Evaluation of *Arachis hypogaea* × *A. cardenasii* Interspecific Lines for Resistance to Insect Pests[1]

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ABSTRACT

Fourteen lines from the interspecific cross *Arachis hypogaea* × *A. cardenasii* were evaluated in the field and seven lines from this cross were evaluated in the laboratory for resistance to insect damage. Laboratory evaluation of interspecific lines against major defoliators of peanut showed variable levels of resistance to the corn earworm, no resistance to the fall armyworm, and moderate resistance to the velvetbean caterpillar as noted by a reduced host suitability index in line IC 2-5. Damage ratings to plants in the field indicated no resistance in the interspecific lines to the tobacco thrips. However, a high level of resistance to the southern corn rootworm was observed in most of the lines. Resistance to the potato leafhopper was indicated by reduced damage ratings for all interspecific lines relative to damage on cv. Florunner. Resistance ratings for the potato leafhopper were highest in lines GP-NC WS 7 and IC 1-19 and was evident even under severe potato leafhopper pressure. The levels of resistance to the southern corn rootworm and potato leafhopper should prove useful in a breeding program to introgress resistance to these insects into elite cultivars.

Key Words: Peanut, groundnut, interspecific hybrids, corn earworm, *Helicoverpa zea*, fall armyworm, *Spodoptera frugiperda*, velvetbean caterpillar, *Anticarsia gemmatalis*, thrips, *Frankliniella fusca*, potato leafhopper, *Empoasca fabae*.

Peanut, *Arachis hypogaea* L., is attacked by a wide variety of insect pests, many of which cause substantial economic losses to the crop each year. As examples, losses in peanut to insects in Georgia were estimated at \$52.6 million in 1991, \$48.8 million in 1992, \$85.4 million in 1993, \$22.3 million in 1994, and \$30.7 million in 1995 (Brown *et al.*, 1992, 1993, 1994, 1995, 1996, 1997). Resistance to a number of insects and diseases transmitted by insects has been identified in *A. hypogaea* (Lynch, 1990; Lynch and Mack, 1995), but in most cases the level of resistance is intermediate and often insufficient for incorporation into cultivars. Similarly, evaluation of the cultivated peanut germplasm collection has identified resistance to insects in a number of plant introductions (PIs) but again, the level of resistance becomes diluted in a peanut breeding program when a resistant cultivar is crossed with a susceptible line.

Many wild progenitors of modern agricultural crops

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evolved defense mechanisms to limit damage by insects (Painter, 1951). High levels of resistance to a number of important insect pests have been identified in wild species of peanut (Lynch and Mack, 1995). For example, the groundnut aphid, *Aphis craccivora* Koch, fed *A. villosa* Benth., *A. diogoi* Hoehne (formerly called *A. chacoensis*), or *A. glabrata* Benth. either failed to reproduce or showed a highly reduced rate of reproduction (Amin, 1985); fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae that were fed leaves of *A. villosa* or *A. burkartii* Handro failed to complete larval development (Lynch *et al.*, 1981); and larvae of the groundnut leaf miner, *Aproaerema modicella* Deventer, failed to complete development on leaves of *A. stenosperma* Krapov. and W. C. Gregory, *A. stenophylla* Krapov. and W. C. Gregory, and *A. villosulicarpa* Hoehne (Amin and Mohammad, 1980; Amin, 1985; J. A. Wightman, G. V. Ranga Rao, and J. P. Moss, pers. commun., 1995).

Stevenson *et al.* (1993a,b) reported that mortality of *Spodoptera litura* (Fab.) neonates that were fed excised leaves of *A. batizogaea* Krapov. et Fern., *A. kemph-mercadoi* Krapov., W. C. Gregory and C. E. Simpson, *A. appressipila* Krapov. and W. C. Gregory, *A. paraguariensis* Chodat & Hassl., *A. stenophylla*, or *A. villosa* exceeded 90%, compared with less than 20% mortality on the susceptible control cv. TMV-2. Chemical analyses of leaves of *A. paraguariensis, A. diogoi*, and the hybrid *A. diogoi* × *A. hypogaea* showed the presence of quercetin diglycocides and caffeoylquinic acids, 1-caffeoyl-4-deoxyquinic acid (1-CdQA), 3-caffeoylquinic acid (3-CQA), and 5-caffeoylquinic acid (5-CQA = chlorogenic acid). Development of *S. litera* larvae that fed on diets treated with 1-CdQA, 3-CQA, and 5-CQA was severely retarded compared with larvae that fed on untreated diet. Yang *et al.* (1993) reported compositional differences in cuticular lipids from peanut blooms and foliage among the wild species that may be related to their resistance to thrips, fall armyworm, and other insects. Thus, a chemical basis of resistance has been suggested for wild species of *Arachis*, and several of them offer potential sources of high levels of resistance that should prove useful for developing commercial germplasm.

