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Lay Interpretation of Results for NPB Project ID 53
Breeding Peanuts for Resistance to Sclerotinia Blight, Leaf Spot, CBR and TSWV.

A series of peanut variety releases by N.C. State University gave evidence of a problem in our program. We had separate subprograms of selection for resistance to the four diseases of consistent economic importance in the North Carolina and Virginia: Sclerotinia blight caused by soilborne fungus *Sclerotinia minor*, early leaf spot caused by foliar fungus *Cercospora arachidicola*, Cylindrocladium black rot (CBR) caused by soilborne fungus *Cylindrocladium parasiticum*, and tomato spotted wilt (TSW) caused by the thrips-vectored *Tomato spotted wilt tospovirus*. When we released a variety resistant to one or even two, it often was badly susceptible to another. We needed to select for resistance to all four simultaneously.

Each year, we cross agronomically superior parents with sources of high-level resistance that are often not agronomically desirable in the Virginia-Carolina area, including runner-type sources. After the cross, we use a form of "shuttle" breeding to get to genetically stable inbred lines in three years. Starting the second generation after the cross, we make plant selections for pod and seed characteristics in North Carolina. We use a winter seed nursery in Puerto Rico to grow a second generation each year, then test the selected families for resistance to the four diseases in separate trials, identifying the best families overall and making plant selections within those families. By the sixth generation after the cross, the families are genetically stable breeding lines that have improved disease resistance and then proceed through the multi-year multi-location testing program that eventually leads to variety release. Highly resistant lines that do not measure up agronomically are recycled as parents in the crossing program.

Two varieties have been released from this project: 'Bailey' in 2008 and 'Sugg' in 2009. Certified seed of Bailey was available to growers for the 2011 growing season, as were limited amounts of Sugg. Both have partial resistance to all four diseases and also have excellent yield potential. At federal support prices for peanuts, saving one or two applications of leaf spot fungicide or a single application of Sclerotinia preventives could mean the difference between profit and loss. Resistant cultivars will help to maintain peanut production and the peanut seed market in North Carolina. In recent years, we have incorporated greater levels of disease resistance and have advanced only families carrying the high-oleic seed oil gene in our accelerated selection program.

Executive Summary for NPB Project ID 53
Breeding Peanuts for Resistance to Sclerotinia Blight, Leaf Spot, CBR and TSWV.

This long-term project was initiated to implement simultaneous selection for resistance to four diseases of consistent economic importance in the North Carolina and Virginia: Sclerotinia blight caused by soilborne fungus *Sclerotinia minor*, early leaf spot caused by foliar fungus *Cercospora arachidicola*, Cylindrocladium black rot (CBR) caused by soilborne fungus *Cylindrocladium parasiticum*, and tomato spotted wilt (TSW) caused by the thrips-vectored *Tomato spotted wilt tospovirus*. Each year, agronomically superior parents are crossed with sources of high-level resistance that are often not agronomically desirable in the VC area. We often make an initial cross in the winter then next summer cross the F_1 plants back to the agronomically desirable parent before the hybrid progeny are subjected to an accelerated program of inbreeding and selection as outlined below:

