotype on expression of resistance to bronze wilt was studied using 'Suregrow 125', 'Tamcot Sphinx', and 'Deltapine 50' as resistant cultivars and 'Stoneville 373', 'Paymaster 1220 B/R' and 'Pima S-7' as susceptible cultivars. Differences in the resistance of cultivars were affected by temperature, photoperiod, relative nitrogen content of fertilizer and fertilizer rate. The following standard screening procedure was adapted from the environmental studies: 1) Seeds are germinated in sterile germination towels wet with a bacterial suspension at 30ºC for 40-44 h; 2) Seedlings are transplanted to 500 g of a mixture of 25% Brazos clay soil (pH 8.2), 75% Brazos fine sand (pH 8.0), 5 g gypsum, and 10 g dolomitic limestone; 3) Incubation is continued at 30ºC for a total of 1 wk from seeding and the temperature is then raised to a continuous 37ºC with a 15-h photoperiod; 4) Each plant is fertilized weekly with 150 mg of Peter's 15-16-17 soluble fertilizer dissolved in 50 ml of water; and 5) After 8 wk plant parts are weighed and assessed for damage, and bacterial content of roots is determined. 'Stoneville 373' and 'Paymaster 1220 B/R' commercial seed, were mostly susceptible to bronze wilt also included resistant individuals. Plants that gave rise to uniformly susceptible or resistant progeny when self-pollenated were used for genetic studies. Resistance to bronze wilt caused by *Agrobacterium tumefaciens* strain 34B was completely dominant or overdominant to susceptibility in all hybrids. Thus, severe bronze wilt occurs only when a homozygous recessive condition is present. Cultivars carrying different bacterial blight resistance genes (*B* genes) also were evaluated for resistance to strain 34B. Cultivars with the B_4, B_N, B_{In}, and B_2,B_3 genes showed higher levels of resistance than similar cultivars that lacked these genes. The 'DPP4' and 'S-295' cultivars which have undefined *B* genes also showed higher levels of resistance to bronze wilt. Cultivars with the B_2 or B_7 gene were more susceptible to bronze wilt than the corresponding cultivar lacking these genes and behaved similar to 'Hartz 1215.' Both cultivars that carried the B_2 gene, alone or combined with B_3, showed more blighting and defoliation of lower leaves and recovered more slowly than the 96 other cultivars when returned to temperatures below 33ºC. The possible importance of *B* genes in bronze wilt susceptibility is discussed. Reactions of 96 modern cultivars and lines to bronze wilt caused by *A. tumefaciens* strain 34B in a greenhouse screen are reported.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:138-144 (2000)
National Cotton Council, Memphis TN

Introduction

Under field conditions individual plants of some cultivars may show very different responses to bronze wilt even though they are in juxtaposition. Some of the variation can be explained by earliness of fruiting or fruit load. Plants that set fruit at lower nodes or set greater numbers of fruit often develop more severe bronze wilt than those that set fruit at higher positions or have fewer fruit. It is also possible that the seeds from which the plants originated were infested with different *Agrobacterium* strains that varied significantly in virulence, or that *Agrobacterium* interacted with another pathogen on one plant but not the other (Bell, 2000a, 2000b). This paper reports genetic differences that occur in bronze wilt susceptibility among and within cultivars and the heritability of these differences.

The cultivar 'Tamcot SP37' is a common parent of many of the short- season cultivars that are highly susceptible to bronze wilt. This cultivar also was the first in which the gene combination B_2, B_3, B_7 was used for resistance to bacterial blight. Because these genes increase hypersensitivity (cell necrosis and browning) in response to the bacterial blight pathogen *Xanthomonas campestris* pv. *malvacearum*, they also may effect necrotic reactions of the cotton plant in response to *Agrobacterium* biovar I. For this reason, the reaction of cultivars carrying different *B* genes to *Agrobacterium tumefaciens* strain 34B were determined and compared with those of a uniformly susceptible line of Hartz 1215 obtained in 1996.

Materials and Methods

Development of Screening Procedure

All experiments were carried out in Conviron model E15 Environment chambers fitted with Philips Very High Output (160 watt) fluorescent lights and 40A (40watt) incandescent lamps. Single plants were grown in solo cups containing about 500 g of pasteurized soil mixture (usually 125 g Brazos Valley clay soil, 375 g Brazos fine sand, 5 g gypsum, and 10 g dolomitic limestone). Peter's soluble fertilizers containing chelated minor elements were used. Photoperiods began with only incandescent lights, one-half of the fluorescent lights were turned on after 15 min and the remaining fluorescent lights were turned on after 30 min. Lamps were turned off in the reverse order at 30 and 15 min before and at the beginning of the dark cycle. A 15-h photoperiod was used, except when photoperiod was the variable studied. Plants were inoculated with a mixture of *Agrobacterium* biovar I strains 1A, 14A, and 34B as described previously (Bell, 1999). Statistical evaluations were based on the student t-test and calculations of least significant differences.