Although most *Arachis* species are diploid, ploidy level varies in several sections of the genus (Stalker and Simpson, 1995). Differences in ploidy, along with several other factors, have resulted in barriers for producing interspecific hybrids. Stalker and Simpson (1995) noted that both pre- and post-fertilization barriers exist when attempts are made to cross wild species with *A. hypogaea*, and they reviewed techniques that have been developed to overcome these barriers.

The interspecific lines used in this study were derived from an *A. hypogaea* (PI 261942) × *A. cardenasii* (GKP 10017, PI 262142) cross made during the mid-1960s by J. Smartt and W. C. Gregory (Stalker *et al.*, 1979). First generation hybrid seed were obtained and colchicine-treated to restore fertility at the hexaploid ($2n = 6x = 60$) level. A fertile plant was self-pollinated and then used for seed increase through the C_5 generation. In 1978, the chromosome number was determined from numerous C_5 plants of a heterogeneous population, and all individuals had lost chromosomes and were tetraploids ($2n = 4x = 40$) (Stalker *et al.*, 1979). The objective of this investigation was to evaluate selected interspecific peanut lines for resistance to several insect pests of peanut.

Materials and Methods

Fourteen single plant selections were made in 1981 from which seed of selfed plants were obtained, planted, and the plants evaluated for tobacco thrips, *Frankliniella fusca* (Hinds); potato leafhopper, *Empoasca fabae* (Harris); corn earworm, *Helicoverpa zea* (Boddie); and southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber resistance during the summers of 1982 and 1991 to 1995 (Table 1). The two parents, *A. hypogaea* subsp. *fastigata* var. *fastigata* (PI 261942) and *A. cardenasii* (PI 262142), cv. Florigiant (susceptible check), and cv. NC 6 and NC Ac 343 (resistant checks) were included in the evaluations, with the exception that NC Ac 343 was not grown during 1981. Only insect damage due to natural infestations of each pest were evaluated. Populations of insects were too low in 1992 and 1994 to evaluate plant damage caused by corn earworm and southern corn rootworm, respectively. Field tests were replicated five times each year in a randomized complete block design at the Peanut Belt Research Station, Lewiston, NC, except during 1995 when only two replications were used. Seeds were planted in two-row plots with 10 seeds/row each spaced 25 cm apart. Normal cultural practices were used except no insecticides were applied to plants during the growing season. Thrips were evaluated during the first week of July by counting the total number of damaged leaves per plot; potato leafhopper damage was evaluated during the third week of August as a percentage of damaged leaves per plot; corn earworm damage was evaluated during the second week of September as the percentage of damaged leaves per plot; and southern corn rootworm damage was evaluated during the first week of October as the percentage of damaged pods on a three-plant sample per plot. A square root transformation was used on the data and means separated by LSDs. All analyses were conducted on and significantly different means were separated on transformed data, but actual means are presented in the tables or text.

Seven lines designated GP-NC WS 7, GP-NC WS 8, GP-NC WS 9, GP-NC WS 10, GP-NC WS 11, IC 1-19, and IC 2-5 from the same interspecific peanut cross, *A. hypogaea* × *A. cardenasii*, were compared to cv. Florunner for resistance to insects during 1994 and 1995 at Tifton, GA. Seed of each line were planted at a rate of 120 kg/ha on a Tifton loamy sand soil type (fine, loamy, siliceous, thermic Plinthic Paleudults) at the Belflower Farm near Tifton, GA. Plots were two rows 6.1 m long on a 1.8-m bed with 81 cm between rows and were replicated four times in a randomized complete block design. In 1994, benefin (1.7 kg ai/ha) plus vernolate (1.9 kg ai/ha) were incorporated in the soil preplant and bentazon (2 × 1.1 kg ai/ha), pyridate (1.1 kg ai/ha), and 2,4-DB (0.3 kg ai/ha) were applied postemergence for weed control. In 1995, benefin (1.7 kg ai/ha) plus imaethapyr (0.07 kg ai/ha) were incorporated into the soil before planting, bentazon (1.1 kg ai/ha) plus metolachlor (2.2 kg ai/ha) plus paraquat (0.14 kg ai/ha) were applied before plant emergence, and pyridate (1.1 kg ai/ha) was applied postemergence for weed control. All plots were treated with chlorothalonil (1.1 L/ha) or tebuconazole (239.5 mL/ha) (1994 = three applications of Bravo followed by three applications of Folicur and then two applications of Bravo; 1995 = two applications of Bravo followed by two applications of Folicur and then two applications of Bravo) for control of early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot [*Cercosporidium personatum* (Berk. & Curt.)], respectively.

