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RESISTANCE IN PEANUT TO MAJOR ARTHROPOD PESTS

ROBERT E. LYNCH
Insect Biology and Population Management Research Laboratory
U. S. Department of Agriculture, Agricultural Research Service
Tifton, GA 31793-0748

ABSTRACT

Resistance of peanut, *Arachis hypogaea* L., and wild species of *Arachis*, to many major arthropod pests has been identified in the United States. Plant resistance has been confirmed to the following species: thrips - *Frankliniella schultzei* (Trybom) and *F. fusca* (Hinds); the groundnut aphid, *Aphis craccivora* Koch; leafhoppers - *Empoasca kerri* Pruthi and *E. fabae* (Harris); lepidopterous defoliators - *Heliothis zea* (Boddie), *Spodoptera frugiperda* (J. E. Smith), and *S. litura* (F.); groundnut leaf miner, *Aproaerema modicella* (Deventer); southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber; lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller); the twospotted spider mite, *Tetranychus urticae* Koch; and podborers such as termites of the genus *Odontotermes*, millipedes of the genus *Peridontopyge* and white grubs, *Eulepida mashona* Arrow. Several peanut cultivars are resistant to multiple pests. Many of the resistant genotypes of *A. hypogaea* are readily available for breeding and development into commercial cultivars. Related diploid species of the section Arachis are cross-compatible with the tetraploid *A. hypogaea* and offer the greatest potential for increasing cultivated peanut resistance to pests. Cooperative research among institutes, research organizations, and countries is needed to evaluate the known sources of resistance for cross-resistance to related species of insects.

RESUMEN

Se ha identificado resistencia en el maní, *Arachis hipogaea* L., y en especies salvajes de *Arachis*, a plagas importantes de artrópodos en los Estados Unidos. Se ha confirmado resistancia a las siguientes especies: tris—*Frankliniella schultzei* (Trybom) y *F. fusca* (Hinds); áfidos—*Aphis craccivora* Koch; saltahojas—*Empoasca kerri* Pruthi y *E. fabae* (Harria); defoliadores lepidópteros—*Heliothis zea* (Boddie), *Spodoptera frugiperda* (J. E. Smith), y *S. litura* (F.); minador—*Aproaerema modicella* (Deventer); *Diabrotica undecimpunctata howardi* Barber; *Elasmopalpus lignosellus* (Zeller); *Tetranychus urticae* Koch; *Odontotermes*; *Peridontopyge* y *Eulepida mashona* Arrow. Varias variedades de maní son resistentes a varias plagas. Muchos de los genotipos resistentes de *A. hypogaea* están disponibles para fitomejoramiento y para desarrollar como variedades comerciales. Especies de diploides relacionadas con la sección de *Arachis* son compatibles en cruces con el tetraploide *A. hypogaea* y ofrecen el mayor potencial para aumentar la resistencia a plagas del mani cultivado. Se necesita cooperar en investigaciones entre institutos, organizaciones de investigación, y entre naciones, para evaluar las fuentes conocidas de resistencia para ver si hay resistencia a otras especies afines de insectos.

The cultivated peanut, *Arachis hypogaea* L., originated in South America along the eastern Andes (Hammons 1982). The genus *Arachis* is composed of 32 identified species (Smartt and Stalker 1982) in six sections with an estimated 40 species yet to be identified (Gibbons 1987). Early explorers disseminated the peanut to Europe, Africa, Asia, and the Pacific Islands, and eventually to the southeastern United States.

Currently, commercial production of peanut is limited to *A. hypogaea* and its botanical types, *A. hypogaea* subspecies *hypogaea* variety *hypogaea* (runner and virginia

market types), *A. hypogaea* subspecies *fastigiata* variety *fastigiata* (valencia market type) and variety *vulgaris* (spanish market type) (Norden et al. 1982). The U.S. ranks third behind China and India in world peanut production. Production in the U.S. is confined to three major areas, the Virginia-Carolina area, the southeast (Alabama, Florida, Georgia), and the southwest (Oklahoma, New Mexico, Texas). The Virginia-Carolina area primarily produces the virginia market type, the southwest area produces spanish, valencia, and runner market types, and the southeast area produces the runner market type. Over 70% of the total U.S. production is the runner market type, ca. 19% is virginia market type, and ca. 9% is the spanish market type. One variety, 'Florunner', accounts for 53.6% of the total U.S. peanut production and 74.3% of the production in the southeast (Holbrook & Kvien 1989). Annually, ca. 635,850 ha (1,570,000 acres) in the U.S. are planted to peanut, with an average yield and value of ca. 2688 kg/ha (2,400 lbs/acre) and over $1 billion, respectively (USDA 1988). Approximately 62.3% of the peanut crop is produced in the southeast, while ca. 19.2% is produced in the southwest and 17.5% is produced in the Virginia-Carolina area. Georgia is the leading state in peanut production, accounting for 40-45% of the annual U.S. production.

Peanut is unusual in that the plant flowers above ground while the fertilized ovule elongates, penetrates the soil, and produces fruit below the surface of the soil. Insects and related arthropods have exploited every niche on this unusual plant. Over 400 species of arthropods have been reported as pests of preharvest peanut (Smith & Barfield 1982) and an additional 80+ species as pests of postharvest peanut (Redlinger & Davis 1982). Insects that feed on peanut are intracellular feeders (e.g., aphids and leafhoppers), intercellular feeders (thrips); defoliators (e.g., lepidopterous larvae); root, peg, or pod feeders (e.g., termites, millipedes, earwigs, ants, coleopterous and lepidopterous larvae); and transmitters of viruses (e.g., aphids - groundnut rosette and peanut stripe virus; thrips - tomato spotted wilt virus and peanut yellow spot virus).