Genetic Studies

The standard method described in the abstract was used for all studies. Ten plants each of 'Stoneville 373,' 'Paymaster 1220 B/R,' 'Tamcot Sphinx,' and 'Suregrow 125' were grown from seed lots submitted for the 1998 Uniform Variety Trials. Plants were maintained under conditions suppressive to bronze wilt (greenhouse planting mix (pH 6.0), temperatures below 33ºC, 15-16-17 fertilizer and supplemental applications of superphosphate (0-46-0; 5 g/L of planting mix). Both self-pollenated and hybrid progeny were produced from each plant and used in resistance studies. Selfed progeny and hybrids of 'Deltapine 50' and 'Pima S-7' were produced in a similar manner.

Bacterial blight differentials were obtained from Dr. Peggy Thaxton and grown in fine sand fertilized with Peter's 15-5-25 fertilizer. Seed from self-pollenated plants were density graded and only dense seed were used for resistance evaluations. All genetic studies were performed using seedlings inoculated with *A. tumefaciens* strain 34B.

Greenhouse Evaluation of Resistance in Cultivars

Cultivars and lines submitted for the 1999 Uniform Variety Trials and the inbred lines 'Stoneville 373-2S,' 'Stoneville 373–6R,' 'Suregrow 125-9R,' and 'Paymaster 1220 B/R-2S' were evaluated in the greenhouse for susceptibility to *A. tumefaciens* strain 34B. Seeds were germinated, inoculated, and transplanted into pasteurized 25% clay-sand mix as described in the standard procedure. Cooling fans were set to come on at 38ºC and infrared and hot water heaters were set to come on at 30ºC. Plants were fertilized with 15-5-25 Peter's soluble fertilizer at a rate of 150 mg/plant/week. Root balls were removed carefully from the plastic cups and scored for root necrosis at the time of initial flower and again at boll opening. Bolls were scored daily for bract necrosis beginning 28 days after anthesis, and foliar symptoms (leaf blight and stem necrosis) were noted at harvest. Seedcotton was dried for at least 48 h at 40ºC in a draft oven before weighing. Ten plants per cultivar were observed. The student t-test and calculations of least significant difference were used to compare all cultivars with 'SG 125.'

Results and Discussion

Effects of Environmental Variables on Resistance

Temperature. The effects of temperature on concentrations of *Agrobacterium* and root weights of plants inoculated with a mixture of *A. tumefaciens* isolates 1A, 14A, and 34B and kept under a 20-h photoperiod are shown in Tables 1 and 2. There was a large and significant (5% confidence level) increase in bacterial populations in all cultivars as temperature increased from 30ºC to 33ºC (Table 1). Populations at 36ºC remain similar to those at 33ºC (Bell, 1999). Significant differences in bacterial concentrations between susceptible and resistant cultivars did not occur at either 30 or 33ºC. Root weights of susceptible cultivars were significantly less than those of resistant cultivars at 36ºC but not at 33ºC (Table 2). Thus, resistance was best determined as changes in root weight at the high temperature (36ºC). When the photoperiod is reduced to a more normal 15 h, 37 or 38ºC are superior to 36ºC for distinguishing resistance.

The effects of lowering night temperatures to 30ºC while retaining 38ºC days are shown in Figure 1. The greatest differences between 'Stoneville 373', the more susceptible cultivar, and 'Deltapine 50', the more resistant cultivar, occurred with the continuous high (38ºC) temperature. It should be noted that the cool nights offered no relief from the damage caused to 'Deltapine 50' and only slight relief to 'Stoneville 373.' Because day temperature is most critical, photosynthesis may be critically involved in bronze wilt damage.

Photoperiod. The effects of photoperiods on root weight of susceptible ('PM 1220' and 'ST 373') and resistant ('SG 125' and 'Sphinx') cultivars inoculated with *Agrobacterium* using two different fertilizers are shown in Figures 2 and 3. The greatest differences among cultivars occurred with the 20-h photoperiod, followed by the 12-h photoperiod. As the photoperiod was increased from 16 h to 20 h, there was greater damage to the roots of the susceptible cultivars ('PM 1220' and 'ST 373') but not to the roots of the resistant cultivars ('SG 125' and 'Sphinx'). I have found that damage to susceptible cultivars at 36ºC and 15-h photoperiod is greater when the chambers are fitted with new light bulbs than when the light bulbs are several months old. Thus, light intensity also appears to affect the relative resistance to bronze wilt. Again, photosynthesis is implicated in damage caused by bronze wilt.

Fertilizer Treatment. The greatest differences in plant weight between susceptible and resistant cultivars occurred with low fertilizer rate (150 mg/plant/wk) (Figure 1) and with 27-15-12 fertilizer composition (Figures 2, 3 and 4). The high phosphorus fertilizer (9-45-15) gave the least damage to roots and the greatest plant weight of either cultivar (Figure 4). In contrast, the low phosphorus fertilizer (15-5-15) gave the least plant weight and extensive root damage to both cultivars. These results confirm our earlier observation that bronze wilt severity is directly proportional to nitrogen fertilizer rates and inversely related to phosphorus fertilizer rates (Bell, 1998a, 1998b 2000a, Bell et. al., 1998). The strong effects of day temperature, light, and nitrogen fertilizers raise the possibility that *Agrobacterium* somehow disrupts nitrogen recycling during photorespiration. Other microorganisms are known to secrete toxins, such as tabtoxin, which inhibit glutamine synthetase (GS) and cause symptoms similar to bronze wilt (Shaner, 1989). When cotton roots are drenched with methionine sulfoximine, a systemic inhibitor of GS, bronzing and blight symptoms develop in leaves.