Laboratory bioassays were conducted with the corn earworm, fall armyworm, and velvetbean caterpillar, *Anticarsia gemmatalis* Hübner. Tests were initiated *ca.* 40 d after plant emergence and conducted throughout the summer while plants were actively producing terminal leaves. Terminal leaves were removed from plants in each field plot, placed in labeled Ziplock® bags, stored on ice in a cooler, and transported to the laboratory for assay. Three to six leaves from each plot, depending on the stage of insect development, were placed in each of 20 insect growth chambers containing moistened cellucotton. Leaves in each chamber were infested with five neonates of the appropriate insect and sealed with a clear plastic lid. Chambers were randomized and placed in an incubator maintained at 27.7 C, 75% RH, and a 16:8 hr (light:dark) photoperiod. Terminals were replaced and/or new terminals treated as above were added each Monday, Wednesday, and Friday. At 6 d after infestation, the number of larvae that established on the leaves was recorded and the number of insects was reduced to one/chamber. Data also were recorded on weight of larvae at 10 d, days to pupation, pupal weight, days to adult eclosion, and sex. All experiments were designed as a randomized complete block with four replications and 20 subsamples. Data were combined over years in a split plot design with years as the whole plot and peanut line as the subplot. Percentage data were transformed to arcsin ÷$\sqrt{\%}$, all data were subjected to analyses of variance (SAS, 1989), and means were separated by the Waller-Duncan k-ratio t-test or LSD.

Insect damage to plants in the field was rated on a 0 to 10 scale where 0 = no damage, 5 = moderate damage, and 10 = extensive damage to the leaves of the plant. Damage by tobacco thrips and potato leafhopper was sufficient in both years to make damage ratings. Ten terminal leaves were removed from plants in each plot, placed in 95% ethanol, and the number of adults and immature thrips was counted under a dissecting microscope. Data were subjected to an analysis of variance and means were separated by the Waller-Duncan k-ratio t-test. Pearson correlation coefficients were determined for number of adult, immature, and total thrips per 10 leaves vs. the thrips damage ratings for 1995.

Results and Discussion

A large variation in resistance to the corn earworm in North Carolina was observed from year to year (Table 1). When insect pressure was low, NC 6 and NC Ac 343

Table 1. Percentage of leaves of interspecific peanut lines from the cross *Arachis hypogaea* × *A. cardensaii* damaged by corn earworm larval feeding in field evaluations at Lewiston, NC.

Genotype	Leaf damage[a]						
	1981	1982	1991	1993	1994	1995	Mean
	%						
A. hypogaea* × *A. cardenasii							
GP-NC WS 7	2.0 de	3.0 b	8.7 ghi	8.0 f	4.4 gh	10.0 cd	5.9
GP-NC WS 8	1.0 e	1.0 c	9.5 e-h	17.0 b-e	7.0 d-g	15.0 cd	8.4
GP-NC WS 9	3.7 cde	1.0 c	9.7 f-i	15.0 de	5.0 fg	15.0 cd	8.2
GP-NC WS 10	3.7 cde	2.0 b	6.6 hi	13.0 e	6.0 efg	10.0 cd	6.9
GP-NC WS 11	3.3 de	2.7 b	16.2 c-h	14.0 de	6.0 efg	15.0 bcd	9.5
IC 1-2	2.7 de	5.0 a	13.4 d-h	13.0 e	7.0 d-g	10.0 cd	8.5
IC 1-11	2.0 de	3.0 b	18.0 c-g	17.0 b-e	9.0 d-g	15.0 bcd	10.7
IC 1-19	4.0 cd	6.3 a	21.7 cd	16.0 cde	5.0 fg	7.5 d	10.3
IC 1-30	2.3 de	2.2 b	15.0 c-h	22.0 ab	19.0 b	30.0 a	15.1
IC 2-2	3.0 de	0.7 c	29.1 abc	14.0 b	12.0 d-g	20.0 abc	13.1
IC 2-5	3.3 de	1.7 bc	12.4 d-h	17.0 b-e	6.0 efg	10.0 cd	8.4
IC 2-12	3.7 cde	2.3 b	20.4 c-g	17.0 b-e	7.0 d-g	20.0 abc	11.7
IC 2-13	3.3 de	3.3 b	22.0 bcd	18.0 bcd	14.0 bc	15.0 bcd	14.3
IC 2-36	3.0 de	2.3 b	20.5 cde	18.0 bcd	6.0 efg	15.0 bcd	10.6
A. hypogaea							
Florigiant	13.3 b	6.3 a	24.7 bcd	15.0 de	12.0 bcd	20.0 abc	15.2
NC 6	4.3 cd	1.0 c	26.8 bcd	18.0 b-e	9.0 c-f	20.0 abc	13.2
NC Ac 343	—	2.0 bc	20.3 c-f	21.0 abc	14.0 abc	25.0 ab	16.5
Parents[b]							
GKP 10017	2.7 de	—	2.7 i	1.0 g	2.0 h	0.0 e	1.7
PI 261942	38.3 a	—	42.6 a	26.0 a	52.0 a	30.0 a	37.8