Recent reviews by Amin & Mohammad (1980), Womack et al. (1981), Wightman (1985), Lynch et al. (1986), Wightman et al. (1987), and Wightman & Amin (1988) have identified the major peanut pests in the U.S., Asia, and Africa (Table 1). In all three areas, similar groups of insects have exploited peanut as a host and, under certain conditions, produce economic losses. In Africa and Asia, the importance of insects may be ranked as follows: 1) termites, 2) white grubs, 3) thrips as a vector of bud necrosis virus (tomato spotted wilt virus), 4) leafhoppers, 5) *A. craccivora* as a vector of groundnut rosette, 6) lepidopterous defoliators. In addition, the groundnut hopper, *Hilda patruelis* Stal., millipedes, *Peridontopyge* spp., a subterranean ant, *Dorylus orientalis* Westwood, would be ranked among the top pests in Southern Africa, West Africa, and Southeast Asia, respectively.

In the U.S., major insect pests vary considerably among years and locations. Soil pests, especially the wireworm, *Conoderus scissus* Schaffer, in the southeast, are becoming an increasing problem. In most years tobacco thrips (*Frankliniella fusca* Hinds), potato leafhopper (*Empoasca fabae* [Harris]) corn earworm (*Heliothis zea* [Boddie]), southern corn rootworm (*Diabrotica undecimpunctata howardi* Barber), lesser cornstalk borer (*Elasmopalpus lignosellus* [Zeller]), and the twospotted spider mite (*Tetranychus urticae* Koch) are among the major pests. The tobacco thrips and the western flower thrips (*F. occidentalis* [Pergande]), as vectors of tomato spotted wilt virus, may take on additional importance since the incidence of the disease increased dramatically in Georgia in 1989 (personal communication, J. W. Todd, Dept. of Entomology, Georgia Coastal Plain Experiment Station, Tifton, GA).

Plant resistance in peanut to insect pests offers a tremendous potential to alleviate production losses, especially in the developing countries and for insects that transmit virus diseases. Over the past 10 years, research on peanut resistance to insects has increased substantially. Major programs have been initiated by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in India by North Carolina

TABLE 1. MAJOR ARTHROPOD PESTS OF PEANUT.[1]

Feeding site	Insect species		
	U.S.	Asia	Africa
Foliage	*Frankliniella fusca* (Hinds)	*Frankliniella schultzei* (Trybom)	*Aphis craccivora* Koch
	Empoasca fabae (Harris)	*Scirtothrips dorsalis* (Hood)	*Empoasca facialis* Jacobi
	Heloithis zea (Boddie)	*Caliothrips indicus* Bagnall	*Empoasca dolichi* Paoli
	Spodoptera frugiperda (J. E. Smith)	*Spodoptera litura* (F).	trips (several species)
	Feltia subterranea (F.)	*Empoasca kerri* Pruthi	*Heliothis armigera* (Hübner)
	Anticarsia gemmatalis (Hübner)	*Heliothis armigera* (Hübner)	*Spodoptera littoralis* (Boisduval)
		Aproaerema modicella (Deventer)	
	Tetranychus urticae Koch	*Aphis craccivora* Koch	
		Amsacta spp.	
Root, peg, or pod	*Diabrotica undecimpunctata howardi* Barber	*Odontotermes* sp.	*Microtermes thoracalis* Sjostedt
		Microtermes sp.	*Hilda patruelis* Stal.
	Elasmopalpus lignosellus (Zeller)	*Lachnosterna consanguinea* (Blanchard)	*Caryedon serratus* (Ol.)
	Conoderus sissus Shaeffer	*Anisolabis stali* (Lucas)	*Eulipida mashona* Arrow
		Dorylus orientalis Westwood	*Peridontopyge* sp.
			Elasmolomus sordidus (F.)

[1]Modified after Amin and Mohammad (1980), Wightman (1985), Lynch et al. (1986), and Wightman et al. (1987).

State University and by the USDA Insect Biology and Population Management Research Laboratory and Department of Entomology, Coastal Plain Experiment Station, Tifton, GA. Germplasm for evaluation is readily available through the Genetic Resources Unit, ICRISAT, where a collection of over 11,500 peanut lines is maintained, and at the USDA Southern Regional Plant Introduction Station, Griffin, GA, where a collection of ca. 8,000 peanut lines is maintained.

Techniques for evaluating peanut germplasm for insect resistance have been described by Amin (1985a). Most evaluations have been conducted in the field with natural insect populations or in a greenhouse using laboratory-reared insects. Several techniques have been employed to enhance or augment field infestations. Populations of *Empoasca kerri* Pruthi were increased by planting one row of cowpea, *Vigna unguiculata* (L.) Walt., a preferred host of the leafhopper, alternately with every four rows of groundnut and the cowpeas infested with laboratory-reared *E. kerri*; cowpea plants were later uprooted and the plants distributed evenly in the field to facilitate transfer of leafhoppers to peanut (Amin et al. 1985). Termite populations were increased in a field by spreading sawdust over the field during the dry season and uniformly releasing winged adults captured from light traps (Amin et al. 1985). Peanut plants have

been artificially infested in the field with corn earworm eggs, neonate fall armyworm larvae, or neonate lesser cornstalk borer larvae mixed with corncob grits or vermiculite and applied with a mechanical infestation device (Wiseman et al. 1980). Twospotted spider mites have been maintained in the greenhouse on lima bean plants from which infested leaves were used to artificially infest peanut (Campbell & Wynne 1980). Screening for thrips and groundnut leafminer has been conducted with natural field infestations, and screening for aphid resistance has been conducted in greenhouses.

Thrips on peanut feed primarily in developing terminals by rasping the developing tissue, which causes scarring and distortion of the leaflets as they emerge (Bass & Arant 1973). Extensive feeding by thrips can result in necrosis and death of individual terminals. Extensive research has been conducted on peanut resistance to thrips, primarily *F. fusca* in the U.S. and *F. schultzei* in India. In the U.S., thrips are early season pests of questionable economic impact (Tappan & Gorbet 1979, 1981, Lynch et al. 1984). In India, thrips have been shown to produce economic yield loss (Senapathi & Patnaik 1973). However, their ability to transmit viral diseases, especially the tomato spotted wilt virus, drastically increases their importance to peanut production (Amin & Mohammad 1980). Peanut resistance to thrips has been identified in numerous plant introductions, wild species, and breeding lines (Table 2). Both antibiosis and nonpreference have been reported as resistance mechanisms in peanut (Kinzer et al. 1972, Amin & Mohammad 1980, 1982). Antibiosis results in both reduced larval survival and reduced fecundity of adults when reared as larvae on peanut (Amin & Mohammad 1980, 1982, Amin 1985b). Resistance approaching immunity has been identified among wild species of *Arachis*; no thrips damage was found among 17 accessions of the wild species during 3 yrs of evaluation (Stalker & Campbell 1983). Resistance to tomato spotted wilt virus has not been found in *A. hypogaea*. However, several *A. hypogaea* genotypes consistently show a low field incidence of tomato spotted wilt virus due to nonpreference of thrips for these cultivars (Amin 1985c, 1987). Conversely, *A. chacoense* has shown resistance to both the virus and its vector (Wightman 1985).

