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Resistance of *Arachis* Species to the Fall Armyworm, *Spodoptera frugiperda*[1]

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ABSTRACT

Fourteen species of *Arachis* were evaluated for survival, leaf consumption, development rate, and preference by the fall armyworm, *Spodoptera frugiperda* (J. E. Smith). Using a host-suitability index, *A. monticola*, *A. hypogaea*, cv. 'Florunner,' *A. stenosperma*, and *A. batizogaea* were the most suitable hosts and were classified susceptible to the fall armyworm. *A. burkartii* and *A. villosa* were the least suitable hosts and were classified resistant. These classifications were also supported, in general, by preference of the insect for the species of *Arachis*.

Key Words: Fall armyworm resistance, peanuts, groundnuts, leaf consumption, survival, preference, host-suitability index.

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is an herbivorous insect with over 50 species of host plants (11). It prefers members of the grass family as hosts, i.e. corn, sorghum, bermudagrass, but it is also an occasional pest of peanuts, *Arachis hypogaea* L., especially in the southern U. S. In Georgia, peanut yield losses attributable to the fall armyworm (FAW) were negligible from 1971-76 with only an estimated $10,000 used for FAW control in 1973 (13). In 1977, however, FAW populations reached epidemic proportions throughout the southern U.S., and peanut losses in Georgia alone exceeded $17 million (14).

Recent studies have emphasized the influence of peanut plant phenology on the FAW. FAW larvae have been reported to consume more leaf tissue on intermediate aged plants (67-92 days) than on younger (45-70 days) or more mature (92-120 days) plants (1). This report also related plant age on which FAW larvae fed to subsequent adult fecundity and longevity. Additional work has further shown that during their development, FAW larvae consumed ca. 100 cm^2 of leaf area and preferred younger leaves (3). Peanut leaf consumption was also noted to decline while larval mortality increased with leaf age.

Only one cultivar of peanuts, Southeastern Runner 56-15 (SER), has been reported to possess resistance to the FAW. In the description of SER (6), it was noted that this cultivar was more resistant to FAW feeding than other commercial cultivars. SER (listed as runner check) was compared with 13 other peanut lines and found to be less susceptible to insect defoliation (10). The influence of this cultivar on the FAW was further evaluated by rearing them for 3 successive generations on foliage of SER. The results showed a cumulative debilitation by increasing the length of the life cycle and decreasing the percentage of moths that emerged (9).

Observations on wild species of peanuts grown in field nursery plots indicated differential damage by foliage feeding insects (R. O. Hammons, personal comm.). Identification of additional germplasm resistant to the FAW would greatly enhance the probability of managing this insect. Therefore, the objective of this study was to evaluate 14 *Arachis* species for resistance to the fall armyworm.

Materials and Methods

In the fall of 1979, cuttings of 13 species of *Arachis* (Table 1) were made from field plots located at the Agronomy Research Farm near Tifton, Ga. After rooting, 3 plants of one species were transplanted into 30.5 x 30.5 cm clay pots containing a 2:1 ratio of sand-Jiffy Mix® mixture, respt. Three pots were established for each species and maintained in a greenhouse with a 14:10 photoperiod. Plants in each pot were fertilized ca. every 4-6 weeks with a $20N:20P_2O_5:20K_2O$ water soluble fertilizer to stimulate vegetative growth. Approximately 40 days prior to initiation of larval feeding trials, several pots were planted with seed of *A. hypogaea* L. cv. 'Florunner' and thinned to 3 plants/pot after seedling emergence.

Table 1. *Arachis* species evaluated for *Spodoptera frugiperda* resistance.

Arachis species	Section[a/]	Coll.[b/]	Coll.No.	PI No.	Origin
A. repens Handro	Caulorhizae	SH	277	162801	Brazil
A. glabrata Benth. (narrow leaf form)	Rhizomatosae	SH	380	163452	Brazil
A. burkartii Handro	Rhizomatosae	GKP (K)	210 (7864)	261851	Argentina
A. correntina (Burk) Krap. *et* Greg. *nom. nud.*	Arachis	GKP	207	261870	Argentina
A. villosa Benth.	Arachis	GKP	218	261872	Argentina
A. cardenasii Krap. *et* Greg. *nom. nud.*	Arachis	GKP (K)	170 (10017)	262141	Bolivia
A. chacoense Krap. *et* Greg. *nom. nud.*	Arachis	GKP (K)	103 (10602)	276235	Paraguay
A. stenosperma Greg. *et* Greg. *nom. nud.*	Arachis	HLK	408	338279	Brazil
A. lignosa (Chod. *et* Hassl.) Krap. *et* Greg. *nom. nud.*	--	HL (K)	327 (14248)	338315	Paraguay
A. villosulicarpa Hoehne (tetraploid form)	Extranervosae	--	--	-- 378181	Brazil (India)
A. batizogaea Krap. *et* Fern.	Arachis	--	--	405082	Argentina
A. monticola Krap. *et* Rig.	Arachis	--	--	405933	Argentina
A. glabrata Benth. cv. 'Florigraze'	Rhizomatosae	--	--	--	Florida
A. hypgoaea L. spp. *hypogaea* var. *hypogaea* cv. 'Florunner'	Arachis	--	--	--	Florida