[a]Means within a column followed by the same letter are not significantly different at P ≤ 0.05. Means are actual percentages, but analyses were conducted on $\sqrt{\%}$ transformed data.

[b]GKP 10017 = *A. cardenasii*; PI 261942 = *A. hypogaea* subs. *fastigata* var. *fastigata*.

expressed equal or higher levels of resistance than interspecific lines. However, during 1991, 1993, and 1994, GP-NC WS 7 and GP-NC WS 10 expressed significantly ($P \leq 0.05$) high levels of resistance. However, in Georgia, laboratory evaluations of the same interspecific lines for corn earworm feeding and development were variable and showed only moderate levels of resistance (Table 2). Significant genotype × year interactions were noted for larval survival at 6 d and for host suitability index. Analysis by year showed that survival and host suitability varied with interspecific lines between years. As an example, larval survival on terminals of GP-NC WS 7 was significantly lower ($F = 2.73$; df = 7; $P = 0.01$) than survival of larvae on Florunner in 1994. However, this trend was exactly the opposite in 1995 when larval survival was significantly higher ($F = 10.57$; df = 7; $P < 0.0001$) on GP-NC WS 7 than survival on Florunner. Larvae reared on leaflets from GP-NC WS 11 required longer to pupate, larvae reared on IC 2-5 produced lighter pupae, and larvae reared on IC 1-19, IC 2-5, and GP-NC WS 8 had lower survival to the adult emergence than larvae reared on Florunner. Host suitability index, a quantitative measure of the cumulative effects of antibiosis (Lynch *et al.*, 1981), also varied among peanut lines between years. In 1994, the host suitability index was significantly lower ($F = 3.69$; df = 7; $P = 0.01$) for larvae reared on peanut lines IC 1-19, IC 2-5, and GP-NC WS 9 than for larvae reared on Florunner. In 1995, larvae reared on these three lines had host suitability indices that were not significantly lower than those reared on Florunner; only larvae reared on GP-NC WS 8 had a significantly lower ($F = 2.94$; df = 7; $P = 0.03$) index than larvae reared on Florunner. Thus, resistance in these interspecific lines to the corn earworm varied considerably between years, and none of the lines were consistently more resistant to the corn earworm than the susceptible control, Florunner.

None of the interspecific lines were more resistant to the fall armyworm than Florunner (Table 3). Significant differences in the development of fall armyworm larvae were noted among interspecific lines for larval weight at 10 d, days to pupation, pupal weight, and days to adult eclosion. However, in each instance, the insects that fed on leaves from the interspecific lines were comparable with those that fed on Florunner leaves. As a result, no differences in the host suitability index (Lynch *et al.*, 1981) were noted for the fall armyworm that were fed leaflets of Florunner or the interspecific lines. Significant differences were noted between years for all of the developmental parameters with the exception of survival to adults. However, since no significant interaction was detected, the response of fall armyworm larvae on a given interspecific line was fairly constant between years.

No significant differences were noted for velvetbean caterpillar in survival at 6 d, larval weight at 10 d, days to pupation, days to adults, or survival to adults among peanut lines (Table 4). Significant differences among interspecific lines were only noted for weight of pupae, but none of the pupae from larvae that fed on leaves of any of the interspecific lines weighed significantly less than larvae that fed on leaves from Florunner. However, IC 2-5 had a significantly lower ($F = 2.09$; df = 7; $P = 0.04$) host suitability index than Florunner. Although not significantly different from that recorded for Florunner, insects on IC 2-5 had the lowest survival at 6 d, the lowest larval weight at 10 d, the lowest pupal weight, the longest developmental time as larvae and pupae, and the lowest

Table 2. Evaluation of interspecific lines from the cross *Arachis hypogaea* × *A. cardensaii* for resistance to corn earworm larval feeding in laboratory tests at Tifton, GA.[a]