Crosses are made in the greenhouse at the N.C. State University campus in Raleigh, NC. The F_1 or first backcross F_1 (BC_1F_1) hybrid plants from the annual summer crossing program are grown at our Puerto Rico Winter Nursery (PRWN) in Juana Diaz, PR. The F_2 populations are subjected to selection for pod and seed characteristics at the Peanut Belt Research Station (PBRS) at Lewiston, NC, in plots provided a full disease control program. There is no chemical control for TSW, and the plants must be spaced 10 inches or more apart to allow for selection of individual plants, so TSW does contribute to the appearance of plants in the selection nursery. F_3 progeny of F_2 plant selections ($F_{2:3}$ families) are grown at the PRWN that winter. At harvest a single pod is harvested from each plant in an $F_{2:3}$ family to provide a single seed representing that plant in an $F_{2:4}$ selection nursery at PBRS, then the rest of the pods are harvested in bulk to provide seed for replicated testing for resistance to the four diseases at sites specially chosen and managed to promote development of diseases: Sclerotinia blight, leaf spot and CBR on infested fields left untreated with the protectant fungicides used to control them, TSW in a trial in which plants are spaced 20 inches apart and left untreated with insecticides that would reduce the population of the thrips that vector the virus. The $F_{2:4}$ or $BC_1F_{2:4}$ families with the best overall resistance to the four diseases are identified, then we make plant selections in those families in the nursery planted for the purpose at PBRS from the $F_{2:4}$ single-seed descent harvest. Progeny of those selections are sent back to the PRWN for another cycle of inbreeding and selection among and within $F_{4:6}$ and $BC_1F_{4:6}$ families the following summer. $F_{6:7}$ progeny of selected F_6 plants are grown at the PRWN, but harvested only in bulk as we do not make single-plant selections beyond the F_6 generation. The $F_{6:8}$ families, now considered genetically stable breeding lines, are tested for disease reactions and also in replicated preliminary trials for yield and grade at PBRS and another research station on the upper coastal plain near Rocky Mount, NC. The most disease-resistant families are retained for continued evaluation in disease trials; those with the best yields and grades advance into the "conventional" testing program (conducted with disease controls) that leads to cultivar release. There is usually some overlap between the two groups, but highly resistant lines that do not make the grade agronomically are used as parents for another cycle of the program. Any line that survives in the conventional advance yield test series for a second or greater year is also evaluated in disease trials.

Two cultivars have been released from this project: 'Bailey' in 2008 and 'Sugg' in 2009. Certified seed of Bailey was available to growers for the 2011 growing season, as were limited amounts of Sugg. Both have partial resistance to all four diseases and also have excellent yield potential. At federal support prices for peanuts, saving one or two applications of leaf spot fungicide or a single application of Sclerotinia preventives could mean the difference between profit and loss. Reduction of chemical inputs requires improvement of the disease resistance available in virginia-type cultivars. Resistant cultivars will help to maintain peanut production and the peanut seed market in North Carolina. In recent years, we have incorporated greater levels of disease resistance and have advanced only families carrying the University of Florida's high-oleic seed oil gene in our accelerated selection program.

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PROGRESS REPORT
TO
NORTH CAROLINA PEANUT GROWERS ASSOCIATION, INC.

TITLE: **Breeding Peanuts for Multiple Disease Resistance**

LEADER: **T. G. Isleib**

DEPARTMENT: **Crop Science**

REPORT:

Grades of the 43 F_8 progenies of F_6 plants selected from resistant $F_{4:6}$ families from the 2004 crossing program were measured in pod samples obtained from the Disease Preliminary Test (DPT) conducted at two locations, the Peanut Belt Research Station (PBRS) and Upper Coastal Plains Research Station (UCPRS) in 2008. Twenty-two $F_{6:9}$ families were selected for further testing of yield, grade, and disease resistance as part of the 2009 Disease Advanced Test; 9 of those 18 plus 9 additional lines (18 total) were selected for entry into the 2009 NCSU Advanced Yield Test (AYT). All of the lines carry the high oleic acid trait patented by the University of Florida.

