Early and Late Leaf Spot Resistance and Agronomic Performance of Nineteen Interspecific Derived Peanut Lines[1]

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ABSTRACT

Nineteen selected interspecific peanut lines with resistance to leaf spot [Cercospora arachidicola Hori and/or *Cercosporidium personatum* (Berk. and Curt.) Deighton] were field tested 3 yr for disease reaction and productivity with and without foliar fungicide protection. Measurements included severity ratings of leaf spot every 2 wk based on the Florida leaf spot disease rating scale, and pod yield. Area under disease progress curves (AUDPC) and pod yield losses were calculated. Differences among the interspecific lines in AUDPC values were significant, and one line had values equal to or lower than that of Southern Runner. One-half of the lines were equal in yield (P=0.01) to Southern Runner. Yields among lines averaged 1 to 50% higher with, as compared to without, chlorothalonil application. Yield losses of individual entries varied significantly from 1 yr to another and incongruous with the AUDPC pattern. Correlations between the AUDPC and yield loss were significant (P=0.01) for the 1989 and 1990, but not for the 1988 data. Results of the study indicate that resistance to both C. arachidicola *and personatum* were incorporated from the wild species parents into productive, runner-type breeding lines, and that the resistance to *personatum* was equal to or better than that of Southern Runner. Additional effort will be required to transfer levels of leaf spot resistance observed in the wild species parents into successful cultivars.

Key Words: *Arachis hypogaea*, groundnut, *Cercospora arachidicola*, *Cercosporidium personatum*, *Phaeoisariopsis personata*, disease progress curve, introgression, interspecific lines.

Leaf spot caused by *Cercospora arachidicola* Hori (early leaf spot) and *Cercosporidium personatum* (Berk. and Curt.) Deighton (late leaf spot), also known as *Phaeoisariopsis personata* (Berk. and Curt.) Arx are important diseases of peanut that occur wherever the crop is cultivated (13). Yield losses up to 50% have been reported in several areas of the world (7, 8, 11, 21), and market quality is affected (5, 10).

Resistant cultivars are the preferred means of managing peanut diseases. High yield and resistance to *C. personatum* have been combined in some intraspecific lines (13); however, success in developing agronomically acceptable varieties resistant to both leaf spot fungi has been limited. High levels of resistance or immunity have been reported in many wild species (1, 4, 18, 19).

Introgression of leaf spot resistance from wild to cultivated species has been investigated by several peanut researchers. Use of wild diploid species in the improvement of cultivated peanut has been hampered by cross incompatibility and sterility (6, 17, 21). Several successes have been reported (16), but no cultivar with the high levels of leaf spot resistance found in select wild species has been released.

Observations in the Texas program have been that the level of resistance in the most productive and leaf spot resistant advanced interspecific breeding lines is similar to that found in derivatives from the best intraspecific crosses. Hypotheses have been made that multiple loci are involved in the genetic control of resistance to both leaf spot pathogens (12,15). The question posed was whether the resistance(s) in interspecific derived lines was a result of the introgression of similar genetic factors, or whether genetic factors vary among lines which result in similar effect; that is, partial resistance. The concern then was whether or not through the introgression process we are arriving with the same result among the different selections, and that result being similar to the partial resistance which has occurred through nature in *Arachis hypogaea* L. If pleitropism, or genetic factors in tight linkage, control leaf spot resistance and reproduction that persists through introgression efforts similar to that which sometimes seems apparent in the cultivated germplasms, then the approach to breeding for resistance might need reconsideration.

The purpose of this study was: (a) to compare the leaf spot

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reactions of selected interspecific derived peanut lines and the partially resistant cv. Southern Runner under natural epidemics of both early and late leaf spot; (b) to identify relationships between pod yield and resistance to leaf spot in the interspecific lines; and (c) to determine if any of these interspecific derived lines have leaf spot resistance that is superior to Southern Runner, or might complement Southern Runner in a variety improvement program.

