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GENOTYPE AND ENVIRONMENTAL EFFECTS ON RESISTANCE TO LATE LEAFSPOT IN GROUNDNUT

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ABSTRACT

Late leafspot caused by *Cercosporidium personatum* Berk. & Curt.) Deighton, is an economically important disease of groundnut (*Arachis hypogaea* L.). Information on the effects of genotype (G) x environment (E) interaction on the disease is , however, limited. The objective of this study was to determine the relative importance of G x E interaction effects on late leafspot. In 1995 and 1996, fifteen advanced breeding lines along with a local check were evaluated in a replicated trial for yield and reaction to late leafspot at Gaya in Niger and Bagauda in Nigeria. Variation among locations within years was significant for pod yield and late leafspot as well as among genotypes. The genotype x year interaction variance for late leafspot was one-fifth the magnitude of the genetic variance while genotype x location variance was larger that the genetic variance. The genotype x year x location variance was two-thirds the magnitude of the genetic variance. Broad-sense heritability was low for pod yield (46%) , high for seed weight (84%) and shelling percentage (86%) and intermediate for late leafspot (53%). The results indicated the need to test breeding lines for resistance to late leafspot in more years and locations. High yielding late leafspot resistant lines were found.

Key Words: Arachis hypogaea, Cercosporidium personatum, disease resistance, breeding

RÉSUMÉ

La cercosporiose tardive causée par *Cercosporidium personatum* (Berk. & Curt.) Deighton, est une maladie économiquement importante de l'arachide (*Arachis hypogaea* L.). La connaissance des effets de l'interaction genotype (G) x environnement (E) sur la maladie est limitée. L'objectif de cette étude était de déterminer l'importance relative des effets de l'interaction G x E sur la cercosporiose tardive. En 1995 et 1996, quinze lignées avancées de sélection en plus d'un témoin local ont été évalués dans un essai répété pour le rendement et cercosporiose tardive à Gaya au Niger et à Bagauda au Nigéria. La variation entre les sites aucours des années était significative pour le rendement en gousses et la cercosporiose tardive aussi bien qu'entre les genotypes. La variance de l'interaction genotype x année représentait le cinquième de la valeur de la variance génétique pendant que celle de l'interaction genotype x site était plus grande que la variance génétique. La variance de l'interaction genotype x année x site représentait les deux tiers de la variance génétique. L'héritabilité au sens large était faible pour le rendement en gousses (46 %), élevée pour le poids des graines (84 %) et le pourcentage au décorticage (86 %), et intermédiaire pour la cercosporiose tardive (53 %). Les résultats indiquent le besoin de tester les lignées de sélection pour leur résistance à la cercosporiose tardive pendant plusieurs années et sites. Des lignées à haut rendement résistantes à la cercosporiose tardive ont été identifiées.

Mots Clés : Arachis hypogaea, Cercosporidium personatum, maladie résistance, sélection

INTRODUCTION

Leaf spots induced by early leafspot (*Cercospora arachidicola*) and late spot (*Cercosporidium personatum* Berk. & Curt.) Deighton, are the most common and destructive diseases of groundnut (*Arachis hypogaea* L.) wherever the crop is grown (Wynne *et al.*, 1991). In West Africa late leafspot has been the more prevalent of the two diseases in the past years, depending on the weather and location. Yield losses of 60 % or more have been reported when fungicides are not used (Waliyar, 1991). The significance of the yield losses, and the difficulties of chemical control in the small scale farm situation typical of most groundnut-growing areas in West Africa have stimulated development of leafspot-resistant cultivars (Nigam *et al.*, 1991). Groundnut haulms are an important source of livestock feed during the dry season. Foliar diseases reduce the vegetative biomass and thus the quality of the fodder. Therefore, groundnut cultivars resistant to the disease would have a dual role of providing pods for human use and fodder for livestock feed.

Laboratory and greenhouse screening methods to determine late leafspot resistance have been proposed (Shokes *et al.* , 1987; Chiteka *et al.*, 1988). However, field evaluation is necessary to determine the value of resistance because many natural variables (e.g. location, temperature, rainfall and humidity) are known to influence the severity of late leafspot (Waliyar, 1993).