Disease data were recorded for the 2009 Disease Selection Test (DST) and Disease Advanced Test (DAT) series: Sclerotinia tests with no application of fluazinam were grown at an infested site in Bertie County, NC; CBR tests with no application of metam sodium in an infested field at the Upper Coastal Plain Research Station (UCPRS) in Edgecombe County; leaf spot tests at the Peanut Belt Research Station (PBRS) at Lewiston, NC in plots that received no fungicide application; and tomato spotted wilt virus tests at PBRS in plots that received no insecticide treatment to manage thrips and that were planted at 20" seed spacing to maximize TSWV incidence. Each test had two replications and 196 genetic entries including F_4 progeny of 52 BC_3F_2 plant selections (all carrying the high-oleic gene, 15 of them high oleic) from 25 crosses made in 2007, F_6 progeny of 50 F_4 selections (all carrying the high-oleic gene, 40 of them high oleic) from superior $F_{2:4}$ families derived from 11 crosses made in 2006, and F_8 progeny of 67 BC_1F_6 selections (all of them high oleic) from superior $BC_1F_{4:6}$ families derived from 6 crosses made in 2005. The $BC_1F_{6:8}$ families will not be subjected to further within-family selection and in addition to the disease trials were tested in replicated trials (Disease Preliminary Tests) grown at PBRS and UCPRS with full disease control programs to assess yield and grade of those families. For each $BC_3F_{2:4}$ and $F_{4:6}$ family, there was a selection plot at PBRS from which plant selections were be made if that family proved to have superior disease resistance based on performance in the Disease Selection Tests. These tests were planted in May. Stand counts were made in June to permit calculation of disease incidence for CBR, Sclerotinia blight, and TSWV. Few early-season symptoms of TSWV were observed in any of the tests but symptoms developed later. Weather conditions in the early season were conducive to development of CBR and Sclerotinia blight but not leaf spot disease. Leaf spot trials were irrigated to provide sufficient humidity to promote disease development.

Because the Disease Selection Tests had 196 entries, only the means for the best ten families of each type and the checks are presented (Table 1). The best ten $F_{2:4}$ families came from four different crosses made in 2006, all of which share ancestry from breeding lines N03078FT, N03079FT, and N03084FT, more disease-resistant sisters of Bailey (tested as N03081T). The best ten $F_{4:6}$ families came from five different backcrosses crosses made in 2005 to move the high-oleic trait into disease-resistant sister lines N03073FT, N03076FT, Bailey, N03088T, and N03090T. The best $F_{6:8}$ families came from three crosses made in 2004 between disease-resistant lines (N03075FT, N04052FCSmT, and N04070CSmT) and high-oleic parents N00098ol and N02060ol. There were differences in the average level of different diseases observed in the different family types. We expected the $F_{6:8}$ families, *i.e.*, those subjected to the most selection for resistance, to have the greatest average level of disease resistance. However, contrary to expectation, the $F_{4:6}$ families showed a greater average level of resistance than did the $F_{6:8}$ families, probably reflecting the conservation of disease resistance genes in the $F_{4:6}$ families derived by backcrossing to a resistant parent versus the $F_{6:8}$ families with equal ancestry from the resistant and high-oleic parents. In making within-family selections, special attention was paid to the top 5, 10 and 20% of the $F_{2:4}$ and $F_{4:6}$ families. Again, there will be no more selection within the $F_{6:8}$ families; we will simply be identifying the best with respect to diseases, yield, and grade.

The Disease Advanced Test (DAT) series had 72 common entries tested for the four diseases that were measurable in 2009: two $F_{6:15}$ families selected from the 2002 Disease Preliminary Test (DPT) for further testing of yield, grade, and disease resistance; one $F_{6:13}$ family selected from the 2004 DPT, one $F_{6:11}$ family selected from the 2006 DPT, seven $F_{6:10}$ families selected from the 2007 DPT, 22 $F_{6:9}$ families selected from the 2008 DPT; one line entered upon the request of Dr. Roy Pittman, the USDA-ARS peanut germplasm curator, 14 lines derived from interspecific hybrids developed by Drs. H.T. Stalker and S.P. Tallury, and 14 checks including released cultivars (NC-V 11, NC 12C, Gregory, Perry, Phillips, Brantley, Bailey, Sugg, VA 98R, CHAMPS, and Florida Fancy) and disease-resistant lines (Georgia Green, N96076L, and PI 576636). There were also two lines that made their way into the DAT by expressing superior disease resistance after surviving in the conventional cultivar develop stream through a second year in the three-location Advanced Yield Test series. Some of these lines originated in the DST program but fell out of the accelerated program because they did not exhibit sufficient resistance to be retained. Such families enter the conventional cultivar development stream that achieves only one generation per year and in which selection and retention in the program are based solely on pod characteristics, yield and grade. Of the 43 experimental lines developed by the breeding program rather than the species program, 21 were also entered in the multiple-location Advanced Yield Test series for broader evaluation of yield and grade, and three were entered in the multiple-location Jumbo Pod Advanced Test (JAT).