Materials and Methods

Nineteen interspecific derived breeding lines with superior leaf spot resistance and seed production, compared to the population of lines from the respective crosses, were chosen for the study. The derivations of 13 of these lines were described by Simpson (16). *Arachis cardenasii* Krapov. and W.C. Gregory (GKP 10017) x *A. diogoi* Krapov. and W.C. Gregory (GKP 10602) (formerly *A.* chacoensis) F_1 hybrids were crossed onto *A. batizocoi* Krapov. and W.C. Gregory (K 9484). The three-species hybrid ($2n$=20), after chromosome doubling with colchicine, was crossed and backcrossed with *A. hypogaea* (cv. Florunner). The BC_2F_1 was crossed with cultivars Florunner, Virginia 72R (VA72R) and Langley. The interspecific lines in this study were derived after four generations of selection and selfing. Southern Runner and Florunner were, respectively, the partially resistant and susceptible checks to late leaf spot. Langley was the susceptible check for early leaf spot.

Experiments were conducted at the Texas Agricultural Research Station near Yoakum. The test was planted in a loamy fine sand soil on a site that had been planted to peanut the two previous years. Leaf spots were a recurrent problem at the test site and disease infected residue, although moldboard plowed into the soil, gave rise to leaf spot infection in most years.

The experimental design in 1988 was a split block, with each main plot derived from an F_4 plant. Entries were planted in single 4.56 m rows spaced 0.91 m apart. Rows were subdivided into two row-section plots 60 cm apart, one protected with chlorothalonil at 2.3 L ha^{-1}, and the other unprotected. The fungicide protected row sections were sprayed every 2 wk starting 30 d after planting (DAP). Southern Runner was planted in every third row, bordering every experimental line for paired plot comparisons. Florunner, Langley, and VA72R were included as checks. The test, composed of three replications and subjected to naturally occurring inoculum, was planted 1 June and dug October 13.

In 1989, the test was arranged in a four-replicate split-plot field design with fungicide as the main plot and lines as subplots. Subplots consisted of two rows 4.56 m long spaced 0.91 m apart. Southern Runner, Florunner, Langley, and VA72R were included as checks. Planting and digging dates were June 16 and October 30, respectively.

In 1990, three experiments, identical except for randomization, were planted 6 June, each with four replications of the same plant material as in 1988 and 1989. One test was designated to receive, and the other two not to receive fungicide protection; one unprotected test each for an early and a late harvest. The early nontreated test was dug October 16, 7 d earlier than both the late and the fungicide protected tests which were dug simultaneously. Cultural practices were in accordance with those recommended for irrigated peanut production in Texas with the exception of fungicidal disease management. Weeds were controlled with preplant incorporated Trifluralin (1.7 L ha^{-1}) and Metachlor (1.8 L ha^{-1}). No insecticide was required. Plots were harvested, insofar as weather permitted, when most entries were considered mature on the basis of vine appearance.

Disease assessment was based on the whole plant with the Florida leaf spot disease rating scale (3), which is a visual rating scale ranging from 1 (no disease) to 10 (plant dead) on the basis of disease incidence and severity in different canopy layers. Disease assessment was made at intervals of 14 d beginning with the appearance of leaf spot. Area under disease progress curves (AUDPC) were calculated according to the method of Shaner and Finney (14) to compare entries for total season disease severity.

All plots were dug with a commercial, two-row, inverter-type digger, partially field cured, and harvested with a plot thresher. Pods were forced-air dried, cleaned, and yield was recorded. A random 250-g pod sample, taken from each plot by means of a riffle divider, was graded by methods described by the Federal State Inspection Service (20). Yield losses due to foliar diseases were computed with the formula: L= [(T - U)/T] x 100, where L= percentage of loss, T= yield in kg ha^{-1} of the treated plot, and U=yield in kg ha^{-1} of the untreated plot of the same line.

In 1988, split-block and paired-plot analyses were made on data, while only split-plot analysis was made on the 1989 data. Data from each of the 1990 tests were analyzed as a randomized complete block design. ANOVA's were made on combined data from both treated and untreated plots. Mean separations were performed on lines per fungicide level. Unless otherwise stated, interpretation is based on the untreated plots.