Genotype	Survival at 6 d 1994	Survival at 6 d 1995	Larval wt at 10 d	Days to pupation	Pupal weight	Days to adults	Survival to adults	Host suitability index[c,d] 1994	Host suitability index[c,d] 1995
	%[b,c]		mg		mg		%[b]		
***A. hypogaea* ×**									
A. cardensaii									
GP-NC WS 7	50.0 b	71.0 a	119.9 ab	19.8 ab	288.9 ab	29.7 a	52.5 ab	11.7 abc	8.6 ab
GP-NC WS 8	71.0 a	57.0 cd	89.1 b	19.9 ab	271.7 ab	28.9 a	43.8 b	12.3 abc	2.6 c
GP-NC WS 9	67.0 ab	63.0 abc	116.8 ab	20.2 ab	275.1 ab	28.4 a	61.3 ab	10.6 bcd	5.9 abc
GP-NC WS 10	79.0 a	49.5 d	115.4 ab	19.4 b	279.5 ab	29.0 a	66.3 ab	13.9 ab	4.9 bc
GP-NC WS 11	74.0 a	59.5 bc	121.1 ab	21.3 a	294.6 a	29.2 a	66.3 ab	14.5 a	6.7 abc
IC 1-19	70.0 a	68.0 ab	120.3 ab	18.6 b	289.3 ab	28.3 a	38.8 b	9.8 cd	9.9 a
IC 2-5	84.0 a	66.5 abc	96.2 b	20.2 ab	251.3 b	29.4 a	42.5 b	7.1 d	5.3abc
A. hypogaea									
Florunner	73.7 a	59.0 bc	137.5 ab	19.5 b	294.1 a	29.5 a	70.0 a	13.7 ab	9.3 ab
Year									
1994	-	-	190.5 A	17.8 B	321.8 A	27.7 B	55.3 A	-	-
1995	-	-	74.5 B	21.5 A	248.9 B	30.6 A	55.9 A	-	-

[a]Means within a column and year followed by the same letter are not significantly different ($P \leq 0.05$) using Waller-Duncan k-ratio t-test.
[b]Percentage data transformed to arcsin $\sqrt{\%}$ for analysis.
[c]Combined analysis for data collected in 1994 and 1995 showed a significant treatment × year interaction for this variable.
[d]The higher the index, the more suitable is the line as a host.

Table 3. Evaluation of interspecific lines from the cross *Arachis hypogaea* × *A. cardensaii* for resistance to the fall armyworm in laboratory tests at Tifton, GA.[a]

Genotype	Survival 6 d	Larval wt at 10 d	Days to pupation	Pupal weight	Days to adults	Survival to adults	Host suitability index[c]
	%[b]	mg		mg		%[b]	
***A. hypogaea* ×**							
A. cardensaii							
GP-NC WS 7	73.6 a	76.9 a	18.5 c	218.1 a	26.6 b	85.0 a	8.6 a
GP-NC WS 8	67.1 a	52.5 c	19.4 ab	200.9 abc	27.3 ab	87.9 a	7.7 a
GP-NC WS 9	62.7 a	74.4 a	18.9 abc	213.2 abc	27.0 ab	75.0 a	7.7 a
GP-NC WS 10	64.4 a	70.7 ab	18.6 bc	218.4 a	26.6 b	88.9 a	8.4 a
GP-NC WS 11	72.3 a	55.2 bc	19.6 a	209.2 abc	27.5 ab	88.3 a	7.9 a
IC 1-19	62.0 a	63.8 abc	19.3 ab	196.3 c	27.3 ab	83.3 a	7.7 a
IC 2-5	71.6 a	74.3 a	18.9 abc	214.1 ab	27.2 ab	82.0 a	8.2 a
A. hypogaea							
Florunner	72.9 a	64.2 abc	19.4 ab	199.7 bc	27.7 a	86.7 a	7.5 a
Year							
1994	52.8 B	33.6 B	20.0 A	214.3 A	28.3 A	81.3 A	7.5 B
1995	75.6 A	81.5 A	18.6 B	205.6 B	26.6 B	86.3 A	8.2 A

[a]Means within a column and year followed by the same letter are not significantly different ($P \leq 0.05$) using Waller-Duncan k-ratio t-test.
[b]Percentage data transformed to arcsin $\sqrt{\%}$ for analysis.
[c]The higher the index, the more suitable is the line as a host.