Clay Content. The effects of clay content on the weight of plants infected with *Agrobacterium* are shown in Figure 5. Although disease severity was proportional to clay content with either variety, the percentage difference between cultivars remained constant and was not affected by clay content. Either 25 or 50% clay gave the greatest absolute differences between susceptible 'Stoneville 373' and resistant 'Deltapine 50'; 25% clay was selected for genetic studies.

Standard Screening Procedures. A screen was selected that realistically duplicated, as much as possible, conditions in the field. Thus, a 15- h photoperiod and 15-16-17 fertilizer were selected rather than the 20-h photoperiod and 27-15-12 fertilizer. The entire protocol, which otherwise uses optimal conditions, is given in the abstract.

Genetic Studies

Inheritance of Susceptibility in Modern Cultivars. Selfed progeny from 10 plants of each 'Stoneville 373,' 'Paymaster 1220 B/R,' 'Suregrow 125,' and 'Tamcot Sphinx' and 20 plants of 'Pima S-7' were screened for resistance to *A. tumefaciens* strain 34B. The results are shown only for 'Stoneville 373' (Figure 6). A similar variation in resistance was obtained for 'Paymaster 1220 B/R, whereas progeny from 'Suregrow 125,' 'Tamcot Sphinx,' and 'Pima S-7' were more or less uniform in behavior. Plants whose progeny gave the lowest coefficients of variation were selected for crosses.

The inheritance of bronze wilt resistance at the F1 hybrid level are shown in Tables 3, 4, and 5. Resistance in either 'Suregrow 125' (Table 3) or 'Tamcot Sphinx' (Table 4) were completely dominant or slightly overdominant to susceptibility in 'Stoneville 373'. Likewise, resistance in 'Suregrow 125' was dominant to susceptibility in 'Paymaster 1220 B/R (Table 4). Resistance in 'Deltapine 50' was overdominant to susceptibility in 'Pima S-7' (Table 5). In this case the resistant condition also caused a significant decrease in *Agrobacterium* populations in roots of F1 hybrids compared to the 'Pima S-7' parent (Table 6). Severe bronze wilt in 'Stoneville 373,' 'Paymaster 1220 B/R,' or 'Pima S-7' only occur in plants with a homozygous recessive genetic state. F2 and backcross progeny are currently being examined to determine whether one or more genes are involved.

Effects of Bacterial Blight Resistance Genes on Bronze Wilt. 'Tamcot SP37' is a parent in the background of several short-season cultivars that are highly susceptible to bronze wilt. It also was the first cultivar in which a combination of bacterial blight resistance genes, B_2, B_3, and B_7, were used for resistance to bacterial blight. Since these genes cause hypersensitive reactions in which plant cells rapidly die and turn brown in response to the bacterium *Xanthomonas campestris* pv. *malvacearum*, it is possible that they condition a similar response to *Agrobacterium* or its metabolites. For this reason cultivars carrying different *B* genes were screened for resistance or susceptibility to *A. tumefaciens* strain 34B. Most of the cultivars and lines used are in a common genetic background and were originally selected as differentials to identify races of bacterial blight (Hunter et. al., 1968). The gene from 'S-295' has not been fully characterized and may be an allele of another gene, such as B_4, even though I have designated it as B_{295}. This line is now used in Africa to confer a high level of resistance to blight.

Root and shoot weights of cultivars carrying different *B* genes and infected with strain 34B are shown in Figure 7. Compared to Stoneville 2B-S9 (CK), which has no major *B* genes, cultivars with several *B* genes showed large increases in both shoot and root weight. Those with the *B* genes B_4, B_N, B_{In}, B_{295}, and B_2,B_3 had more resistance than the CK to bronze wilt caused by *A. tumefaciens* strain 34B. In contrast, those with B_2 and B_7 were no more resistant to *Agrobacterium* than the CK, and may, in fact, have increased susceptibility. 'Stoneville 20' with the B_7 gene had significantly higher *Agrobacterium* concentrations in the root at 5 wk than any other cultivar (Figure 8). It also recovered much slower than the CK variety when they were returned to temperature below 33ºC. 'Hartz 1215' responded to *A. tumefaciens* strain 34B in a manner almost identical to that of 'Stoneville 20' at 37ºC (Figure 9) and when returned to temperatures below 33ºC. Both B_2 and B_7 genes need to be evaluated for effects on bronze wilt susceptibility.

Evaluation of Bronze Wilt Resistance in Modern Cultivars and Lines. Seedcotton yields and the frequency of plants with bronze wilt symptoms when inoculated with *Agrobacterium* strain 34B are shown in Table 7. Sixty-two cultivars and lines yielded significantly less seedcotton than 'Suregrow 125' which has consistently expressed resistance in our previous tests. Seven cultivars yielded better than 'Suregrow 125' and none of these had a bronze wilt incidence greater than 20%. Only 23 of 90 cultivars did not have any plants with bronze wilt symptoms. Thus, genes for susceptibility to bronze wilt are apparently widespread in modern cultivars.