Results

Leaf Spots. Both early and late leaf spot were abundant in 1988 and 1990; early leaf spot predominated and disease pressure was less intense in 1989. Early leaf spot lesions appeared within 30 d after planting each year. The relative performance among lines was consistent over years for neither disease rating nor yield; therefore, results are presented on a year basis. Disease symptoms appeared first as small lesions on the upper leaf surface of nontreated plants of all lines. Over time, these became large on some lines and intermediate on others. Sporulation first occurred on the lines about 45 to 50 DAP.

Disease severity, as measured by the Florida scale (FS), increased throughout each season in all lines and cultivars (Figs. 1 and 2). Differences among lines in disease severity were not significant (P=0.05) until about 100 DAP. Line 16 had a lower disease progression than all check cultivars, including Southern Runner. Disease ratings for the most susceptible lines at harvest ranged between 6 and 7.9 in all tests.

Data for breeding lines in the highest and lowest 30 percentiles, based on disease evaluations, are presented in Table 1. Disease scores were low, in general, for lines 7, 8, 11, 16, and 18, although exceptions were noted such as shown for the final Florida scale rating of line 7 in 1989 and the AUDPC for line 11 in 1989. Line 16 was the only entry included in the least diseased statistical group based on both evaluation methods in all tests. Lines 8 and 11 were included in the least diseased statistical group in all tests according to the Florida scale and 7 and 18 were in the same

Table 1. Disease severity based on the final Florida scale ratings (FSR) and area under disease progress curve (AUDPC) values for selected lines and checks at Yoakum, TX, 1988-1990.[a]

	1988		1989		1990-1		1990-2	
Line #	FSR	AUDPC	FSR	AUDPC	FSR	AUDPC	FSR	AUDPC
4	3.7 de	425 a	3.5 cd	273 ab	5.0 b-d	296 a	4.2 fg	331 b
6	5.3 a-d	397 a	3.8 b-d	252 b-d	4.5 b-e	251 c-e	5.5 c-e	327 bc
7	4.3 c-e	292 f	4.3 bc	228 ef	4.0 d-g	203 g-j	4.0 g	262 e-g
8	3.7 de	278 f	3.3 cd	201 gh	3.5e-g	214 g-i	3.7 g	273 d-f
11	4.3 c-e	302 d-f	3.3 cd	258 bc	3.3 fg	199 ij	4.2 fg	243 fg
16	3.0 e	212 g	3.0 d	183 h	3.0 g	197 ij	4.0 g	242 g
18	4.7 b-d	280 f	3.0 d	195 gh	3.0 g	181 j	3.7 g	255 e-g
19	4.0 de	299 ef	3.8 b-d	210 fg	4.0 d-g	218 f-i	4.5 e-g	273 d-f
20	6.0 ab	332 b-d	5.0 ab	237 c-e	5.5 a-c	251 c-e	7.1 ab	337 b
22	5.0 b-d	340 bc	4.0 b-d	211 fg	5.3 a-c	264 b-d	5.5 c-e	300 cd
24	6.0 ab	361 b	4.3 bc	240 c-e	4.3 c-f	226 e-h	5.9 cd	321 bc
25	4.7 b-d	301 d-f	4.5 b	238 c-e	6.3 a	280 ab	5.6 cd	315 bc
Florunner	4.7 b-d	345 bc	4.8 ab	254 b-d	4.8 b-d	240 d-f	6.4 bc	322 bc
Langley	6.7 a	342 bc	6.0 a	288 a	6.3 a	266 bc	7.9 a	380 a
So Runner	4.7 b-d	308 d-f	4.5 b	235 de	3.5 e-g	233 e-g	4.5 e-g	264 e-g
VA72R	5.7 a-c	325 b-e	3.8 b-d	196 gh	4.5 b-e	200 ij	5.2 d-f	282 de
Mean	4.9	318	4.1	230	4.4	233	5.1	295
LSD	1.6	30	1.2	22	1.1	25	1.0	30

[a]Line means are based on four replications except for 1988 (three replications). Means followed by the same letters are not different at P = 0.05 level. 1990 - 1 and 1990 - 2 correspond respectively to 1990 early harvest and 1990 late harvest.