a/ Sectional classification from Gregory *et al.*, (5).

b/ Abbreviations of collectors: SH = Stephens-Hartley; K = Krapovickas; GKP = Gregory-Krapovickas-Pietrarelli; G = Gregory; HLK = Hammons-Langford-Krapovickas; HL = Hammons-Langford.

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Fall armyworm larvae used in the evaluations were from a laboratory culture reared as previously described (12). Instar determinations were made by preserving larvae in alcohol that had been reared by this method and comparing the larvae with instar descriptions (2, 11). Larvae reared on this diet at 26.7C and 80% RH had 6 instars. These preserved larvae were then used as a standard for comparing larvae reared on peanut leaves.

Larval Survival, Leaf Comsumption, and Development

For larval feeding tests, two newly emerged leaves (ca. 2-10 days after unfolding) of each species were placed in a floral Aqua Pic ® and the water pic inserted through the bottom of a 473 ml waxed paper cup. Leaves within a cup were then infested with three 1st-instar FAW larvae, and the cups were capped with clear plastic lids. The cups were then placed in an incubator maintained at 26.7 ± 2C., 80 ± 5% RH, and a 14:10 photoperiod.

The experiment was replicated in time with 5 cups/peanut species/replicate and four replications. Peanut leaves in each cup were observed daily for larval survival and rate of larval development. As larvae molted to the 3rd instar, 5 from each host species were weighed, placed individually in paper cups with water pics and peanut leaves, and observed for survival, developmental rate, and leaf consumption (96.8% of the total leaf consumption occurs from the 3rd-6th instar (3). Freshly excised leaves of the species on which the larva was feeding were measured with a LI-COR 3000 ® area meter before they were inserted in the water pics for larval feeding. Each larva was again observed daily and weighed after each molt. The remaining leaf material was measured after each molt, or as additional food was required, and new leaves were measured and added for larval feeding. After completion of larval development, pupae were weighed.

Data were recorded on rate of larval development, leaf consumption, time to pupation, and pupal weight, and were analyzed by least squares analysis. Least square means were separated by the method described for means with unequal replication in Duncan's multiple range test (7).

Larval Preference for *Arachis* spp.

Larval preference for the 14 species of *Arachis* was evaluated in a free-choice test in a randomized complete block design with 20 replications. Each replicate contained leaves of each species arranged in 25 cm diam. plastic dish. Filter paper was divided into 14 equal sections, moistened to prevent leaf desiccation, and placed in the bottom of each dish. Two freshly excised, newly emerged leaves of each peanut species were randomly assigned and placed on the filter paper around the outer edge of each dish. Fifty 1st-instar larvae were then placed in the center of each dish, and the dish was capped with a clear plastic lid to prevent larval escape. Each dish was then individually placed in a cardboard box, the box was sealed to prevent light from influencing larval preference, and the box containing the dish was placed in an incubator maintained as described above.

After 24 h, data were recorded on the number of larvae feeding on leaves of each species. Larvae on the sides or top of the dish were not recorded. Data were therefore expressed as a percentage of the larvae that chose a particular species and converted to arcsine $\sqrt{\%}$ for analysis. Means were separated by Duncan's multiple range test.

Results and Discussion

Differences in the rate of development of FAW larvae on *Arachis* spp. were readily apparent (Table 2). At 5 days, larvae on all species had entered the 2nd stadium with the exception of larvae on *A. burkartii* which was still in the 1st stadium. Larval growth on *A. monticola* was significantly faster than on *A. cardenasii, A. chacoense, A. correntina, 'Florigraze', A. lignosa, A. villosulicarpa,* and *A. villosa.* By 10 days, difference in larvae growth rates were even more pronounced. Larvae on *A. monticola* were in the 4th stadium, and larvae on Florunner, *A. stenosperma, and A. batizogaea* were in the mid- to late-3rd stadium. Conversely, significantly slower larval growth was noted for larvae on *A. lignosa, A. villosulicarpa, A. villosa, A. chacoense, and A. correntina.* Trends were similar at 15 and 20 days in that larvae on *A. monticola* and Florunner showed the fastest rate of devleopment, although not significantly faster than for several other species, while larvae feeding on *A. repens, A. glabrata, and A. chacoense* showed the slowest rate of development.