Acala Maxxa is of special interest since it suffered severe yield loss but did not show any of the bronze wilt symptoms. This cultivar does not carry any *B* genes and supports very high *Agrobacterium* populations, usually in excess of 30 million/g, without showing considerable root or foliar necrosis. Bell (2000b) noted that *Agrobacterium* strains that develop high populations are more pathogenic than those that develop low or moderate populations. Thus, the high populations of *Agrobacterium* alone in 'Acala Maxxa' may be causing considerable yield loss. This also could be true for other cultivars that had significant yield losses without expressing bronze wilt symptoms.

Conclusions

Many modern cultivars include some plants that carry genes which cause increased susceptibility to bronze wilt. Resistance is completely dominant or overdominant to the recessive susceptibility genes at least in 'Stoneville 373,' 'Paymaster 1220 B/R,' and 'Pima S-7.' The bacterial blight resistance genes, i.e. *B* genes, show specific interactions with *A. tumefaciens* strain 34B and therefore are possible sources of susceptibility or resistance to bronze wilt. Both the B_2 and B_7 genes, which are present in 'Tamcot SP37', are possible sources of susceptibility to bronze wilt. The B_7 gene is especially suspect, because 'Stoneville 20' which carries this gene shows responses to *Agrobacterium* infections indistinguishable from those of 'Hartz 1215' and susceptible lines derived from 'Stoneville 373' and 'Paymaster 1220 B/R.' B_7 is also the only *B* gene of those studied that expresses blight resistance in the recessive state, like the gene(s) responsible for bronze wilt susceptibility.

Literature Cited

Bell, A. A. 1998a. *Agrobacterium* bronzing and wilt: epidemiology and control. Abstract Book, World Cotton Research Conference-2. 268.

Bell, A. A. 1998b. *Agrobacterium* bronzing and wilt: effects of nutrition. Phytopathology. 88:S7.

Bell, A. A. 1999. *Agrobacterium* bronzing and wilt: cultivar reactions and effects of temperature. Proceedings Beltwide Cotton Conferences. 117-120.

Bell, A. A. 2000a. *Agrobacterium* bronzing and wilt: epidemiology and control. *In*: Kechagia, U. (ed.), Proceedings World Cotton Research Conferences-2, September 6-11, 1998, Athens, Greece (in press).

Bell, A. A. 2000b. Role of *Agrobacterium* in bronze wilt of cotton. Proceedings Beltwide Cotton Conferences. (this volume).

Bell, A. A. 2000c. Synergistic interactions between *Rhizoctonia solani* and *Agrobacterium tumefaciens* in causing crown gall of cotton. Proceedings Beltwide Cotton Conferences. (this volume)

Bell, A. A., Y. Cui, C. Magill, H. Orta and M. Hawkins. 1998. *Agrobacterium* wilt and bronzing: the new challenge. Proceedings Beltwide Cotton Conferences. 136.

Bell, A. A., H. Orta and Y. Cui. 1997. *Agrobacterium* root rot and wilt: a widespread seedborne disease of cotton and legumes. Proceedings Beltwide Cotton Conferences. 105.

Hunter, R. E., L. A. Brinkerhoff and L. S. Bird. 1968. The development of a set of Upland cotton lines for differentiating races of *Xanthomonas malvacearum*. Phytopathology. 58:830-832.

Shaner, D. L. 1989. Sites of action of herbicides in amino acid metabolism: Primary and secondary physiological effects. Recent Advances in Phytochemistry. 23:227-261.

Table 1. Effect of increasing temperature on *Agrobacterium* concentrations in roots of 8-wk-old plants inoculated with *Agrobacterium* strains 1A, 14A, and 34B.

	Millions cfu/g	
Cultivar (Reaction)[a]	30ºC	33ºC
Stoneville 373 (S)	6.3	28.1*
Paymaster 1220 B/R (S)	13.7	34.3*
Deltapine 50 (R)	14.6	27.2*
Suregrow 125 (R)	9.8	25.0*
Tamcot Sphinx (R)	9.7	29.9*

[a]S = susceptible and R = resistant to bronze wilt.
*Significantly greater than at 30ºC (5% level of confidence).

Table 2. Effect of increasing temperature on root weight of 8-wk-old plants inoculated with Agrobacterium strains 1A, 14A, and 34B.

	g/plant	
Cultivar (Reaction)[a]	33ºC	36ºC
Stoneville 373 (S)	10.4	1.4*
Paymaster 1220 B/R (S)	10.7	1.6*
Deltapine 50 (R)	10.3	5.5
Suregrow 125 (R)	13.5	11.6
Tamcot Sphinx (R)	12.6	6.1

[a]S = susceptible and R = resistant to bronze wilt.
*Significantly less than values for the resistant cultivars.

Table 3. Root weights of parent and F1 hybrid plants inoculated with *A. tumefaciens* strain 34B in standard screen.