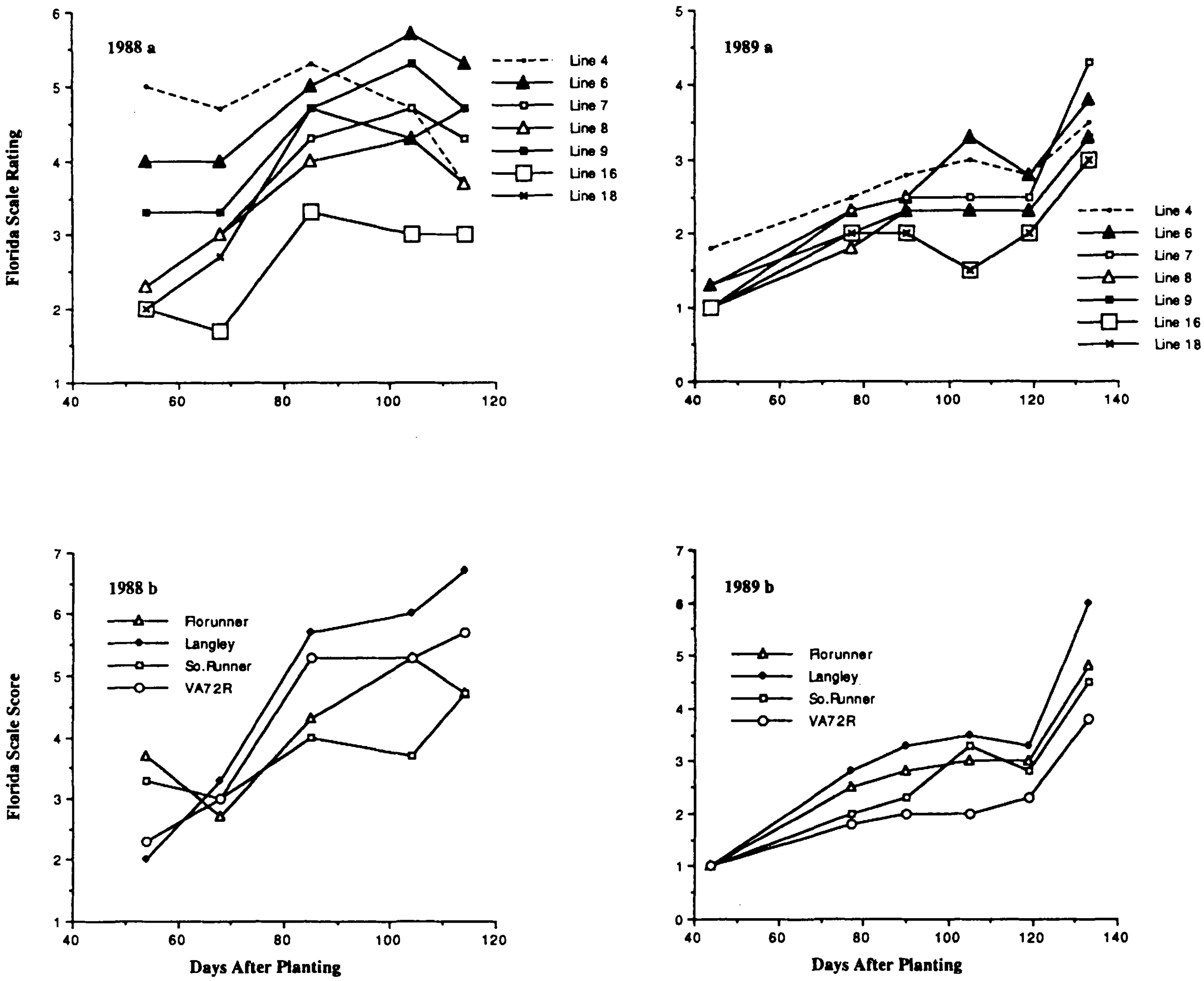

Fig. 1. Disease progress curves of selected interspecific lines as compared with Southern Runner and the cultivated checks in 1988 and 1989.