Table 4. Evaluation of interspecific lines from the cross *Arachis hypogaea* × *A. cardensaii* for resistance to the velvetbean caterpillar in laboratory tests at Tifton, GA.[a]

Genotype	Survival 6 d	Larval wt at 10 d	Days to pupation	Pupal weight	Days to adults	Survival to adults	Host suitability index[c]
	%[b]	mg		mg		%[b]	
***A. hypogaea* ×**							
A. cardenasii							
GP-NC WS 7	74.3 a	82.9 a	18.1 a	207.4 ab	26.2 a	78.3 a	8.0 a
GP-NC WS 8	68.3 a	78.7 a	17.8 a	193.8 abc	25.8 a	90.0 a	7.8 a
GP-NC WS 9	67.0 a	79.6 a	18.1 a	205.6 ab	26.2 a	83.3 a	8.1 a
GP-NC WS 10	75.7 a	86.4 a	17.5 a	197.4 abc	25.6 a	88.3 a	8.3 a
GP-NC WS 11	75.0 a	81.5 a	17.7 a	212.0 a	25.7 a	83.3 a	8.8 a
IC 1-19	72.7 a	83.5 a	18.1 a	198.8 abc	26.2 a	83.3 a	7.9 a
IC 2-5	64.0 a	72.4 a	18.5 a	180.2 c	26.7 a	70.0 a	6.2 b
A. hypogaea							
Florunner	70.0 a	92.8 a	18.1 a	190.9 bc	26.4 a	80.0 a	8.2 a
Year							
1994	66.7 A	125.6 A	16.6 B	246.7 A	24.5 B	90.0 A	10.7 A
1995	73.1 A	61.3 B	18.7 A	174.0 B	27.0 A	78.8 B	6.5 B

[a]Means within a column and year followed by the same letter are not significantly different ($P \leq 0.05$) using Waller-Duncan k-ratio t-test.
[b]Percentage data transformed to arcsin $\sqrt{\%}$ for analysis.
[c]The higher the index, the more suitable is the line as a host.

percentage survival to adult emergence of all lines evaluated. The cumulative effect of these variables resulted in a significantly lower host suitability index for velvetbean caterpillar larvae that fed on leaves of IC 2-5 than for larvae that fed on leaves of Florunner. Significant differences also were noted between years for all the variables measured, but the lack of a genotype × year interaction suggested that velvetbean caterpillar larvae responded to the different peanut lines in a similar manner in both years.

A combined analysis of the thrips damage ratings showed no significant differences among interspecific lines or between years, and no genotype × year interaction (Table 5). Preliminary analyses in 1994 had shown marginally significant differences in thrips damage ratings among interspecific lines, but no significant differences were noted among lines in 1995. Also, no significant differences were noted in the number of adult, immature, or total thrips per 10 leaves collected in 1995. Similarly, Pearson correlation coefficients for the number of adult thrips (R^2 = 0.3210, P = 0.07), number of immature thrips (R^2 = 0.1832, P = 0.32), or total number of thrips (R^2 = 0.2822, P = 0.12) vs. thrips damage ratings were all nonsignificant.

Interspecific lines appeared to have high levels of resistance to potato leafhopper damage (Tables 5, 6). Potato leafhopper damage (i.e., a "V"-shaped yellowing of the tips of the leaflets) was extensive and was rated during 7 yr in North Carolina and on two separate occasions during 2 yr in Georgia. Field tests in North Carolina indicated that several interspecific lines have high levels of resistance, but not significantly greater than NC 6. A combined analysis of the four ratings in Georgia during 1994 and 1995 showed significant differences among interspecific lines that were consistent both within a year and across years. In 1994, leafhopper damage was significantly lower on all interspecific lines than on Florunner. Damage was significantly lower on GP-NC WS 7 and IC 1-19 than on all other interspecific lines. Damage ratings also were significantly lower on GP-NC WS 8 and GP-NC WS 11 than ratings on GP-NC WS 9 and GP-NC WS 10. Leafhopper damage was even more extensive in 1995, and damage ratings were significantly lower on all interspecific lines than on Florunner. As in 1994, damage was significantly lower on GP-NC WS 7 and IC 1-19 than on all other interspecific lines. Damage ratings also were significantly lower on GP-NC WS 9 and GP-NC WS 11 than on GP-NC WS 8 and GP-NC WS 10.

Evaluation of the interspecific lines for resistance to southern corn rootworm in the field showed that the interspecific lines consistently had significantly higher levels of resistance (Table 7) to this insect than NC 6, a cultivar released during the mid-1970s with resistance to this insect (Campbell *et al.*, 1977). The interspecific lines retained high levels of resistance even during years (1991, 1992) when rootworm populations were extremely high.