Leafhopper adults and nymphs feed on the lower surface of peanut leaves by inserting their stylets into the midrib or vein to inject saliva and withdraw plant fluids (Bass & Arant 1973, Womack et al. 1981). Their feeding causes leaflets to turn yellow from the point of feeding to the apical end. These symptoms are commonly referred to as "hopperburn" in peanut. Research to identify sources of resistance to *E. fabae* in the U.S. and *E. kerri* in India has been extensive (Table 3). Excellent sources of resistance to both species of leafhoppers have been found in *A. hypogaea* from the North Carolina accessions (Campbell & Wynne 1980, Campbell et al. 1971, 1975, 1976, Amin & Mohammad 1980, Amin et al. 1985). Stalker & Campbell (1983) reported immunity to damage by leafhoppers among 21 accessions of wild species of *Arachis*.

Campbell et al. (1976) reported that the resistance to leafhoppers in the North Carolina peanut lines was associated with their thick epidermis, long trichomes on the lower epidermis, and a higher percentage of straight trichomes; more susceptible lines had either trichomes that curved inward or an appressed surface texture on their leaves. Nonadditive genetic variance has been reported for peanut trichome characters in general, while additive variance has been found for long trichomes on the midrib and petioles (feeding sites of the leafhopper), and for leafhopper damage (Dwivedi et al. 1986). Antibiosis expressed as reduced fecundity for leafhoppers feeding on the resistant genotypes may also be present in both cultivated and wild peanut genotypes (Campbell & Wynne 1980, Amin & Mohammad 1982, Amin & Singh 1983, Amin 1985b). Resistance to "yellowing," i.e., the damage symptoms, has been reported for several peanut lines with moderate resistance to leafhoppers (Amin et al. 1985). These lines supported intermediate populations of leafhoppers but did not show damage symptoms that other lines with similar populations of leafhoppers showed.

TABLE 2. PEANUT LINES REPORTED RESISTANT TO DAMAGE BY *FRANKLINIELLA* THRIPS.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	F. fusca	Reference	*F. schultzei*	Reference
A. hypogaea	PI 179843	Leuck e al. 1969b	NC Ac 343	Amin et al. 1985
	PI 221708	Kinzer et al. 1972	NC Ac 1705	Amin et al. 1985
	PI 240567	Leuck et al. 1968	NC Ac 1741	Amin et al. 1985
	PI 244602	Leuck et al. 1968	NC Ac 2142	Amin et al. 1985
	PI 259594	Young et al. 1972	NC Ac 2144	Amin et al. 1985
	PI 263391	Leuck et al. 1968	NC Ac 2154	Amin et al. 1985
	PI 266257	Leuck et al. 1969b	NC Ac 2214	Amin and Mohammad 1980
	PI 268649	Kinzer et al. 1972		Amin et al. 1985
	PI 268678	Kinzer et al. 1972	NC Ac 2230	Amin et al. 1985
	PI 268706	Kinzer et al. 1972	NC Ac 2232	Amin and Mohammad 1980
	PI 268734	Kinzer et al. 1972		Amin et al. 1985
	PI 268767	Kinzer et al. 1972	NC Ac 2240	Amin et al. 1985
	PI 268769	Kinzer et al. 1972	NC Ac 2242	Amin et al. 1985
	PI 268770	Young et al. 1972	NC Ac 2243	Amin and Mohammad 1980
	PI 268771	Young et al. 1972		Amin et al. 1985
	PI 268804	Kinzer et al. 1972	NC Ac 2460	Amin et al. 1985
		Young et al. 1972	NC Ac 2462	Amin et al. 1985
	PI 269710	Leuck et al. 1968	NC Ac 7481	Amin et al. 1985
	PI 280688	Kinzer et al. 1972		
		Young et al. 1972		
	PI 288149	Leuck et al. 1968		
	PI 290599	Young et al. 1972		
	PI 292948	Leuck et al. 1969a		
	PI 306233	Young et al. 1972		
	PI 313187	Leuck et al. 1969a,b		
	PI 319177	Leuck et al. 1969b		
	PI 319772	Leuck et al. 1969b		
	PI 366048	Lynch (unpubl. data)		

	PI 445947	Lynch (unpubl. data)		
	PI 445948	Lynch (unpubl. data)		
	PI 445949	Lynch (unpubl. data)		
	PI 445950	Lynch (unpubl. data)		
	PI 445951	Lynch (unpubl. data)		
	PI 445953	Lynch (unpubl. data)		
	PI 445958	Lynch (unpubl. data)		
	NC-6	Campbell & Wynne 1980		
	NC 4144	Leuck et al. 1968		
	NC 10247	Lynch (unpubl. data)		
	NC 10450	Leuck et al. 1969b		
	NC 10464	Leuck et al. 1969b		
	NC 15729	Lynch (unpubl. data)		
	NC Ac 9082	Leuck et al. 1968		
	NC-GP 342	Campbell & Wynne 1980		
	NC-GP 343	Campbell & Wynne 1980		
	GFA Spanish	Leuck et al. 1968		
	SH-62-9	Leuck et al. 1969b		
	Spanette	Leuck et al. 1968		
	Spanish 18-38	Leuck et al. 1968		
	Starr	Leuck et al. 1969a		
	T 1148	Leuck et al. 1969b		
	T 1939	Leuck et al. 1969b		
	Tifton 8	Coffelt et al. 1985		
		Leuck et al. 1969b		
	Tifton B-11	Leuck et al. 1968		
A. sp.	PI 262278	Stalker & Campbell 1983	PI 10596	Amin 1985
	PI 262286	Stalker & Campbell 1983		
	PI 262287	Stalker & Campbell 1983		
	PI 262306	Stalker & Campbell 1983		
	PI 262793	Stalker & Campbell 1983		
	PI 262794	Stalker & Campbell 1983		
	PI 262797	Stalker & Campbell 1983		
	PI 262798	Stalker & Campbell 1983		
	PI 262828	Stalker & Campbell 1983		