Studies on leafspot resistance have reported only partial resistant in the cultivated groundnut. This resistance has been described as rate-reducing (Gorbet *et al.*, 1990). It has been found that late leafspot is controlled by only a few recessive genes. Jogloy *et al.* (1987) reported broad sense heritability for components of resistance to late leaf spot to range from low to moderate (13-68%). Narrow-sense heritability for parameters of resistance was consistently low (0-13%). They concluded that selection for leafspot resistance in early generations was not effective. Iroume and Knauft (1987) in studying early generation selection methods for identification of peanut crosses with combined high yield and disease resistance, concluded that selection for yield under disease pressure was advantageous in developing high yielding, leafspot tolerant genotypes.

High levels of late leafspot resistance have been found in the germplasm (Subrahmanyam *et al.*, 1984). However, the most resistant lines have late maturity and low yields. Past breeding efforts have been hampered by such a strong relationship between leafspot resistance and late maturity. A cultivar having disease resistance, early maturity, high pod and haulm yield would bring more income to the farmers.

Genotype (G) x environment (E) interaction and its effects on progress to selection has been known for many years. The effects of G x E on yield and other agronomic traits in groundnut were reviewed by Kauft and Wynne (1995), but gaps still remain for foliar diseases. This information would be useful for developing effective selection strategies for foliar disease resistance. The objective of this study was to determine the relative importance of G x E interaction effects on late leafspot and document progress made in breeding for resistance.

MATERIALS AND METHODS

Fifteen advanced breeding lines and a widely grown early-maturing cultivar (55-437) were evaluated for yield and resistance to late leafspot disease under natural conditions in 1995 and 1996 at two locations in the savanna zone of West Africa. The 15 breeding lines were selected from an F_6 foliar disease observation nursery based on early maturity, high pod yield and resistance to late leafspot. The trial was conducted at Gaya (lat. 11° 59'N, long. 3° 30'E) in Niger and at Bagauda (lat. 11° 40'N, 8° 30'E.) in Nigeria. Before sowing 100 kg/ha of single superphosphate was incorporated into the soil when ridging. The plots consisted of four ridges and were 4 m long. Spacing between ridges was 0.5 m at Gaya and 0.75 m at Bagauda according to local practice. Spacing between plants on a ridge was 10 cm. Entries were arranged in a 4 x 4 lattice with three replications. Sowing was done manually in June and harvesting in October (Table 1). No fungicides were applied and conditions did not warrant use of insecticides.

Disease assessment was made 15 days before harvest. Visual ratings of each plot were on 1-9 subjective scale, where 1= very highly resistant, 2 = highly resistant, 3 = moderately resistant, 4 =

slightly resistant, 5 = intermediate, 6 = slightly susceptible, 7 = moderately susceptible, 8 = highly susceptible, and 9 = very highly susceptible or plants dead from leaf spot (Pittman,1995)

At harvest, all plants in a plot were hand-lifted. Maturity was indicated by the blackening of the internal shell wall (Williams and Drexler, 1981). Pods were separated from haulms and dried in the sun until constant weight. The pods were later cleaned to remove soil, inert matter and pegs. Shelling percentage was determined from a 200-g sample of pods and seed weight was taken by weighing 100 sound mature kernels from each plot.

The statistical model was a combination of random and mixed effects and is expressed as follows:

$$T_{ijkl} = \mu + Y_i + L_j + YL_{ij} + R_{k\,(ij)} + G_l + G_{yil} + GL_{jl} + GYL_{ijl} + E_{ijkl}$$

where T_{ijkl} was observation of lth genotype (G) in the kth replicate (R) within the ith year (Y) and jth location (L); μ is the overall mean ; YL_{ij}, GY_{il}, GL_{jl}, and GYL_{ijl} were the interactions; and E_{ijkl} was the residual error. GENSTAT (Genstat Committee, 1993) programs and procedures were used for data analysis. To compare relative magnitude of main effects and interaction variances, variance components were estimated using the Restricted Maximum Likelihood (REML) procedure. Broad sense heritability was calculated from the variance components. The computational formula used for heritability was:

$$h^2 = \sigma^2_G / [+\sigma^2_G + \sigma^2_{GY}/y + \sigma^2_{GL}/l + \sigma^2_{GYL}/yl + \sigma^2_E/ryl]$$

where h^2 is the heritability, σ^2_G, σ^2_{GL}, σ^2_{GYL}, and σ^2_E refers to the G, GY, GL, GYL and error variances, respectively; y, l, and r refers to the number of years, locations and replications per location per year, respectively (Nyquist, 1991).

RESULTS

Environmental conditions (rainfall, temperature, and relative humidity) during the crop season in each year were favourable for fungal development. Monthly rainfall was well distributed, with the highest rainfall obtained during August at each location (Table 1).

There were significant differences among genotypes for all traits measured (Table 2). Year effects were highly significant ($P \leq 0.01$) for all traits, while location effects were not significant for late leafspot. The year x location interaction was not significant for late leafspot. The interactions involving genotype (genotype x year, genotype x location, and genotype x year x location) were significant for late leafspot. Variance components of these effects were smaller than the components of main effect genotype (Table 3). The only exception was the variance

TABLE 1. Monthly and total rainfall (mm), relative humidity, temperature sowing and harvest dates during the experiment at Gaya and Bagauda in 1995 and 1996

Rainfall (mm)	Gaya 1995	Gaya 1996	Bagauda 1995	Bagauda 1996
June	138	90	150	81
July	232	200	278	236
August	320	295	221	300
September	24	95	150	90
October	0	20	39	41
Total	714	700	838	853
Average max. Relative humidity (%) in August	85	86	96	97
Average temperature (°C)				
Average maximum	36.0	37.2	28.9	27.8
Average minimum	27.8	28.4	19.2	20.6
Sowing date	26 June	28June	27 June	25 June
Harvest date	10 Oct	17 Oct	15 Oct	15 Oct

component of genotype x location interaction that was larger than the genotype effects. For the agronomic traits, interactions involving genotype were significant for pod yield (G x Y), seed weight (G x L) and shelling percentage (G x L). Broad sense heritability estimates were intermediate for late leafspot, low for pod yield, high for seed weight and shelling percentage.

Means of fifteen genotypes and the susceptible check averaged across years and locations are presented in Table 4. Late leafspot reaction among lines ranged from a 3.9 rating (slightly resistant) for ICGV 92086 to a rating of 8.6 (very highly susceptible) for 55-437. Resistant genotypes were those with a leafspot score of 5 or less. Based on this criterion, 8 genotypes satisfied this requirement.

Pod yield varied from 1.12 t ha^{-1} for ICGV 92086 to 2.52 t ha^{-1} for ICGV 92088 while haulm yield ranged from 2.15 t ha^{-1} for 55-437 to 3.98 t ha^{-1} for ICGV 92083 (Table 4). The range of 100-kernel weight varied from 32.52g (55-437) to 59.02 g (ICGV 92099). Shelling percentage varied from 57.7 to 77.26%. Genotypes, such as ICGV 92081 and ICGV 93093 had low disease scores and yielded more than 2.0 t ha^{-1} of pods and more than 3.0 t ha^{-1} of haulms (Table 3). These genotypes also matured in less than 110 days from sowing at both locations (data not shown). They also had larger kernels than the widely grown c.v. 55-437.

Due to the significant genotype x year interaction for late leafspot score, means for each year and location were summarised separately (Table 5). Genotype reaction to late leafspot was consistent

TABLE 2. Mean squares from analysis of variance of late leafspot (LLS) scores, pod yield, haulm yield, seed weight, and shelling percentage