Disease data from the 2009 season on preliminary and advanced F_6-derived lines was combined with data collected from 2000-2008, and means adjusted to a common environmental effect were computed. Adjusted means were converted to a zero (worst) to one (best) scale for each of the four diseases, and an arithmetic mean disease score was computed. All diseases were weighted equally. Similarly, an adjusted mean yield was computed using all data collected from plots with conventional disease management from 2000 through 2009. Of the 20 best lines for disease resistance, 12 came from the accelerated resistance selection program (Figure 1), 11 of them high-oleic selections from the 2007 through 2009 DPT. Although it is often the case that the most disease-resistant lines are not the highest yielding or have the best grade, many of these selections yielded extremely well. As one would expect for a set of lines yield-tested for the first time, among the 67 selections from the 2009 DPT are some with poor yields. There is not yet any grade data for those selections; it will be obtained in the winter of 2009-2010. The commercial value of these selections cannot be known with certainty until they have passed through a multiple-year multiple-location testing program, but several of them appear to combine high yield with good disease resistance. Two of Dr.Tallury's lines, SPT 07-01 and SPT 09-02, combined outstanding disease resistance with high yield.

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Table 1. Adjusted means from the 2009 Disease Selection Tests: best ten BC$_3$F$_{2:4}$, F$_{4:6}$ and BC$_1$F$_{6:8}$ families compared with checks. Early leafspot tested at PBRS in plots without fungicide; TSWV at PBRS in plots with 20" seed spacing and without insecticide, CBR at UCPRS on infested soil without metam sodium, and Sclerotinia plots at Roxobel in Bertie Co. on infested soil without application of fluazinam or boscalid.