	Root Weight (g)*		
Cross	S Parent	F1	R Parent
SG 125-7 x ST 373-1	4.56	6.17	6.21
ST 373-4 x SG 125-7	4.28	6.38	6.21
ST 373-2 x SG 125-5	3.73	6.51	6.28
SG 125-9 x St 373-8	4.02	7.18	6.27
ST 373-9 x SG 125-7	4.31	6.62	6.03
ST 373-9 x SG 125-8	4.31	6.35	6.74
MEAN	4.20	6.54	6.29

*Inoculated plants grown 8 wk at 37ºC.

Table 4. Root weights of parent and F1 hybrid plants inoculated with *A. tumefaciens* strain 34B in standard screen.

	Root Weight (g)*		
Cross	S Parent	F1	R Parent
PM 1220-5 x SG 125-3	4.93	6.10	6.24
PM 1220-6 x SG 125-7	5.19	6.99	7.38
SG 125-7 x PM 1220-8	5.61	7.07	7.38
MEAN	5.24	6.72	7.00
Sphinx-10 x ST 373-3	4.35	7.66	6.73
Sphinx-9 x ST 373-3	4.35	7.71	8.00
MEAN	4.35	7.69	7.37

*Inoculated plants grown 8 wk at 37ºC.

Table 5. Root weights of parent and F1 hybrid plants inoculated with *A. tumefaciens* strain 34B in standard screen.

	Root Weight (g)*		
Cross	S Parent	F1	R Parent
Pima S7-1 x DP-50	5.00	6.69	5.84
Pima S7-4 x DP-50	5.17	7.67	--
Pima S7-5 x DP-50	4.78	6.79	-
Pima S7-6 x DP-50	4.94	6.42	-
Pima S7-7 x DP-50	5.02	7.35	6.05
Pima S7-8 x DP-50	5.00	6.62	--
Pima S7-9 x DP-50	4.52	6.03	--
MEAN	4.92	6.80	5.95

*Inoculated plants grown 9 wk at 37ºC.

Table 6. *Agrobacterium* concentrations in roots of parent and F1 hybrid plants inoculated with *A. tumefaciens* strain 34B in standard screen.

	Root Weight (g)*		
Cross	S Parent	F1	R Parent
Pima S7-1 x DP-50	8.58	3.28	3.58
Pima S7-4 x DP-50	8.28	1.56	--
Pima S7-5 x DP-50	7.32	2.90	-
Pima S7-6 x DP-50	6.06	3.22	-
Pima S7-7 x DP-50	7.16	1.94	2.52
Pima S7-8 x DP-50	8.52	2.62	--
Pima S7-9 x DP-50	5.90	2.70	--
MEAN	7.40	2.60	3.05

*Inoculated plants grown 9 wk at 37ºC.

Table 7. Seedcotton yields (g/plant) and expression of bronze wilt symptoms (% of plants) in cultivars inoculated with *Agrobacterium tumefaciens* strain 34B in the greenhouse[a].

Cultivar	Yield (g) Mean(SD)	Bronze Wilt Symptoms Percent (type)
Acala Maxxa 1999	2.94 (.48)**	0
ACSI Exp 0052	3.69 (.51)**	10(b)[†]
ACSI Exp 0222	3.85 (.60)*	30(b,r)
Agri Pro HS 44	4.92 (.50)	10(r)
Agri Pro 4103	4.37 (1.00)	0
Agri Pro 7115	3.42 (.82)**	0
Agri Pro 7126	4.04 (.69)	10(b)
Agri Pro 9220	3.60 (.61)*	0
Agri Pro 9257	3.37 (.46)**	10(b)
All Tex Atlas	3.47 (.49)**	30(b,f)
All Tex Excess	3.10 (.53)**	60(b)
Americot 951	3.25 (.41)**	80(b,r)
Deltapine 20B	3.17 (.71)**	20(b,r)
Deltapine 33B	3.75 (.63)*	30(b)
Deltapine 50	3.59 (.72)*	10(b)
Deltapine 215B	2.99 (.49)**	100(b,f)
Deltapine 237B	3.07 (.43)**	80(b)
Deltapine 388	3.14 (.52)**	70(b)
Deltapine 436RR	3.77 (.50)*	0
Deltapine 448B	3.19 (.61)**	70(b,r)
Deltapine 451B/R	4.01(.60)	30(b)
Deltapine 458B/R	4.48 (.86)	10(b,f)
Deltapine 675	4.37 (1.07)	10(b)
Deltapine 2156	3.35 (.52)**	90(b,f)
Deltapine 2379	3.70 (.42)**	70(b)
Deltapine 3315 Nu Cotton	4.58 (.94)	20(b,r)
Deltapine 5415RR	4.78 (.99)	10(b)
Deltapine 9229B	4.23 (1.06)	30(b,r)
Deltapine 9725	3.47 (.65)**	30(b,r)
Deltapine 9815RR	3.34 (.33)**	90(b)
Deltapine 9818RR	3.78 (.63)*	80(b)
FiberMax 819	3.81 (.63)*	20(b,f)
FiberMax 832	3.70 (.38)**	10(f)
FiberMax 989	4.49 (.64)	0
HCR 7051	3.39 (.71)**	10(r)
HCR 7061-39	3.60 (.66)**	20(r)
HCR 7114-46	4.16 (.93)	0
HCR 9228	4.41 (.62)	0
HCR 9239	4.06 (.66)	10(r)