In summary, several accessions of *A. cardenasii* have been reported with resistance to the groundnut aphid or to the groundnut leaf miner, but susceptible to *S. litura* or *Sphenoptera indica* (Lynch and Mack 1995). Laboratory evaluations of several lines from the interspecific cross *A. hypogaea* × *A. cardenasii* against major defoliators of peanut showed variable levels of resistance to the corn earworm, no resistance to the fall armyworm, and moderate resistance to the velvetbean caterpillar as noted by a reduced host suitability index in line IC 2-5. Damage ratings to plants in the field also showed no resistance to tobacco thrips in North Carolina or Georgia (Table 6). However, resistance to the potato leafhopper was observed for all interspecific lines relative to Florunner.

Table 5. Field damage ratings for tobacco thrips and potato leafhopper on interspecific lines from the cross *Arachis hypogaea* × *A. cardensaii* at Tifton, GA.[a]

Genotype	Thrips/10 terminals		Thrips damage rating[b]	Potato leafhopper damage rating[b]	
	Adults	Immatures		1994[c]	1995[c]
	------ No. ------				
A. hypogaea* × *A. cardensaii					
GP-NC WS 7	2.0 a	5.8 a	5.0 a	3.4 d	5.3 d
GP-NC WS 8	1.8 a	12.0 a	5.3 a	4.9 c	6.2 b
GP-NC WS 9	2.3 a	12.0 a	5.8 a	5.3 b	5.7 c
GP-NC WS 10	3.8 a	14.8 a	5.5 a	5.4 b	6.2 b
GP-NC WS 11	1.0 a	7.8 a	5.0 a	4.8 c	5.6 c
IC 1-19	1.8 a	10.5 a	5.3 a	3.4 d	5.2 d
IC 2-5	2.0 a	12.0 a	5.5 a	5.0 bc	5.9 bc
A. hypogaea					
Florunner	4.0 a	5.0 a	6.0 a	6.0 a	6.8 a
Rating					
1	-	-	5.5 A	4.5 B	5.0 B
2	-	-	5.7 A	5.0 A	6.6 A

[a]Treatment means within a column followed by the same lower case letter or rating means followed by the same upper case letter are not significantly different (P ≤ 0.05) using Waller-Duncan k-ratio t-test.

[b]Damage rated on a 0 to 10 scale where 0 = no damage and 10 = extensive damage.

[c]Combined analysis for damage ratings made 19 and 31 Aug. 1994 and 11 July and 15 Aug. 1995.

Table 6. Percentage of leaves damaged by potato leafhopper for interspecific peanut lines from the cross *Arachis hypogaea* × *A. cardensaii* in field evaluations at Lewiston, NC.

Genotype	Leaf damage[a]							
	1981	1982	1991	1992	1993	1994	1995	Mean
	%							
A. hypogaea* × *A. cardenasii								
GP-NC WS 7	15.0 b-e	21.7 gh	0.0 gh	4.0 f	1.0 hi	0.2 e	15.0 bcd	7.0
GP-NC WS 8	18.0 bcd	29.0 e-g	0.9 e-h	32.0 bc	7.0 c-f	0.0 e	0.0 d	14.5
GP-NC WS 9	11.7 cde	31.7 def	0.8 e-h	25.0 cd	6.0 d-h	0.0 e	0.0 d	12.5
GP-NC WS 10	13.3 b-e	37.3 b	1.4 d-h	23.0 cde	4.0 e-i	2.0 de	0.0 d	13.5
GP-NC WS 11	4.0 def	24.0 fgh	0.1 gh	10.0 def	0.0 i	1.0 de	10.0 bcd	5.5
IC 1-2	9.7 cde	28.3 e-g	0.9 e-h	8.0 ef	3.0 f-i	0.0 e	5.0 cd	8.3
IC 1-11	1.7 ef	22.7 gh	1.7 ab	11.0 def	6.0 c-g	2.0 de	30.0 ab	12.5
IC 1-19	14.7 b-e	14.0 h	1.3 d-h	31.8 bc	7.0 c-g	1.2 de	0.0 d	11.7
IC 1-30	4.7 def	16.7 h	0.4 fgh	23.0 cd	17.0 b	10.0 bc	10.0 bcd	13.6
IC 2-2	37.3 ab	46.7 b	4.7 c	60.0 a	16.0 b	9.0 bcd	20.0 abc	32.3
IC 2-5	11.7 cde	36.7 cde	1.3 d-h	35.0 bc	5.0 e-h	3.0 cde	5.0 cd	16.3
IC 2-12	30.0 abc	58.3 a	4.4 cd	39.0 bc	3.4 f-i	2.0 de	10.0 bcd	24.5
IC 2-13	28.7 bc	42.3 bc	8.8 b	58.0 a	11.0 bcd	6.0 b-e	35.0 ab	31.6
IC 2-36	15.0 cde	31.0 d-g	1.4 d-h	30.0 bc	7.0 c-g	1.0 de	0.0 d	14.2
A. hypogaea								
Florigiant	3.3 def	46.0 b	0.9 e-h	17.0 cde	13.0 bc	0.0 e	55.0 a	22.5
NC 6	3.3 def	17.3 h	1.4 e-h	23.0 cde	2.0 ghi	1.0 de	0.0 d	8.0
NC Ac 343	--	17.3 h	0.0 h	30.0 bc	5.0 e-h	0.2 e	25.0 a-d	15.5
Parent								
GKP 10017[b]	0.0 f	--	2.2 c-f	3.0 f	0.0 i	0.0 e	0.0 d	0.9
PI 261942[b]	53.3 a	--	18.2 a	48.0 ab	66.0 a	31.0 a	40.0 ab	42.8