Table 2. Average developmental stage for fall armyworm larvae feeding on different species of peanuts.

Species or Cultivar	Average Developmental Stage[a] at Indicated Age (days) 5	10	15	20
A. monticola	2.65 a	4.10 a	5.95 a	7.42 a
A. glabrata	2.47 ab	3.15 bcd	4.18 cde	5.40 cd
cv. Florunner	2.40 ab	3.84 ab	5.68 ab	7.25 ab
A. stenosperma	2.35 ab	3.47 abc	5.31 abc	6.81 abc
A. batizogaea	2.31 ab	3.50 abc	5.38 abc	6.77 abc
A. repens	2.22 ab	3.22 bcd	4.17 de	4.94 d
A. cardenasii	2.00 b	3.25 bcd	4.50 cde	6.00 abcd
A. chacoense	2.00 b	2.33 ef	3.83 def	5.80 bcd
A. correntina	2.00 b	2.17 f	3.80 ef	6.00 abcd
cv. Florigraze	2.00 b	3.00 cde	5.00 abcd	6.75 abc
A. lignosa	2.00 b	2.71 def	4.60 bcde	6.00 abcd
A. villosulicarpa	2.00 b	2.71 def	4.14 def	6.33 abcd
A. villosa	2.00 b	2.50 def	3.00 f	--
A. burkartii	1.50 c	--	--	--

a/ Average developmental stage for the surviving larvae. Larval development rated on a 1-8 scale with 1-6 representing the 1st-6th instar, resp., 7 for the prepupa, and 8 for the pupal stage.

These trends extended throughout larval development to pupation as presented in Table 3. Larvae on *A. monticola* and Florunner required the shortest time to complete larval development, an average of 19.5 days, followed by larvae on *A. batizogaea and A. stenosperma,* 21.5 and 21.6 days, resp. The greatest amount of time to pupation

Table 3. Survival, leaf consumption, time to pupation, and pupal weight for fall armyworms feeding on different species of peanuts.

Species or Cultivar	Survival[a] (%)	Leaf Consumption[b] (cm^2)	Time to Pupation (days)	Pupal Weight (mg)
A. monticola	90.0	118.44 ab	19.5 c	167.1 b
A. stenosperma	80.0	115.78 abc	21.6 bc	154.9 bc
cv. Florunner	75.0	118.08 abc	19.5 c	162.2 b
A. batizogaea	65.0	112.88 abc	21.5 bc	172.5 ab
A. repens	55.0	129.28 a	28.6 a	135.1 c
A. glabrata	35.0	74.04 e	23.6 abc	154.9 bc
A. chacoense	25.0	88.19 cde	26.8 ab	151.8 bc
A. correntina	20.0	91.67 bcde	24.8 abc	159.3 bc
cv. Florigraze	20.0	76.50 de	23.3 bc	157.0 bc
A. lignosa	20.0	92.06 bcde	23.3 bc	141.0 bc
A. cardenasii	15.0	106.41 abc	24.3 abc	154.1 bc
A. villosulicarpa	15.0	103.62 abcd	22.3 bc	208.8 a
A. villosa	0.0	--	--	--
A. burkartii	0.0	--	--	--

a/ Percentage survival to pupation based on 20 larvae/species.

b/ Leaf consumption measured from the 3rd-6th instars.

was recorded for larvae on *A. repens*, 28.6 days, and *A. chacoense*, 26.8 days. Larvae on these two species occasionally had 7 or 8 larval molts prior to pupation.

Larval survival to pupation (Table 3) also tended to be related to rate of larval development. Survival was greatest on *A. monticola* (90%) and *A. stenosperma* (80%), followed by Florunner (75%) and *A. batizogaea* (65%). Only 15-20% of the larvae were able to complete larval development on *A. villosulicarpa, A. cardenasii, A. lignosa, A. correntina* and *Florigraze*. No larvae feeding on *A. burkartii* and *A. villosa* completed larval development; only 2 larvae feeding on each of these species survived more than 5 days.