group in three of the four tests. No entry, other than 16, was in the least diseased statistical group for all tests according to AUDPC scores, and only line 18 was included in three of the four tests. Southern Runner was in that select group in both 1990 tests based on FS ratings, but only in the late 1990 test for AUDPC score. Statistical differences (P=.05) between Florunner and Southern Runner were more frequent for AUDPC values than for FS ratings.

Langley was consistently in the most susceptible statistical group for FS rating and in two of the four tests for AUDPC scores. Breeding line 4 was consistently in the highest diseased group according to AUDPC but not for FS ratings, and line 20 was consistently in the most diseased group for FS ratings, but not for AUDPC. Thus, interpretations on the relative disease severity of the entries might differ for the two methods of discrimination.

The correlation of lines for AUDPC were significant (P=0.01) for any 2 yr and "r" ranged from 0.50 to 0.61. Correlation between the early and late harvest, unsprayed tests conducted in 1990 were higher (r=0.80) than among years. Differences in disease severity might have affected the estimates of correlation among values over years. Nevertheless, the significant positive correlations gave verification of the partial resistance to leaf spot in these interspecific lines.

Yield. In 1988 the test was harvested at 135 DAP when, based on plant appearance, the unprotected Florunner and several other leaf spot susceptible lines were considered to have attained maximum harvestable yield. Harvest at this age was obviously early for some entries, such as Southern Runner, with lower disease severity and/or longer growth duration. Pod yield for the untreated plots ranged from 950 to 2300 kg ha^{-1} (Table 2). Two breeding lines, 9 (not shown) and 24, and Florunner yielded more (P=0.05) than Southern Runner.

Plant condition and development were considerably different at harvest in 1989 as compared with 1988. Whereas the earlier maturing and possibly more susceptible entries were favored in 1988, the later maturing and more leaf spot resistant entries were favored in 1989 when digging was delayed by rain and humid conditions. In untreated plots in 1989, pod yields ranged from 425 kg ha^{-1} for Langley to