HCR 9240	4.24 (.87)	0
HCR 9310	4.11 (.71)	20(f)
HS 12	5.15 (.61)	0
Paymaster 330	3.70 (.57)*	0
Paymaster 1218B/R	3.94 (.39)*	100(b,f,r)
Paymaster 1220RR	3.79 (.54)*	80(b,r)
Paymaster 1244RR	3.75 (.67)*	50(b)
Paymaster 1330BG	4.22 (.74)	60(b,f)
Paymaster 1440	4.02 (.67)	30(b,f,r)
Paymaster 1560BG	3.52 (.68)**	100(b,f,r)
Paymaster 1560B/R	3.97 (.37)*	50(b,f)
Paymaster 2145RR	2.94 (.63)**	80(b,r)
Paymaster 2200RR	3.02 (.29)**	100(b,r)
Paymaster 2280B/R	3.15 (.33)**	100(b,f,r)
Paymaster 2326RR	3.03 (.75)**	40(b)
Paymaster 2326B/R	3.33 (.54)**	30(b)
Paymaster Texas	2.71 (.65)**	80(b,r)
PSC 161	3.40 (.66)**	40(r)
PSC 355	3.36 (.57)**	20(b)
PSC 569	3.96 (.36)*	0
PSC 636	3.02 (.61)**	50(b,r)
PSC 894	3.65 (.31)**	20(b,r)
PSC 952	3.67 (.52)**	100(b)
SeedCo 9023	2.88 (.44)**	80(b,f,r)
Stoneville BXN 16	2.61 (.58)**	90(b,f,r)
Stoneville BXN 47	3.51 (.34)**	10(b)
Stoneville 239	3.75 (.37)**	10(b)
Stoneville 373	4.38 (.83)	0
Stoneville 474	4.45 (.83)	20(f)
Stoneville 9901	4.91 (.84)	0
Stoneville 9902	4.18 (.83)	0
Stoneville 9903	4.73 (.64)	10(r)
Stoneville 9904	3.77(.50)*	0
Sure - Grow 105	4.60 (.99)	10(r)
Sure - Grow 125	4.56 (.62)	0
Sure - Grow 125RR	3.85 (.93)	10(r)
Sure - Grow 125B/R	3.78 (.74)*	0
Sure - Grow 248	4.20 (1.07)	0
Sure - Grow 501	4.03 (60)	0
Sure - Grow 501B/R	3.15 (.43)**	70(b,f,r)
Sure - Grow 747	3.11 (.53)**	50(b,f,r)
Sure - Grow 821	3.23 (.46)**	70(b,f,r)
Tamcot Luxor	2.47 (.52)**	70(b,f,r)
Tamcot Sphinx	2.46 (.43)**	30(b,f,r)
Terra 208	2.92 (.61)**	20(f,r)
Terra 292	3.45 (.73)**	0
Texas 366	3.00 (.57)**	60(b,f,r)
Texas 224	3.23 (.45)**	20(r)
Texas 229	2.87 (.51)**	40(b,r)
Texas 300	3.57 (.38)**	40(b,f,r)
Texas 418	3.63 (.83)*	20(r)
Texas 88G 104	4.06 (.83)	0
UAP 6101	3.91 (.83)	0
Stoneville 373-2 S	2.86 (.46)**	1(r)
Stoneville 373-6 R	3.96 (.23)*	0
Sure - Grow 125-9 R	3.72 (.45)**	0
Paymaster 1220 B/R-2 S	3.49 (.28)**	60(b,f)

[a]Seeds were germinated in towels wet with bacterial suspension for 48 h at 30˚C and were planted 9/2/99 to 9/4/99 in a mixture of Brazos Valley sand and clay (3:1; pH 8.3). Single plants (10 per cultivar) were grown in 500 g soil mix which received 150 mg of Peter's 15-5-25 soluble fertilizer weekly. Cooling fans were set at 38˚C (100˚F) and heaters at 30˚C (86˚F).

*,** - yield significantly less than that of Suregrow 125 at the 5% and 1% level of confidence, respectively.

† - b = premature bract necrosis; f = foliar and/or stem necrosis; r = root necrosis.

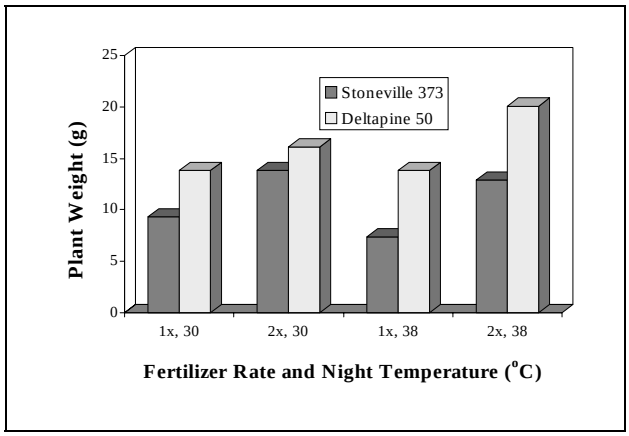

Figure 1. Effect of fertilizer rate (1x = 150 mg Peter's 15-16-17 fertilizer/plant/wk) and night temperature on weights of 8-wk-old plants inoculated with *A. tumefaciens* strains 1A, 14A, and 34B and incubated at 38ºC, 15-h days.