TABLE 2. (Continued)

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	F. fusca	Reference	*F. schultzei*	Reference
	PI 262848	Stalker & Campbell 1983		
	PI 276203/ 276309	Stalker & Campbell 1983		
	PI 276223	Stalker & Campbell 1983		
	PI 276225	Stalker & Campbell 1983		
	PI 276228	Stalker & Campbell 1983		
	PI 276233	Campbell & Wynne 1980 Stalker & Campbell 1983		
	PI 338265	Stalker & Campbell 1983		
	PI 338267	Stalker & Campbell 1983		
	PI 338305	Stalker & Campbell 1983		
	PI 338320	Stalker & Campbell 1983		
A. sp.	PI 338452	Stalker & Campbell 1983		
	PI 338454	Stalker & Campbell 1983		
	10002 GKP	Stalker & Campbell 1983		
	1960 #100	Stalker & Campbell 1983		
A. batizocoi	PI 298639	Campbell & Wynne 1980		
A. chacoense	PI 276235	Stalker & Campbell 1983	—[1]	Amin & Mohammad 1980 Amin 1985
A. correntina	PI 262808	Stalker & Campbell 1983		
A. duranensis	PI 219833	Stalker & Campbell 1983	—[1]	Amin & Mohammad 1980
A. glabrata	PI 262797	Campbell & Wynne 1980	—	Amin & Mohammad 1980
A. macedoi	PI 276203	Campbell & Wynne 1980		
A. monticola	PI 219824	Leuck et al. 1968 Campbell & Wynne 1980 Lynch (unpubl. data)		
A. paraguariensis	11488 (KC)	Stalker & Campbell 1983		
A. pusilla	PI 338449	Stalker & Campbell 1983		

A. rigonii	PI 262142	Stalker & Campbell 1983
A. repens	PI 276199	Stalker & Campbell 1983
A. stenosperma	PI 338279	Campbell & Wynne 1980 Stalker & Campbell 1983
	PI 338280	Stalker & Campbell 1983
A. villosa	PI 331196	Campbell & Wynne 1980
A. villosa-correntina	Manfredi #5	Stalker & Campbell 1983
A. villosa-correntina	*Manfredi* #6	Stalker & Campbell 1983
A. villosulicarpa	PI 263396	Leuck et al. 1968

[1]Also resistant to *Scirtothrips dorsalis* (Amin 1985).

TABLE 3. PEANUT LINES REPORTED RESISTANT TO DAMAGE BY *EMPOASCA* LEAFHOPPERS.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	E. fabae	Reference	*E. kerri*	Reference
A. hypogaea	PI 234423	Lynch (unpubl.data)	NC Ac 343	Amin & Mohammad 1980
	PI 269691	Lynch (unpubl. data)		Amin et al. 1985
	PI 383421	Lynch (unpubl. data)	NC Ac 406	Amin & Mohammad 1980
	NC 6	Campbell & Wynne 1980		Amin et al. 1985
		Stalker & Campbell 1983		
		Lynch (unpubl. data)	NC Ac 489	Amin & Mohammad 1980
				Amin et al. 1985
	NC Ac 343	Campbell et al. 1976	NC Ac 785	Amin et al. 1985
		Campbell & Wynne 1980	NC Ac 1337	Amin et al. 1985
	NC Ac 10207	Campbell et al. 1976	NC Ac 1705	Amin et al. 1985
		Campbell & Wynne 1980	NC Ac 1741	Amin et al. 1985
	NC Ac 10211	Campbell et al. 1976	NC Ac 2142	Amin et al. 1985
		Campbell & Wynne 1980	NC Ac 2144	Amin & Mohammad 1980
	NC Ac 10247	Campbell et al. 1975, 1976	NC Ac 2214	Amin & Mohammad 1980
		Campbell & Wynne 1980		Amin et al. 1985
	NC Ac 10272	Campbell et al. 1975, 1976	NC Ac 2230	Amin et al. 1985
		Campbell & Wynne 1980	NC Ac 2232	Amin & Mohammad 1980
		Lynch (unpubl. data)		Amin et al. 1985
	NC Ac 10277	Campbell et al. 1976	NC Ac 2240	Amin & Mohammad 1980
		Campbell & Wynne 1980		Amin et al 1985
	NC Ac 15729	Campbell et al. 1975, 1976	NC Ac 2242	Amin & Mohammad 1980
		Campbell & Wynne 1980		Amin et al. 1985
	NC Ac 15730	Campbell et al. 1976	Nc Ac 2243	Amin & Mohammad 1980
		Campbell & Wynne 1980		Amin et al. 1985
	NC Ac 15736	Campbell et al. 1976	NC Ac 2462	Amin & Mohammad 1980
	NC Ac 15739	Campbell et al. 1976	NC Ac 2477	Amin et al. 1985
	NC Ac 15744	Campbell et al. 1976	NC Ac 2663	Amin & Mohammad 1980