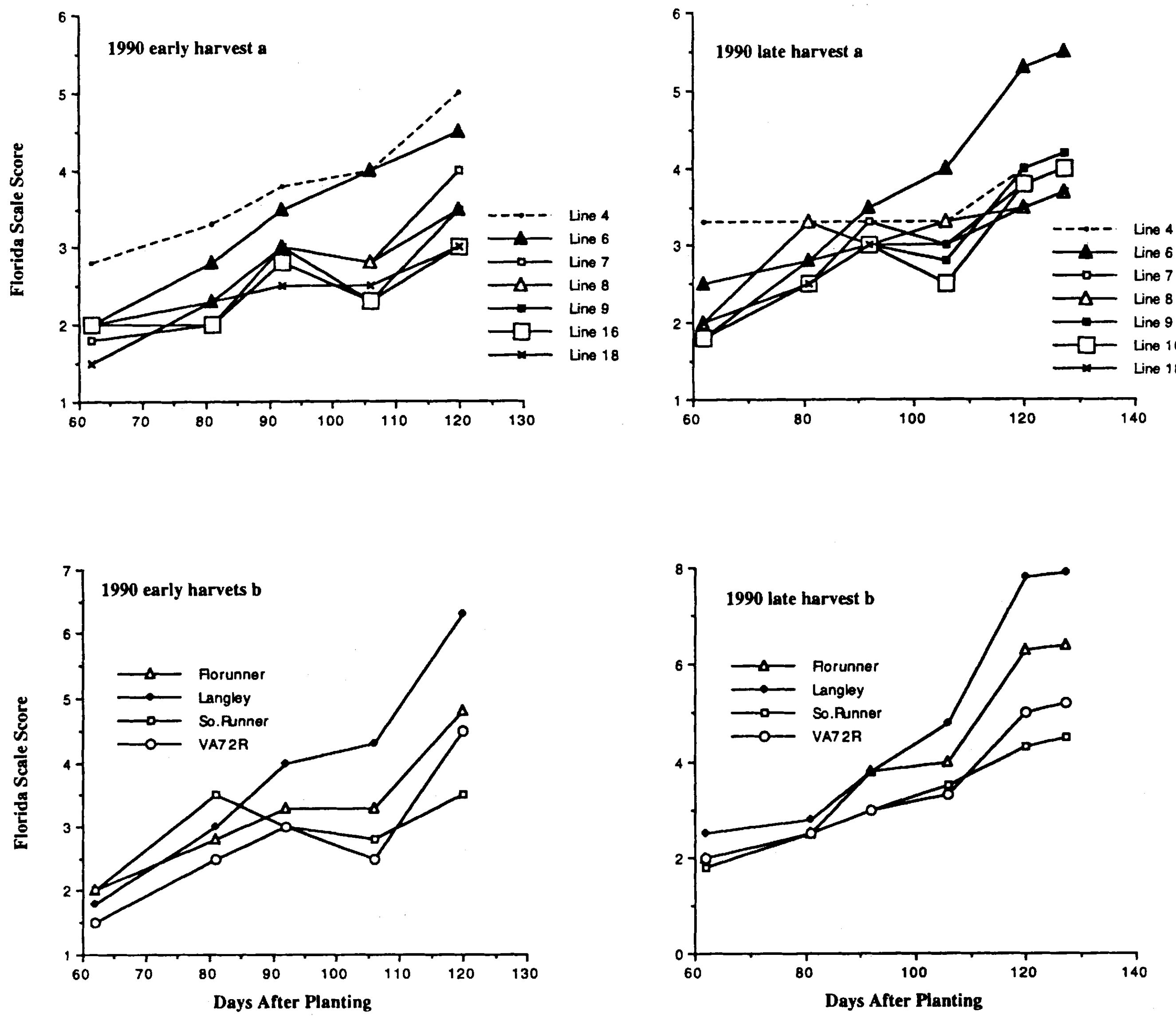

Fig. 2. Disease progress curves of selected interspecific lines as compared with Southern Runner and the cultivated checks in 1990.

1254 kg ha^{-1} for line 8 (Table 2). Lines 8, 11, and 16 had the same yield (P=0.05) as Southern Runner. Pod yields of Florunner, Langley, and Virginia 72R were significantly lower (P=0.05) than that of Southern Runner.

Two types of scenarios were observed in 1990. Pod yields were the highest in the early harvested test and ranged between 2174 and 3782 kg ha^{-1}. Line 8 produced the highest yield but did not differ statistically from Southern Runner. At the late harvest, none of the lines yielded significantly more than Southern Runner. The highest yield was recorded for line 11 while Langley, which was considerably past its' optimal digging date, yielded least. Considering yields on a line basis according to the most optimal of the two digging dates, three lines (8, 11, and 16) were dug with yields equal to Southern Runner.

Variations in yield between the early and late harvest in 1990 were observed among both the cultivars and the interspecific lines. Among the cultivars, Langley sustained the most reduction in pod yield from 2347 to 512 kg ha^{-1} (Table 2); a result of its short growth duration and high level of disease as compared with that of the other cultivars. Variations in yield loss for the interspecific lines ranged between -24 and 57%. The largest increase in yield was for line 4. Considering that this line had an average pod yield not significantly different (P=0.05) from Southern Runner, it might be concluded that: (a) line 4 is late maturing like Southern Runner, and/or (b) disease pressure was not sufficient enough to prevent line 4 from continuing to partition carbohydrates to the pods, resulting in a better expression of its high yield potential. Similar situations were found for lines 6, 7, 11, 16, and 18. However, the majority of the lines were early maturing as reflected by the overall high yield in early as compared to late harvested tests in 1990.