Entry	Defol-iation score	Rank among 196	Cylindro-cladium black rot	Rank among 196	Sclerotinia blight	Rank among 196	Tomato spotted wilt virus	Rank among 196	Arith-metic disease index§	Rank: Over-all	Rank: Among families I
	1=none to 9=complete		*incidence*		*incidence*		*incidence*		*0=worst to 1=best*		
BC$_3$F$_{2:4}$ families	**3.43±0.06$^{\alpha}$**		**0.339±0.023$^{\alpha}$**		**0.756±0.010$^{\beta}$**		**0.154±0.015$^{\alpha}$**		**.687**		
X07105 (BC3F1-02-01-B: F04)	3.18±0.40^{a}	74	0.046±0.160^{az†}	159	0.510±0.106**	54	0.032±0.101^{a†}	17	.791	2	1
X07100 (BC3F1-02-01-B: F04)	3.21±0.40^{a}	77	0.253±0.160^{az†}	175	0.427±0.106^{a*}	16	0.000±0.101^{a†}	7	.779	4	2
X07076 (BC3F1-03-01-B: F04)	2.96±0.40^{a**}	46	0.289±0.160^{az*}	179	0.431±0.106^{a*}	19	0.091±0.101^{a†}	41	.752	9	3
X07074 (BC3F1-02-01-B: F04)	3.32±0.40^{a}	94	0.285±0.160^{az*}	178	0.432±0.106^{a*}	20	0.021±0.101^{a†}	13	.751	10	4
X07084 (BC3F1-02-01-B: F04)	2.96±0.40^{a**}	46	0.362±0.160^{az**}	183	0.495±0.106**	49	0.018±0.101^{a†}	12	.749	14	5
X07091 (BC3F1-06-02-B: F04)	3.18±0.40^{a}	74	0.111±0.160^{az†}	164	0.527±0.106	67	0.097±0.101^{a†}	49	.742	15	6
X07102 (BC3F1-05-03-B: F04)	2.79±0.40^{a*}	19	0.142±0.160^{az†}	167	0.596±0.106	94	0.143±0.101^{a†}	84	.731	18	7
X07102 (BC3F1-05-01-B: F04)	3.29±0.40^{a}	87	0.100±0.160^{az†}	162	0.484±0.106**	40	0.138±0.101^{a†}	82	.729	19	8
X07083 (BC3F1-05-01-B: F04)	3.50±0.40^{a}	122	0.160±0.160^{az†}	170	0.516±0.106**	61	0.065±0.101^{a†}	31	.720	24	9
X07101 (BC3F1-01-01-B: F04)	3.71±0.40	148	0.260±0.160^{az†}	176	0.408±0.106^{a†}	10	0.040±0.101^{a†}	20	.719	25	10
F$_{4:6}$ families	**3.42±0.07$^{\alpha}$**		**0.323±0.028$^{\alpha}$**		**0.752±0.012$^{\beta}$**		**0.160±0.018$^{\alpha}$**		**.677**		
X06131 (F2-01-S-03-B: F06)	2.71±0.40^{a*}	12	0.278±0.160^{a*}	70	0.201±0.106^{a†}	2	0.024±0.101^{a†}	15	.873	1	1
X06130 (F2-09-S-01-B: F06)	2.71±0.40^{a*}	12	0.150±0.160^{a†}	27	0.471±0.106**	34	0.167±0.101^{a*}	108	.761	7	2
X06131 (F2-02-S-01-B: F06)	2.75±0.40^{a*}	14	0.408±0.160^{a**}	132	0.411±0.106^{a†}	11	0.075±0.101^{a†}	36	.757	8	3
X06126 (F2-04-S-02-B: F06)	2.46±0.40^{a†}	2	0.159±0.160^{a†}	29	0.606±0.106	100	0.148±0.101^{a†}	88	.751	11	4
X06131 (F2-02-S-05-B: F06)	2.96±0.40^{a**}	46	0.128±0.160^{a†}	22	0.511±0.106**	56	0.126±0.101^{a†}	70	.750	12	5
X06132 (F2-03-S-01-B: F06)	2.93±0.40^{a**}	40	0.086±0.160^{a†}	9	0.487±0.106**	43	0.171±0.101^{a*}	110	.750	13	6
X06131 (F2-02-S-02-B: F06)	3.04±0.40^{a**}	60	0.467±0.160	146	0.510±0.106**	55	-0.036±0.101^{a†}	3	.739	16	7
X06130 (F2-14-S-03-B: F06)	3.04±0.40^{a**}	60	0.351±0.160^{a**}	109	0.426±0.106^{a*}	15	0.108±0.101^{a†}	58	.725	21	8
X06132 (F2-03-S-02-B: F06)	3.07±0.40^{a}	64	0.237±0.160^{a†}	50	0.664±0.106	133	0.007±0.101^{a†}	9	.725	22	9