	Campbell & Wynne 1980	
NC Ac 15745	Campbell et al. 1975, 1976	
	Campbell & Wynne 1980	
PI 262278	Stalker & Campbell 1983	
PI 262286	Stalker & Campbell 1983	
PI 262287	Stalker & Campbell 1983	
PI 262306	Stalker & Campbell 1983	
PI 262793	Stalker & Campbell 1983	
PI 262794	Stalker & Campbell 1983	
PI 262797	Stalker & Campbell 1983	
PI 262798	Stalker & Campbell 1983	
PI 262828	Stalker & Campbell 1983	
PI 262848	Stalker & Campbell 1983	
PI 276203/ 276309	Stalker & Campbell 1983	
PI 276223	Stalker & Campbell 1983	
PI 276225	Stalker & Campbell 1983	
PI 276228	Stalker & Campbell 1983	
PI 276233	Campbell & Wynne 1980	
	Stalker & Campbell 1983	
PI 338265	Stalker & Campbell 1983	
PI 338267	Stalker & Campbell 1983	
PI 338305	Stalker & Campbell 1983	
PI 338452	Stalker & Campbell 1983	
PI 338454	Stalker & Campbell 1983	
1960 #100	Stalker & Campbell 1983	
10002 GKP	Stalker & Campbell 1983	
PI 298639	Campbell & Wynne 1980	
PI 276235	Stalker & Campbell 1983	
PI 262808	Stalker & Campbell 1983	
—	Stalker & Campbell 1983	

NC Ac 2666	Amin et al. 1985	
NC Ac 2700	Amin et al. 1985	
NC Ac 2888	Amin & Mohammad 1980	
NC Ac 17888	Amin et al. 1985	
Gujarat narrow leaf mutant	Amin et al. 1985	

A. batizocoi
A. chacoense
A. correntina

TABLE 3. (Continued)

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	E. fabaea	Reference	*E. Kerri*	Reference
A. duranensis	PI 219833	Stalker & Campbell 1983		
A. glabrata	PI 262797	Campbell & Wynne 1980		
A. macedoi	PI 276203	Campbell & Wynne 1980		
A. monticola	PI 219824	Leuck et al. 1968		
		Campbell & Wynne 1980		
		Lynch (Unpubl. data)		
A. paraguariensis	11488 (KC)	Stalker & Campbell 1983		
A. pusilla	PI 338449	Stalker & Campbell 1983		
A. rigonii	PI 262142	Stalker & Campbell 1983		
A. repens	PI 276199	Stalker & Campbell 1983		
A. stenosperma	PI 338279	Campbell & Wynne 1980		
		Stalker & Campbell 1983		
	PI 338280	Stalker & Campbell 1983		
A. villosa	PI 331196	Campbell & Wynne 1980		
A. villosa-correntina	Manfredi #5	Stalker & Campbell 1983		
A. villosa-correntina	Manfredi #6	Stalker & Campbell 1983		

The groundnut aphid, *A. craccivora*, is an important vector of viral diseases to peanut. Seven viral diseases are known to be transmitted to peanut by aphids, but *A. craccivora* is the only aphid that is known to transmit all seven viruses (Wightman 1985). *A. craccivora* and the rosette virus were the major causes of the epidemic that reduced peanut yield in West Africa by almost 75% in 1975 (Gibbons 1977). Research with cultivars of *A. hypogaea* to identify resistance to groundnut aphid has not been very successful (Table 4). Only two genotypes, ICG 5240 and EC 36892, have been identified as highly resistant to *A. craccivora* in the field (Bock, Amin, Wightman, unpublished) and are being used in breeding programs for Africa. However, a high level of resistance to the groundnut aphid that approaches immunity has been identified in *A. chacoense, A. glabrata, A. marginata* amd the interspecific hybrid *A. chaconese x A. villosa* (Amin & Mohammad 1982, Amin 1985b). Germplasm with resistance to infection by the rosette virus has been identified (Table 4) and is being used extensively in breeding programs for Africa. Resistance to rosette in peanut is recessive and governed by two genes (Nigam 1987).

The most common defoliators of peanut, worldwide, are *Heliothis* and *Spodoptera* species (Smith & Barfield 1982). Neonates of these defoliators initially feed in terminals or, in the case of *Heliothis*, flowers. Later stage larvae feed openly on the plant but still show a decided preference for terminals and newly expanded leaflets (Garner & Lynch 1981). Moderate levels of resistance to *H. zea* have been identified in the cultivated species of *A. hypogaea* (Table 5). Hammons (1970a) noted resistance to damage by leaf-chewing insects, presumably *H. zea* and/or *S. frugiperda*, in 'Spancross'. Campbell et al. (1982) reported that peanut introductions from South America are susceptible to defoliation by *Heliothis*; PI 269062 from China is resistant, and the sister lines NC-GP 343 and NC Ac 342, and NC-6, a progeny of NC 343 x Va-61 R, are moderately resistant to defoliation by *Heliothis*. Resistance to *H. zea* approaching immunity was reported among the wild species of *Arachis*; 20 accessions had less than 2% damage compared with 38% for 'Florigiant', the susceptible check.

The mechanisms of resistance to *H. zea* include nonpreference and antibiosis (Campbell & Wynne 1980, Campbell et al. 1982, Stalker & Campbell 1983, Holley et al. 1984). Holley et al. (1984) reported that a flavone glucoside in peanut leaves is probably responsible for antibiosis against *H. zea* larvae. They also reported that results from laboratory assays in which *H. zea* larvae were fed foliage of NC-6 x 'Florigiant' are inconsistent and could not be used in lieu of results from field evaluations. However, laboratory assays with wild species resulted in 100% mortality of *Heliothis* larvae fed *Arachis* sp. (Coll. No. 10596C) and *A. batizocoi* (Stalker & Campbell 1983). Furthermore, progeny of interspecific hybrids *A. hyogaea x A. cardenasii, A. hyogaea x A. duranensis*, and *A. hypogaea x (A. batizocoi x A. spegazzinii)* showed potential as sources of resistance to the corn earworm and the potato leafhopper.