Except for the 1988 data, rankings of the lines for pod yield did not vary greatly as evidenced by positive and significant (P=0.01) correlations between the 1989 and 1990 data. The coefficients of correlation ranged from 0.57 to 0.74. Nevertheless, there was a significant interaction among lines and years for pod yield.

Table 2. Pod yield (kg ha^{-1}) and percentage pod loss of selected breeding lines and checks at Yoakum, TX, 1988-1990.[a]

Line #	1988 Pod yield	1988 Pod loss	1989 Pod yield	1989 Pod loss	1990-1 Pod yield	1990-1 Pod loss	1990-2 Pod yield	1990-2 Pod loss
	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%
4	1594 d-f	9.4 a-e	799 cd	21.3 b-d	2779 c-e	14.3 b-f	3459 ab	-6.6 fg
6	1406 gh	-4.8 d-f	790 cd	33.5 bc	2432 ef	25.9 a-c	2529 cd	22.9 de
7	1464 f-h	-8.6 ef	788 cd	30.0 b-d	2174 f	12.1 c-f	2399 cd	3.0 e-g
8	1514 e-h	25.0 a	1254 a	-1.1 ef	3782 a	-4.8 f	3311 b	8.3 ef
11	1612 d-f	-11.1 f	1130 ab	-7.3 f	3432 ab	20.9 a-c	3780 a	12.8 ef
16	1354 h	19.3 ab	1089 ab	8.4 d-f	3048 b-d	1.1 ef	3693 ab	-19.8 g
18	1717 cd	9.9 a-e	826 cd	21.6 b-d	2612 d-f	1.2 ef	2741 c	-3.7 fg
19	950 i	-3.6 c-f	656 d	23.5 b-d	2424 ef	35.8 a	2200 de	22.8 de
20	1572 d-g	14.7 a-d	628 de	42.9 ab	2609 d-f	25.2 a-d	1114 g	68.1 ab
22	1859 bc	14.8 a-c	934 bc	32.8 bc	3100 bc	17.6 a-e	2308 d	38.6 cd
24	2300 a	8.3 a-f	910 bc	39.5 bc	2742 c-e	30.2 a-c	1588 f	59.6 bc
25	1523 e-h	18.6 ab	824 cd	38.5 bc	2592 ef	17.4 a-e	1871 ef	40.4 cd
Florunner	1975 b	13.1 a-d	920 bc	40.7 bc	3144 bc	18.9 a-e	1733 f	55.5 bc
Langley	1463 f-h	27.0 a	425 e	63.9 a	2347 ef	33.9 ab	512 h	85.6 a
So. Runner	1581 d-g	3.2 b-f	1215 a	18.6 c-e	3449 ab	5.1 d-f	3774 a	-3.8 fg
VA72R	1660 de	25.3 a	728 cd	25.2 b-d	3474 ab	-66.6 g	1892 ef	9.3 ef
Mean	1523	10.0	870	27.0	2884	11.8	2431	24.6
LSD	175	19.5	230	22.3	450	20.1	400	23.7

[a]Line means are based on four replications except for 1988 (three replications). Means followed by the same letters are not different at P = 0.05 level. 1990 - 1 and 1990 - 2 correspond respectively to 1990 early harvest and 1990 late harvest.

Yield losses were higher in late harvested experiments in 1989 and 1990, as compared to early harvests. Heavy disease pressure and vine deterioration near the end of the growing season might explain these severe losses. Overall, yield loss was more variable among years than either AUDPC or yield. Year to year correlations for this parameter were generally not significant. Significant (P=0.01) correlation of AUDPC scores were found for the 1989 and the 1990 late harvest (r=0.71), and the two 1990 tests (r=0.66).