X06130 (F2-14-S-04-B: F06)	3.43±0.40^{a}	110	0.325±0.160^{a**}	99	0.446±0.106^{a*}	28	0.054±0.101^{a†}	26	.714	27	10
BC$_1$F$_{6:8}$ families	**3.28±0.06$^{\alpha}$**		**0.351±0.023$^{\alpha}$**		**0.807±0.010$^{\gamma}$**		**0.214±0.014$^{\beta}$**		**.629**		
X05242 (BC1F1-02-01-S-01-S-01: F08)	2.96±0.40^{a**}	46	0.117±0.160^{a†}	18	0.549±0.106	76	0.035±0.101^{a†}	19	.782	3	1
X05242 (BC1F1-02-01-S-02-S-02: F08)	2.93±0.40^{a**}	40	0.019±0.160^{a†}	3	0.686±0.106	140	0.014±0.101^{a†}	11	.777	5	2
X05254 (BC1F1-09-02-S-02-S-01: F08)	3.00±0.40^{a**}	54	0.109±0.160^{a†}	16	0.444±0.106^{a*}	25	0.125±0.101^{a†}	69	.771	6	3
X05242 (BC1F1-02-01-S-01-S-04: F08)	2.79±0.40^{a*}	19	0.326±0.160^{a**}	100	0.493±0.106**	46	0.110±0.101^{a†}	62	.733	17	4
X05239 (BC1F1-06-01-S-03-S-01: F08)	2.79±0.40^{a*}	19	0.179±0.160^{a†}	34	0.508±0.106**	53	0.189±0.101^{a*}	115	.727	20	5
X05242 (BC1F1-02-01-S-02-S-01: F08)	3.39±0.40^{a}	105	0.003±0.160^{a†}	1	0.631±0.106	116	0.094±0.101^{a†}	46	.719	26	6
X05239 (BC1F1-06-01-S-01-S-02: F08)	3.14±0.40^{a}	67	0.193±0.160^{a†}	40	0.495±0.106**	48	0.167±0.101^{a*}	107	.705	31	7
X05254 (BC1F1-09-02-S-02-S-06: F08)	2.82±0.40^{a**}	21	0.096±0.160^{a†}	11	0.799±0.106^{z}	172	0.098±0.101^{a†}	50	.700	34	8
X05249 (BC1F1-07-01-S-01-S-05: F08)	2.89±0.40^{a**}	32	0.377±0.160^{a**}	120	0.526±0.106**	65	0.118±0.101^{a†}	66	.699	35	9
X05242 (BC1F1-02-01-S-01-S-05: F08)	2.86±0.40^{a**}	26	0.368±0.160^{a**}	116	0.647±0.106	124	0.061±0.101^{a†}	30	.695	36	10
Checks	**4.09±0.15$^{\beta}$**		**0.667±0.062$^{\beta}$**		**0.688±0.028$^{\alpha}$**		**0.167±0.039$^{\alpha\beta}$**		**.630**		
Phillips	4.96±0.40^{z}	195	0.713±0.160^{z}	189	0.625±0.106	111	0.184±0.101^{a*}	113	.377	192	8
Bailey	3.61±0.40	141	0.249±0.160^{a†}	54	0.486±0.106**	42	0.161±0.101^{a†}	96	.655	70	4
Sugg	3.46±0.40^{a}	117	0.533±0.160	162	0.572±0.106	86	-0.012±0.101^{a†}	4	.656	69	3
VA 98R	5.18±0.40^{z}	196	0.927±0.160^{z}	195	0.593±0.106	92	0.215±0.101^{a**}	129	.304	196	10
CHAMPS	4.61±0.40^{z}	189	0.702±0.160^{z}	187	0.320±0.106^{a†}	6	0.401±0.101^{z}	190	.402	189	7
Georgia Green	4.75±0.40^{z}	192	0.547±0.160	167	0.640±0.106	117	0.323±0.101^{z}	174	.368	193	9
GP-NC 343	3.39±0.40^{a}	105	0.630±0.160	178	0.731±0.106	154	0.170±0.101^{a*}	109	.514	163	5
N96076L	2.64±0.40^{a†}	5	0.800±0.160^{z*}	192	0.431±0.106^{a*}	17	-0.039±0.101^{a†}	2	.723	23	1
N09047olCSmT	4.93±0.40^{z}	194	1.104±0.160^{z}	196	0.277±0.106^{a†}	3	0.102±0.101^{a†}	53	.427	185	6
PI 576636	3.36±0.40^{a}	101	0.469±0.160	147	0.296±0.106^{a†}	4	0.164±0.101^{a†}	101	.682	46	2
Mean of all entries	4.88		0.138		0.136		0.274		.683	120.5	
Standard value	2.00		0.000		0.250		0.000				