Much less research has been conducted to identify peanut resistance to *Spodoptera* in peanut (Table 5). Hammons (1970b) noted resistance to damage by the fall armyworm, *S. frugiperda*, in 'Southeastern Runner 56-15' (SER 56-15). Leuck & Skinner (1971) found reduced survival and increased generation time for *S. frugiperda* larvae reared on SER 56-15 compared with larvae reared on 'Starr'. Similarly, reduced survival and weight gain for *S. litura* larvae fed foliage of C-501 were observed (Tiwari et al. 1980). Lynch et al. (1981) evaluated 14 species of Arachis for resistance to the fall armyworm and reported reduced survival and leaf consumption, increased time for development, and differences in accession preference by larvae. Using a host suitability index, *A. hypogaea* cv. 'Florunner', *A. monticola, A. stenosperma*, and *A. batizogaea* were the most suitable hosts for larvae of the fall armyworm, while *A. repens, A. glabrata cv. 'Florigraze', A. chacoense, A. villosulicarpa, A. correntina, A. lignosa, A. cardenasii, A. burkartii*, and *A. villosa* were the least suitable hosts; no larvae survived on *A.*

TABLE 4. PEANUT LINES REPORTED RESISTANT TO DAMAGE BY *APHIS CRACCIVORA* OR ROSETTE.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	A. craccivora	Reference	*Rosette*	Reference
A. hypogaea	NC Ac 2214 (7)	Amin & Mohammad 1980	KH-149 A	Bockelee-Morvan 1983
	NC Ac 2214 (8)	Amin & Mohammad 1980	KH-241 D	Bockelee-Morvan 1983
	ICG 5240	Amin (unpubl.)	RMP 12*	Bockelee-Morvan 1983
	EC 36892	Bock, Amin, Wightman (unpubl.)	RMP 91*	Bockelee-Morvan 1983
			RG 1	Nigam 1987
			RGI/6	Nigam 1987
			69-101	Bockelee-Morvan 1983
A. sp.	PI 10596	Amin & Mohammad 1982		
		Amin 1985b		
	PI 276233	Amin & Mohammad 1982		
A. chacoense	—	Amin & Mohammad 1980, 1982		
		Amin 1985b		
A. chacoense x *A. cardenasii*	—	Amin & Mohammad 1982		
A. chacoense x *A. villosa*	—	Amin 1985b		
A. correntina	—	Amin & Mohammad 1982		
		Amin 1985b		
A. duranensis	—	Amin & Mohammad 1982		
		Amin 1985b		
A. glabrata	—	Amin & Mohammad 1982		
		Amin 1985b		
A. marginata	—	Amin & Mohammad 1982		
A. repens	—	Amin 1985b		
A. villosa	—	Amin 1985b		

*Highly resistant.

TABLE 5. PEANUT LINES REPORTED RESISTANT TO DAMAGE BY *HELIOTHIS ZEA* OR *SPODOPTERA* SPP.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	Heloithis zea	Reference	*Spodoptera* spp.	Reference
A. hypogaea	PI 149268	Leuck et al. 1969b	C 501 (1)	Rao et al. 1982
	PI 158854	Lynch (unpubl. data)	GBPRS 312 (1)	Amin 1987
	PI 196613	Leuck et al. 1969b	SER 56-15 (f)	Hammons 1970b Leuck & Skinner 1971
	PI 196618	Leuck et al. 1969b		
	PI 196659	Leuck et al. 1969b		
	PI 196675	Lynch (unpubl. data)		
	PI 234423	Lynch (unpubl. data)		
	PI 244601	Leuck et al. 1969b		
	PI 268854	Leuck et al. 1969b		
	PI 268856	Leuck et al. 1969b		
	PI 268867	Leuck et al. 1969b		
	PI 268928	Leuck et al. 1969b		
	PI 269062	Campbell et al. 1982		
	PI 290689	Lynch (unpubl. data)		
	PI 295202	Leuck et al. 1969b		
	PI 295204	Leuck et al. 1969b		
	PI 295205	Leuck et al. 1969b		
	PI 295988	Leuck et al. 1969b		
	PI 298844	Leuck et al. 1969b		
	PI 315631	Leuck et al. 1969b		
	PI 331334	Leuck et al. 1971		
	PI 339970	Leuck et al. 1971		
	PI 339976	Leuck et al. 1971		
	PI 341269	Leuck et al. 1971		
	PI 342657	Leuck et al. 1971		
	PI 355276	Lynch (unpubl. data)		
	NC 6	Campbell & Wynne 1980 Campbell et al. 1982		

TABLE 5. (Continued)

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	Heloithis zea	Reference	*Spodoptera* spp.	Reference
	NC 342	Campbell et al. 1982		
	NC 343	Campbell et al. 1982		
	NC 15745	Lynch (unpubl. data)		
	NC 17404	Campbell et al. 1982		
	NC 17166	Campbell et al. 1982		
	NC 17168	Campbell et al. 1982		
	Early Bunch	Campbell & Wynne 1980		
	Spancross	Hammons 1970a		
A. sp.	PI 262278	Stalker & Campbell 1983		
	PI 262286	Stalker & Campbell 1983		
	PI 262287	Stalker & Campbell 1983		
	PI 262306	Stalker & Campbell 1983		
	PI 262793	Stalker & Campbell 1983		
	PI 262794	Stalker & Campbell 1983		
	PI 262797	Stalker & Campbell 1983		
	PI 262798	Stalker & Campbell 1983		
	PI 262828	Stalker & Campbell 1983		
	PI 262848	Stalker & Campbell 1983		
	PI 276203/ 276309	Stalker & Campbell 1983		
	PI 276223	Stalker & Campbell 1983		
	PI 276225	Stalker & Campbell 1983		
	PI 276228	Stalker & Campbell 1983		
	PI 276233	Stalker & Campbell 1983		
	PI 338265	Stalker & Campbell 1983		
	PI 338267	Stalker & Campbell 1983		
	PI 338305	Stalker & Campbell 1983		
	PI 338452	Stalker & Campbell 1983		
	PI 338454	Stalker & Campbell 1983		