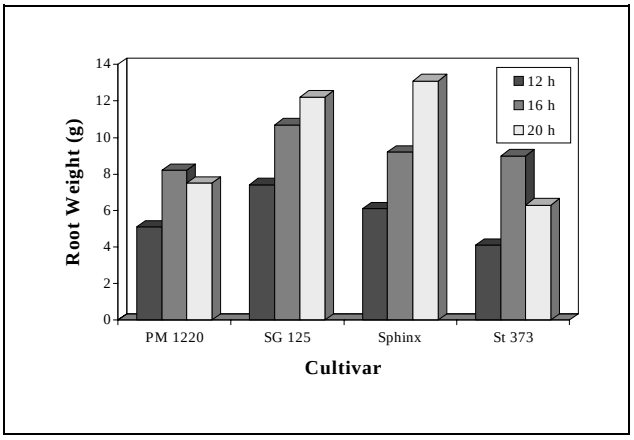

Figure 2. Effect of 12-, 16-, and 20-h photoperiod on root weights of 8-wk-old plants inoculated with *A. tumefaciens* strains 1A, 14A, and 34B incubated at 36ºC and fertilized with 15-16-17 fertilizer (300 mg/plant/wk).

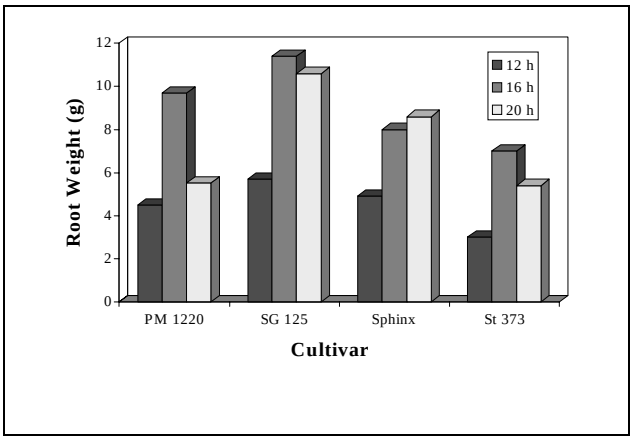

Figure 3. Effect of 12-, 16-, and 20-h photoperiods on root weights of 8-wk-old plants inoculated with *A. tumefaciens* strains 1A, 14A, and 34B, incubated at 36ºC and fertilized with 27-15-12 fertilizer (167 mg/plant/wk).

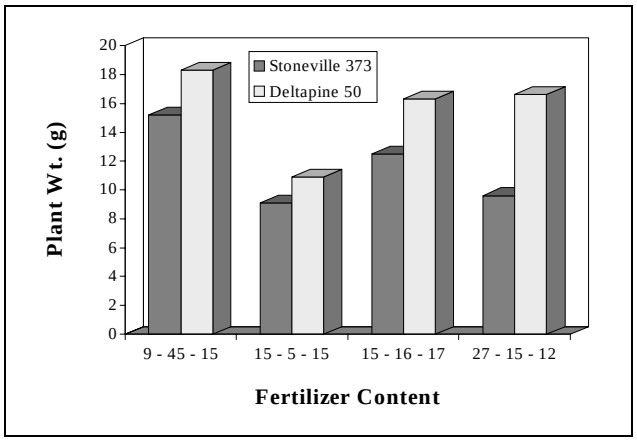

Figure 4. Effect of fertilizer composition on weight of 8-wk-old plants inoculated with *A. tumefaciens* strains 1A, 14A, and 34B at 37ºC. Each fertilizer was used at 150 mg/plant/wk rate.

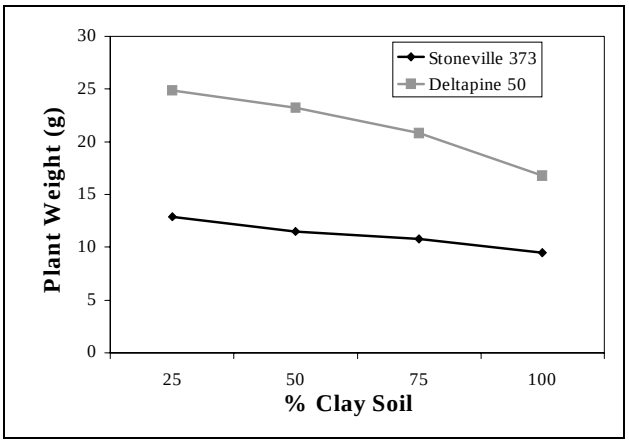

Figure 5. Effect of clay content on weight of 8-wk-old plants inoculated with *A. tumefaciens* strains 1A, 14A, and 34B at 37ºC. Plants fertilized weekly with 150 mg 15-16-17 fertilizer.