[a]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$. Means are actual percentages, but analyses were conducted on transformed data.

[b]GKP 10017 = *A. cardenasii*; PI 261942 = *A. hypogaea* subs. *fastigata* var. *fastigata*.

Resistance to the potato leafhopper was highest in GP-NC WS 7 and IC 1-19, and resistance was evident even under extremely high infestations. The level of resistance to the potato leafhopper in GP-NC WS 7 and IC 1-19 should be utilized in plant breeding programs. In addition, very high levels of resistance to southern corn rootworm were observed in many interspecific lines. The use of insect resistance genes derived from *A. cardenasii* should prove useful when introgressed with *A. hypogaea* for development into cultivars.

Acknowledgments

The technical assistance of Lloyd Copeland and Ernest Harris is gratefully appreciated.

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Table 7. Percentage of pods damaged by southern corn rootworm for interspecific peanut lines from the cross *Arachis hypogaea* × *A. cardensaii* in field evaluations at Lewiston, NC.

Genotype	Pod damage[a]						
	1981	1982	1991	1992	1993	1995	Mean
	%						
A. hypogaea* × *A. cardenasii							
GP-NC WS 7	2.3 cd	18.7 bcd	6.4 d-g	4.6 i	4.0 f	15.0 ab	8.5
GP-NC WS 8	2.0 d	6.0 cd	7.8 d-g	10.6 ghi	9.0 def	15.0 ab	8.4
GP-NC WS 9	2.0 d	8.3 cd	10.0 def	5.6 i	16.0 a-d	15.0 ab	10.5
GP-NC WS 10	3.0 cd	14.7 bcd	4.8 f-g	4.8 i	14.0 b-e	15.0 ab	9.4
GP-NC WS 11	2.0 d	6.7 cd	6.2 d-g	6.6 hi	6.0 ef	17.5 ab	7.5
IC 1-2	2.7 cd	12.0 bcd	6.0 d-g	13.8 f-i	12.0 c-f	5.0 ab	8.6
IC 1-11	2.0 d	22.0 ac	9.4 d-g	14.4 f-i	11.0 c-f	7.5 ab	11.1
IC 1-30	2.0 d	7.0 cd	6.0 d-g	28.2 d-g	15.0 a-d	10.0 ab	11.4
IC 1-19	3.0 cd	18.7 bcd	8.2 d-g	10.8 ghi	10.0 c-f	20.0 ab	11.8
IC 2-2	2.0 d	14.0 bcd	12.2 de	38.4 cde	16.0 a-d	0.0 b	13.8
IC 2-5	5.3 cd	2.7 d	3.4 g	13.2 e-i	17.0 a-d	0.0 b	6.9
IC 2-12	5.0 cd	28.3 abc	8.0 d-g	4.4 i	9.0 def	35.0 ab	15.0
IC 2-13	4.0 cd	12.7 bcd	10.0 d-g	14.4 e-i	17.0 a-d	7.5 ab	11.9
IC 2-36	2.7 cd	20.7 a-d	5.2 e-g	17.2 e-i	16.0 a-d	7.5 ab	11.6
A. hypogaea							
Florigiant	49.0 a	38.3 a	85.6 a	78.6 a	27.0 a	30.0 ab	51.4
NC 6	15.7 b	9.3 cd	51.6 b	56.8 abc	10.0 c-f	25.0 ab	28.1
NC Ac 343	--	13.0 bcd	36.4 c	62.0 ab	11.0 cde	30.0 ab	30.5
Parent[b]							
PI 261942	8.0 bc	--	12.8 d	37.4 bcd	25.0 a	45.0 a	25.6

[a]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$. Means are actual percentages, but analyses were conducted on $\sqrt{\%}$ transformed data.

[b]*A. cardenasii* (GKP 10017) was not evaluated because pods could not be recovered in the field.

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Accepted 6 Aug. 1997