§ Average of four disease scores, each adjusted to a 1 (best) to 0 (worst) scale.
α,β Group means followed by the same greek ;letter are not significantly different by t-test (P<0.05).
**,*,† Indicate means not significantly different from the standard value at the 1%, 5%, and 10% levels of probability, respectively, by t-test from a standard value.
a,z Denote means not significantly different from the best and worst in the test, respectively, at the 5% level by t-test.

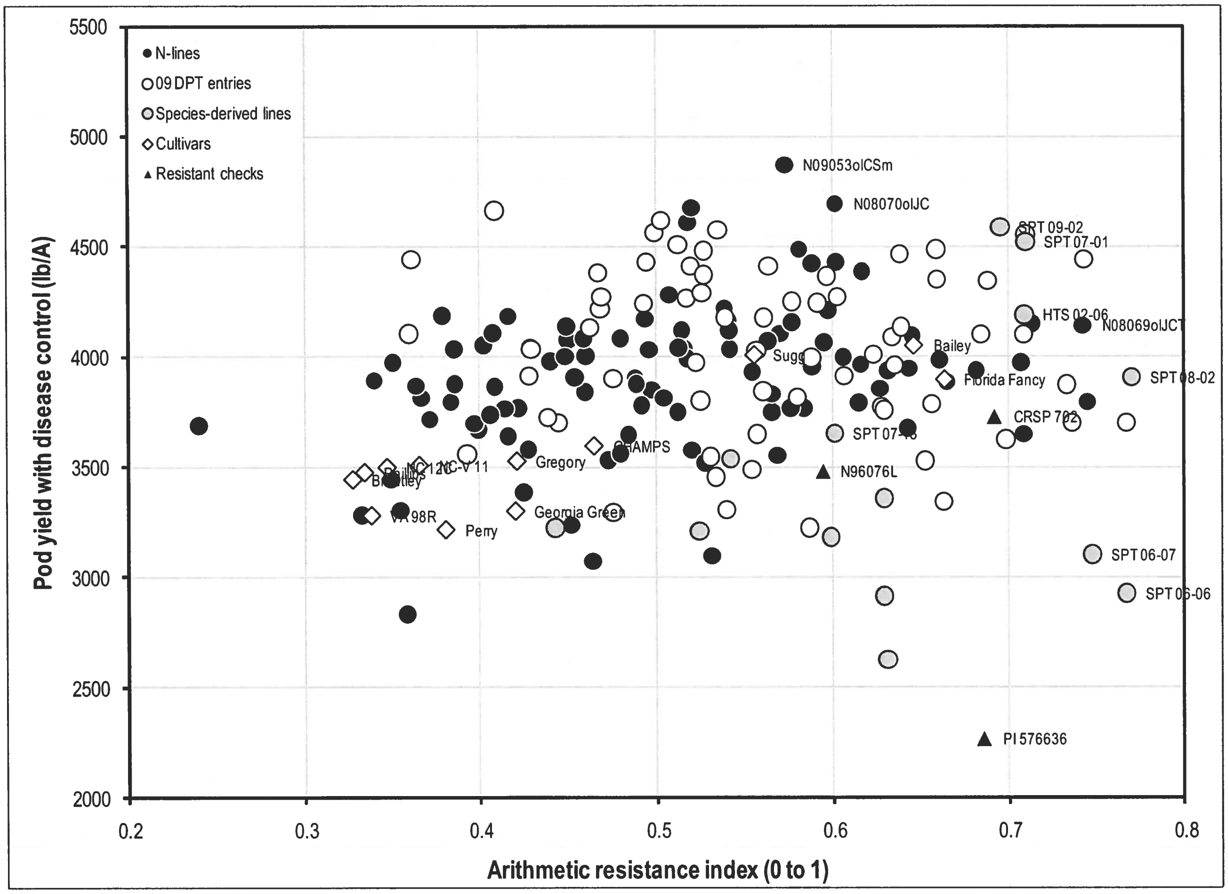

Figure 1. Pod yield with disease control versus arithmetic disease resistance index (mean of three disease scores adjusted to a scale of 0=worst to 1=best).

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IMPACT STATEMENT

The second cultivar release from this project was initiated in June, 2009: breeding line N03091T was proposed for release under the name "Sugg" in honor of the late Joseph "Joe" Sugg and Norfleet "Fleet" Sugg, two cousins who served consecutively as executive directors of the N.C. Peanut Growers Association for over 25 years. Seed multiplication of Sugg is on schedule for distribution to certified seed producers in 2011. Sugg has partial resistance to the four most common economically important diseases of peanut in North Carolina: early leafspot, Cylindrocladium black rot, Sclerotinia blight, and tomato spotted wilt virus. With current peanut prices, saving one or two applications of leafspot fungicide or a single application of Sclerotinia preventives could mean the difference between profit and loss. Reduction of chemical inputs requires improvement of the disease resistance available in virginia-type cultivars. Resistant cultivars will help to maintain peanut production and the peanut seed market in North Carolina.