	1960 #100	Stalker & Campbell 1983		
	10002 GKP	Stalker & Campbell 1983		
	GK-10596C	Campbell et al. 1982		
	GKP 9645	Campbell et al. 1982		
	GKP 9649	Campbell et al. 1982		
	Manfredi #5	Campbell et al. 1982		
A. batizocoi	GKP 9484	Campbell et al. 1982		
A. burkartii			PI 261851 (f)	Lynch et al. 1981
A. cardenasii			PI 262141 (f)	Lynch et al. 1981
A. chacoense	PI 276235	Stalker & Campbell 1983	PI 276235 (f)	Lynch et al. 1981
A. correntina	PI 262808	Stalker & Campbell 1983	PI 261870 (f)	Lynch et al. 1981
	—	Stalker & Campbell 1983		
A. duranensis	PI 219833	Stalker & Campbell 1983		
A. glabrata			Florigraze (f)	Lynch et al. 1981
A. lignosa			PI 338315 (f)	Lynch et al. 1981
A. paraguariensis	11488 (KC)	Stalker & Campbell 1983		
A. pusilla	PI338449	Stalker & Campbell 1983		
A. rigonii	PI 262142	Stalker & Campbell 1983		
A. repens	PI 276199	Stalker & Campbell 1983	PI 162801 (f)	Lynch et al. 1981
A. stenosperma	PI 338279	Stalker & Campbell 1983		
	PI 338280	Stalker & Campbell 1983		
A. villosa			PI 261872 (f)	Lynch et al. 1981
A. villosa-correntina	Manfredi #5	Stalker & Campbell 1983		
A. villosa-correntina	Manfredi #6	Stalker & Campbell 1983		
A. villosulicarpa			PI 378181 (f)	Lynch et al. 1981

[1](1) = *S. litura*
(f) = *S. frugiperda*

burkartii or *A. villosa*. Both nonpreference and antibiosis resistance mechanisms among the *Arachis* species were found to be operative against larvae of the fall armyworm (Lynch et al. 1981).

In the southeast, especially in North Carolina and Virginia, the twospotted spider mite, *T. urticae*, is often a major pest of cultivated peanut (Campbell et al. 1974, Smith & Barfield 1982) The application of fungicides on a 10-14 day schedule for control of leafspots, *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. & Curt.) Deigh., plus the application of insecticides for insect control synergize spider mite outbreaks (Campbell 1978). Peanut lines with resistance to spider mites are listed in Table 6. Johnson et al. (1980) reported nonpreference to spider mite feeding in PI 262286 and PI 262840. However, only moderate levels of resistance to the spider mite were reported among advanced breeding lines NC Ac 302, 343, 469, 17347, and 17367 (Johnson et al. 1982). Higher levels of resistance to the spider mite have been reported among the wild species of *Arachis*. Leuck & Hammons (1968) found resistance to *T. tumidellus* in *Arachis* sp. (PI 268241), *A. villosulicarpa* (PI 263396), and *A. repens*. Johnson et al. (1977) also found resistance to the twospotted spider mite, especially among the Rhizomatosae; PI 338296, PI 338317, PI 262840, and PI 262827 remained almost mite-free throughout their evaluation. PI 331194 from section Arachis, PI 276203 from section Extranervosae, and PI 262142 from section Erectoides also had lower damage ratings than susceptible standards, but only members of section Arachis readily hybridize with *A. hypogaea*. Tolerance, nonpreference, and antibiosis mechanisms of resistance to spider mites have been identified in peanut (Johnson et al. 1977, 1980, 1982).

Larvae of the southern corn rootworm (SCRW) feed on developing peanut pods below the soil surface, most often in heavier, poorly drained soils (Bass & Arant 1973). Fronk (1950) and Alexander & Boush (1964) reported that damage by SCRW was greater on spanish peanut lines than on virginia lines. Smith (1970) and Smith & Porter (1971) noted differences in percentage of damaged pods among cultivated peanut lines when they were artificially infested with second-instar larvae of the SCRW, but not a high level of resistance. Even lines with moderate levels of resistance to pod injury at low levels of infestation were susceptible at higher levels. Similar results were reported by Chalfant & Mitchell (1970), who reported only a moderate level of resistance to pod injury by the SCRW in the field. However, Campbell et al. (1977) reported a high level of resistance, 85% less damage in NC6 than in 'Florigiant' (Table 7). NC-6 also had moderate resistance to the potato leafhopper and the corn earworm and a low level of resistance to the tobacco thrips (Campbell et al. 1977, Campbell & Wynne 1980, 1985). The resistance in NC-6 resulted in the use of 60 to 80% less insecticides for SCRW, leafhopper, and thrips control than was required for control of these insects on 'Florigiant' (Campbell & Wynne 1985).

The lesser cornstalk borer (LCB) larvae are primarily subterranean, feeding on the main stem of seedling peanut, tunneling in the lateral branches of more mature plants, or feeding on the developing pegs and pods (Tippins 1982). Larvae prefer immature pods before the mesocarp develops structural rigidity (Lynch 1984). LCB is most often an economic pest on well drained, sandy soils, especially during periods of inadequate soil moisture (Tippins 1982). Peanut resistance to both plant and pod damage by LCB has been reported (Table 7). Schuster et al. (1975) reported that runner cultivars 'Florunner', 'Florigiant', 'Early Runner', all appeared to possess a moderate level of antibiosis to LCB and were less susceptible than spanish cultivars. Females emerging from the spanish cultivar 'Spanhoma' produced significantly more eggs than females emerging from the runner cultivar 'Florunner' (Berberet et al. 1982). Greenhouse evaluation of 490 peanut lines for resistance in the seedling stage to LCB damage showed a moderate level of resistance to plant damage in 'Early Runner', Virginia Bunch 67', 'Florunner', Florigiant', and 'Dixie Spanish' (Smith et al. 1980a, b). Stalker et al. (1984)

TABLE 6. PEANUT LINES REPORTED RESISTANT TO DAMAGE BY *TETRANYCHUS* SPIDER MITES.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	T. urticae	Reference	*T. tumidellus*	Reference
A. hypogaea	PI 262286	Johnson et al. 1980		
	PI 262840	Johnson et al. 1980		
	NC 6	Johnson et al. 1982		
	NC 17	Campbell et al. 1974		
	NC Ac 302	Johnson et al. 1980		
		Johnson et al. 1982		
	NC Ac 343	Johnson et al. 1982		
	NC Ac 469	Johnson et al. 1982		
	NC Ac 827	Johnson et al. 1980		
	NC Ac 17347	Johnson et al. 1982		
	NC Ac 17367	Johnson et al. 1982		
	GK-53	Johnson et al. 1980		
	Va 72R	Campbell et al. 1974		
A. sp.	PI 276233	Johnson et al. 1977	PI 262841	Leuck & Hammons 1968
	PI 338317	Johnson et al. 1977		
A. correntina	PI 331194	Johnson et al. 1977		
A. glabrata	PI 262797	Johnson et al. 1977		
A. macedoi	PI 276203	Johnson et al. 1977		
A. repens			—	Leuck & Hammons 1968
A. villosa	PI 331196	Johnson et al. 1977		
A. villosulicarpa			PI 263396	Leuck & Hammons 1968

TABLE 7. PEANUT LINES REPORTED RESISTANT TO SOUTHERN CORN ROOTWORM, *DIABROTICA UNDECIMPUNCTATA HOWARDI*, OR LESSER CORNSTALK BORER, *ELASMOPALPUS LIGNOSELLUS*.