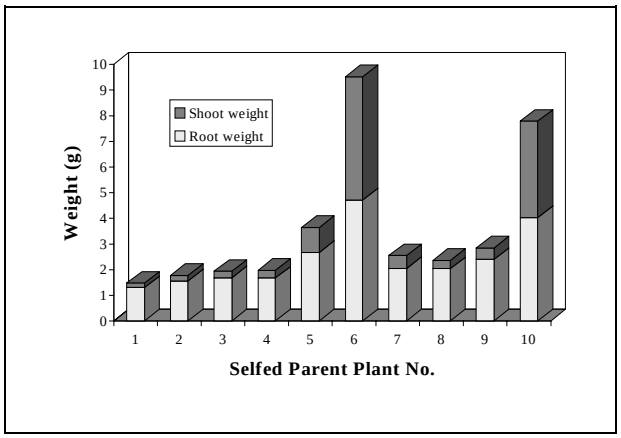

Figure 6. Root and shoot weights of progeny from selfed plants of Stoneville 373 inoculated with *A. tumefaciens* strains 1A, 14A, and 34B using the standard screen.

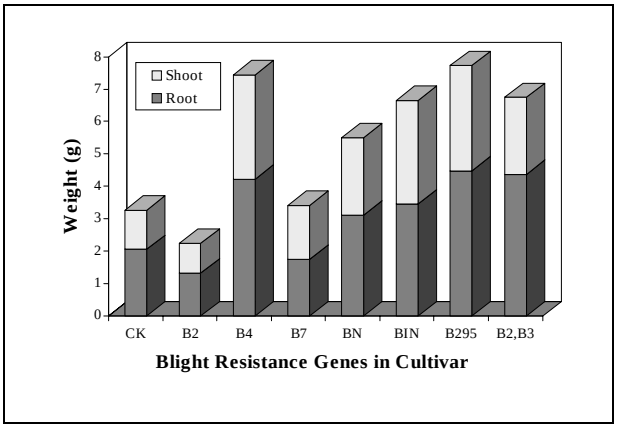

Figure 7. Shoot and root weights of plants of cultivars carrying different *B* genes at 8 wk after inoculation with *A. tumefaciens* strain 34B.
CK = 'Stoneville 2B-59,' B_2 = 'Mebane B-1,' B_4 = 'Empire-B_4', B_7 = 'Stoneville 20,' B_N = '20-3,' B_{In} = '1-10B,' B_{295} = 'S-295,' and B_2,B_3 = '101-102B.'

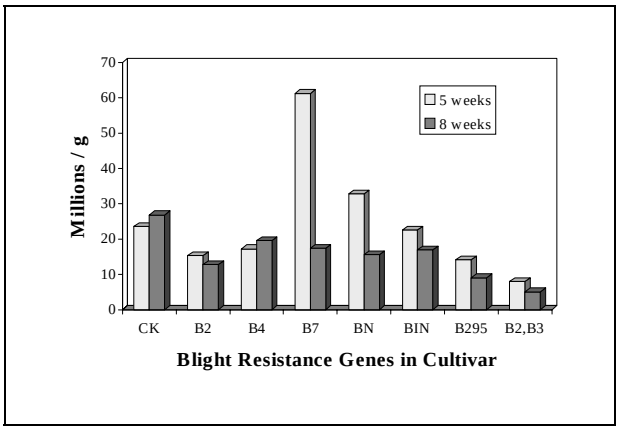

Figure 8. *Agrobacterium* concentrations (million of cfu/g) in roots of 'Stoneville 2B-59' (CK), 'Mebane B-1' (B_2), 'Empire-B4' (B_4), 'Stoneville 20' (B_7), '20-3' (B_N), '1-10B' (B_{In}), 'S-295' (B_{295}), and '101-102B' (B_2,B_3) cultivars and lines at 5 and 8 wk after inoculating germinating seed with *Agrobacterium* strain 34B.

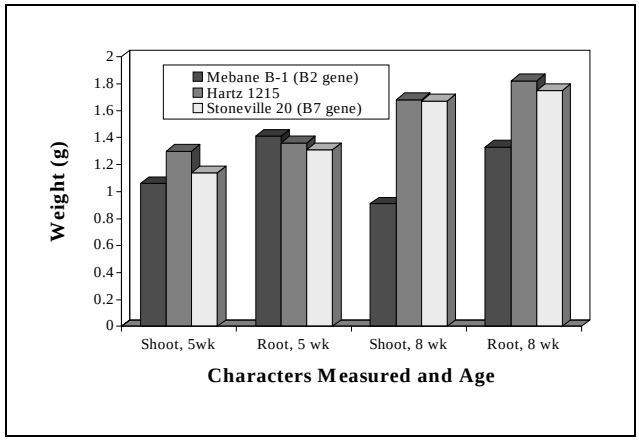

Figure 9. Comparison of shoot and root weights at 5 and 8 wk after inoculating germinating seed with *A tumefaciens* strain 34B.