Leaf consumption by FAW larvae was greatest on *A. repens*, 129.28 cm², but did not differ significantly from that on *A. monticola*, Florunner, *A. stenosperma, A. batizogaea, A. cardenasii, and A. villosulicarpa*. Significantly less leaf area was required by larvae on *A. glabrata*, 74.04 cm², and Florigraze, 76.50 cm², to complete development than for most of the other species. Apparently these closely related peanuts are nutritionally superior per unit surface area for FAW larvae than are most of the other species evaluated.

Pupal weights were greatest for FAW larvae that fed on *A. villosulicarpa* (Table 3), averaging 208.8 mg, and were significantly greater than pupal weights for larvae that fed on all other species, with the exception of *A. batizogaea. A. monticola* and Florunner produced pupae that weighed slightly less, 167.1 and 162.2, resp. Conversely, *A. repens*, which consumed the greatest amount of leaf tissue and required the longest development period, produced pupae that weighed only 135.1 mg, a value significantly lower than that for the above species.

Antibiosis, the adverse effects of a resistant plant on an insect, was noted for FAW larvae on several species of *Arachis*. However, the magnitude of the response, i.e. low survival, increased time to complete larval development, increased leaf consumption, and lower pupal weights, varied with the peanut species.

As a quantitative measurement of the cumulative effects of antibiosis, we propose the host-suitability index (Table 4). This index measures the insect-host relationships to rate the overall performance from susceptible (high values or high degree of suitability) to resistant (low values or low suitability). As noted in Table 4, the index is composed of insect survival, development time, leaf consumption, and pupal weight or fecundity. Insect survival is paramount in this relationship since survival is the first prerequisite for propagation of the species. Secondly, the insect should consume the least amount of the host while attaining the greatest pupal weight on a minimum of host tissue. The insect should also complete its development in a minimum of time. Consumption of the least amount of host tissue during development precludes excessive host damage and allows more insects/host to complete development. Insect fecundity depends on the quality of the host and can be related to pupal weight (8). Rapid development avoids extensive exposure to environmental pressures, parasites, predators, etc. Thus, the arrangement of these terms in Table 4 expresses these relationships as host suitability.

Table 4. Fall armyworm larval preference for *Arachis* spp. and suitability of these species as hosts.

Species or Cultivar	Preference[a/] (%)	Host Suitability Index[b/]
cv. Florunner	15.6 a	5.3
A. monticola	14.6 a	6.5
A. lignosa	14.6 a	1.3
A. batizogaea	11.7 ab	4.6
A. glabrata	11.1 ab	3.1
cv. Florigraze	8.5 bc	1.8
A. chacoense	4.3 cd	1.6
A. cardenasii	3.9 cd	0.9
A. villosulicarpa	3.7 cd	1.4
A. stenosperma	3.2 d	5.0
A. repens	2.8 d	2.0
A. villosa	2.5 d	0.0
A. correntina	2.0 d	1.4
A. burkartii	1.5 d	0.0

a/ Percentage of 1st-instar larvae that preferred an indicated species in a free-choice test. Data converted to $\sqrt{\%}$ for analysis.

b/ Host Suitability Index =

$$\frac{\text{Pupal Weight (or fecundity)}}{\text{Leaf Consumption}} \Big/ \text{Development Time} \times \% \text{ Survival.}$$

According to this index, *A. monticola*, Florunner, *A. stenosperma, and A. batizogaea* are the most suitable hosts and should be classified as susceptible. Conversely, *A. villosa and A. burkartii* are the least suitable hosts and should be classified as resistant.

This classification as resistant or susceptible is also supported, for the most part, by FAW preference for the various species of *Arachis* (Table 4). First stage FAW larvae preferred Florunner, *A. monticola* and *A. lignosa* for feeding, while *A. burkartii, A. correntina and A. villosa* were least preferred. With the exception of *A. lignosa* which was one of the preferred species in the choice test while being only a moderately suitable host, and *A. stenosperma* which was very suitable as a host but only moderately preferred, the data for these two classifications tended to be closely related. However, these slight disparities may be related to differences in the types of resistance, i.e. nonpreference vs. antibiosis, and will require further research for elucidation.

The significance of these findings can best be realized by crossing compatibility in present peanut breeding programs. With regard to the species, *A. hypogaea*, intrasectional hybridization has been reported to be more successful than intersectional combinations (4). Thus, *A. villosa, A. cardenasii, and A. correntina* would seem to offer the greatest potential for transferring FAW resistance into cultivated peanuts. Intersectional hybrids with *A. burkartii* may prove to be more difficult to obtain.

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