Species of *Arachis*	Cultivar, PI, or accession resistant to:			
	D. undecimpunctata howardi	Reference	*E. lignosellus*	Reference
A. hypogaea	NC-GP 343	Campbell et al. 1971		
	NC 6	Campbell et al. 1977	PI 262042	Campbell & Wynne 1980
		Campbell & Wynne 1980	PI 269005	Campbell & Wynne 1980
		Campbell & Wynne 1985	PI 269116	Campbell & Wynne 1980
	NC 13	Chalfant & Mitchell 1970		Stalker et al. 1984
	NC 10211	Smith 1970	PI 269118	Campbell & Wynne 1980
		Smith & Porter 1971	PI 272000	Stalker et al. 1984
	NC 10219	Smith 1970	PI 265743	Campbell & Wynne 1980
	NC 10446	Smith 1970	PI 275744	Campbell & Wynne 1980
	NC 10449	Smith 1970		Stalker et al 1984
	NC Ac 343	Campbell & Wynne 1980	Early Runner	Schuster et al. 1975
	NC Ac 17167	Campbell & Wynne 1980		Smith et al. 1980a,b
	NC Ac 17201	Campbell & Wynne 1980	Florigiant	Schuster et al. 1975
	NC Ac 17205	Campbell & Wynne 1980		Smith et al. 1980a,b
	NC Ac 17215	Campbell & Wynne 1980	Florunner	Schuster et al. 1975
	Ga. Sta. Runner	Chalfant & Mitchell 1970		Campbell & Wynne 1980
				Smith et al. 1980a,b
			Va. Bunch 67	Schuster et al. 1975
				Smith et al. 1980a,b
A. sp.			PI 261877	Stalker et al. 1984
			PI 262278	Stalker et al. 1984
			PI 298636	Stalker et al. 1984
			PI 338297	Stalker et al. 1984
			GKP 10127	Stalker et al. 1984
			KC 11488	Stalker et al. 1984.

TABLE 8. PEANUT LINES REPORTED RESISTANT TO POD SCARIFICATION BY TERMITES.

Species of *Arachis*	Cultivar with resistance to *Odontotermes* sp.			
	Highly resistant	Reference	Moderately resistant	Reference
A. hypogaea	NC Ac 2240 T	Amin et al. 1985	NC Ac 343	Amin & Mohammad 1982
	NC Ac 2240 DP	Amin et al. 1985		Amin et al. 1985
	NC Ac 2242	Amin et al. 1985	NC Ac 1705	Amin et al. 1985
	NC Ac 2243 T	Amin & Mohammad 1982	NC Ac 2142	Amin et al. 1985
		Amin et al. 1985	NC Ac 2230	Amin et al. 1985
	NC Ac 2243 DP	Amin & Mohammad 1982	NC Ac 10033	Amin et al. 1985
		Amin et al. 1985	NC Ac 17888	Amin et al. 1985
			FESR 386	Amin & Mohammad 1982
				Amin et al. 1985
			RMP 40	Amin & Mohammad 1982
				Amin et al. 1985
			M13	Amin & Mohammad 1982
				Amin et al. 1985

reported peg and pod resistance to LCB damage; PI 269116, PI 275744, PI 262000, PI 269006, PI 261955, and PI 269005 had significantly less LCB damae than 'Florigiant'. They also reported high levels of resistance in several of the wild species of *Arachis*.

In India, and especially in Africa, termites are among the most important pests of cultivated peanut (Amin & Mohammad 1982, Wightman 1985, Lynch et al. 1986). Termites damage plants by either tunneling in the main stem, which causes the plant to wilt and die, or by feeding on pods, which results in pod scarification or penetration (Johnson et al. 1981, Johnson & Gumel 1981). Resistance to pod scarification by termites has been reported by Amin & Mohammad (1980 and Amin et al. (1985) (Table 8). NC Ac 2243T, NC Ac 2243DP, NC Ac 2240T, NC Ac 2240DP, and NC Ac 2242 are highly resistant to pod scarification by termites.

Research to identify resistance to the groundnut leafminer and 'pod-borers', i.e., millipedes, wireworms, and earwigs is under way (Wightman et al. 1987). ICG 2271 (NC Ac 343) is reported to have resistance to several species of insects including *A. modicella*, thrips, leafhoppers, and "pod-borers" (Amin 1987). In addition, NC Ac 2240 is resistant to pod-boring insects (Wightman et al. 1987).

In conclusion, resistance in peanut to most of the major insect pests has been identified. However, cross-resistance to congeneric insects has not been investigated or confirmed in most instances and warrants further investigation. Also, resistance to multiple insects has been identified in both cultivated peanut (Campbell & Wynne 1980, Amin et al. 1985, Amin 1987) and in a number of wild species of *Arachis* (Stalker & Campbell 1983). In addition, high levels of resistance to some major disease pathogens of peanut have been identified in the wild species of *Arachis* (Gibbons 1987). These accessions, especially diploid species of the section Arachis, which are cross-compatible with the tetraploid *A. hypogaea*, offer tremendous potential for the development of cultivars with increased levels of resistance to both insects and plant pathogens. Cooperative research among research institutes, organizations, and countries is needed for evaluation of peanut germplasm for cross-resistance and resistance to multiple pests.

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