Discussion

Modifications in the experimental design were made each year with the intention of enhancing the information that could be gained. Seed availability restricted plot size in 1988 and the design chosen was for paired comparisons. This was changed to a split-plot design in 1989 to facilitate data analysis. Potential bias as a result of choice of the appropriate dates for digging was a concern both in 1988 and 1989. Digging when the earlier maturing and more heavily diseased plots seemed necessary because of forthcoming pod loss. This approach penalized the full expression of yield of entries with intact vines as a result of disease resistance. Conversely, delaying digging until optimum for the less diseased plots, as done in 1989, resulted in yield loss from the potential that might have been harvested from the heavily diseased and/or earlier maturing lines. In 1990, duplicate tests without fungicide were planted so that an early and late harvest of all lines could be effected. Rain caused delay beyond optimum for the early entries and digging of the late was delayed to the extent possible to provide the minimal 1 wk difference in digging dates.

Gorbet and coworkers (5) showed that Southern Runner has partial resistance to *C. personatum* but not *C. arachidicola*. The resistance was expressed as a long latent period which was not investigated in this study. Our results confirmed the partial resistance of Southern Runner to *C. personatum*, and indicate that line 16 had equal or less disease than Southern Runner. Line 16 has both resistance to *C. arachidicola* and *C. personatum* as it had low disease ratings in all years. Its disease rating was significantly lower than Florunner. The areas under the disease progress curves for Line 11 were significantly lower than Florunner except in 1989 where only early leaf spot was present. This suggests that this line has resistance to *C. personatum* but its reaction to *C. arachidicola* might be similar to that of Florunner. On the other hand, the AUDPC values of Line 8 were similar to those of Southern Runner indicating a reaction to *C. personatum* similar to that of Southern Runner. It was better for disease than Florunner in all tests indicating a reaction to *C. arachidicola* equal or better than that of Florunner.

It is encouraging that line 16 yielded as much as Florunner and Southern Runner over the 3-yr period and expressed more resistance to *C. arachidicola* and *C. personatum*. Yield is the predominant prerequisite for commercial utilization of interspecific lines. In previous studies, improved disease resistance was reported to be associated with low yield (9), and/or small pod and seed size (18).

Perhaps the principal concern that emerges from this study is the lack of strong correlation between the AUDPC and the amount of pod yield loss. This might suggest that the loss in pod yield was a result not only of these diseases but other factors as well. In 1988, the correlation between AUDPC and pod yield loss was negative and not significant (r=-0.17), while for the other tests, these correlations were positive, and significant (P=0.01) ("r" ranged from 0.44 to 0.58). Consequently, ranking of the lines using the AUDPC values differed markedly from that for yield loss. Line 16 had the lowest AUDPC value, but yet it had the highest numerical yield loss in 1988. Line 11 also had a pod yield loss that did not reflect the amount of disease observed. Backman and Crawford (2) reported that early and late leaf spot levels 2 to 3 wk before harvest were related to dry pod yield in Florunner. The lack of correspondence between AUDPC and yield could be due to differences in tolerance between the lines. This would complicate a combination of the two criteria for classifying these lines. Seed yields, like pod yields, were higher in 1988 than in 1989, a result of seasonal effects and plant condition at harvest. Seed yields were closely associated with pod yields and grade differences resulted only in some rank order differences in pod and seed yields. In 1988, a total of 7 lines yielded more than Southern Runner, which might have been dug before maturity. In 1989, line 8 had better pod yield but the same seed yield as Southern Runner. Shelling percentages were higher in six lines than in Southern Runner. Seed weight for the lines ranged from 45 to 64 g/100 seed. Indications are that good yield and shelling property potentials are present in these lines.

Altogether, these results suggest that genes conditioning early and late leaf spot resistance, high yield, and acceptable shelling percentages were combined in at least one interspecific line. The development of superior leaf spot resistant varieties will require continued crossing and careful selection. Selection of partially resistant, high yielding runner-type segregates with resistance to *C. personatum* equal or superior to Southern Runner should be possible among the interspecific lines. Large populations and rigorous selection might be required for the identification of agronomically acceptable segregates with resistance adequate to consistently negate the benefit of fungicide application.

Acknowledgments

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