Source of variation	df	LLS score	Pod yield	Haulm yield	Seed weight	Shelling (%)
Year (Y)	1	68.28**	4.59**	6.17**	279.80**	293.26**
Location (L)	1	3.39	2.91*	1.12**	4360.55**	2210.69**
Y x L	1	0.95	0.00	0.07	709.17**	239.64*
Replication (YL)	8	1.31	0.43	0.60	16.30	37.71
Genotype (G)	15	15.84**	1.72**	2.05**	427.42**	318.34**
G x Y	15	2.86**	0.94**	0.10	28.52	47.25
G x L	15	2.70**	0.29	0.18	46.31*	54.88*
G x Y x L	15	1.77**	0.35	0.48	16.09	49.29
Error	120	0.50	0.23	0.26	26.85	31.99

*, ** significant at P = 0.05 and 0.01 probability level, respectively

TABLE 3. Variance components (± SE) and broad sense heritability ((± SE) estimates for pod yield, seed weight, shelling percentage and late leafspot (LLS)

Parameter+	Pod yield	Seed weight	Shelling %	LLS
σ^2_G	0.070 ± 0.06	30.7 ± 13.12	22.13 ± 10.05	0.671 ± 0.53
σ^2_{GY}	0.098 ± 0.06	2.07 ± 1.99	-0.34 ± 4.16	0.102 ± 0.20
σ^2_{GL}	0.010 ± 0.02	5.04 ± 2.98	0.93 ± 4.49	0.821 ± 0.20
σ^2_{GYL}	0.041 ± 0.04	-3.58 ± 2.27	5.77 ± 6.16	0.423 ± 0.22
σ^2_E	0.226 ± 0.03	26.85± 3.47	31.99 ± 4.13	0.500 ± 0.06
h^2 (heritability)	0.46 ± 102	0.84 ± 102	0.86 ± 107	0.53 ± 107

+ Variance component (σ^2) are genotypes (G), Genotype x year (GY), genotype x location (GL), genotype x year x location (GYL) and error (E)

TABLE 4. Genotype means for late leaf spot (LLS) (scale 1-9), pod yield (t ha^{-1}), seed weight (g), and shelling % averaged over Gaya and Bagauda in 1995 and 1996

Genotype	LLS	Pod yield	Haulm yield	Seed weight	Shelling %
ICGV 91225	5.9	1.80	3.50	46.97	61.68
ICGV 91231	5.1	1.98	3.46	49.40	74.38
ICGV 92100	6.7	1.50	3.07	43.83	62.07
ICGV 92101	6.6	1.86	3.35	52.61	62.63
ICGV 92102	6.5	2.25	3.46	51.91	61.89
ICGV 92103	5.4	1.71	2.97	42.41	62.85
ICGV 92081	4.4	2.05	3.67	50.08	63.93
ICGV 92082	5.5	2.14	3.87	54.41	68.92
ICGV 92083	5.4	1.55	3.97	44.78	62.90
ICGV 92086	3.9	1.12	3.94	44.16	57.68
ICGV 92088	5.7	2.52	3.11	51.13	67.20
ICGV 92092	4.4	1.28	2.63	46.22	68.75
ICGV 92093	4.6	2.35	3.75	45.25	68.33
ICGV 92095	5.0	1.71	3.09	47.39	70.18
ICGV 92099	5.7	1.79	3.16	59.02	64.30
55-437 (Check)	8.6	1.60	2.15	32.52	77.26
SE (±)	0.20	0.137	1.28	1.496	1.633

TABLE 5. Late leaf spot rating (scale 1-9) of fifteen breeding lines and a susceptible check at two locations in 1995 and 1996

	Gaya		Bagauda		
Genotype	1995	1996	1995	1996	Mean
ICGV 91225	6.3	7.0	4.0	6.2	5.9
ICGV 91231	2.3	6.7	4.7	6.8	5.1
ICGV 92100	7.3	8.0	5.3	6.2	6.7
ICGV 92101	7.3	8.0	6.0	5.2	6.6
ICGV 92102	7.7	7.7	5.0	5.8	6.5
ICGV 92103	4.7	5.3	4.7	6.8	5.4
ICGV 92081	2.7	5.7	4.3	5.1	4.5
ICGV 92082	7.0	5.7	4.3	5.0	5.5
ICGV 92083	4.3	6.7	4.7	5.8	5.4
ICGV 92086	2.3	3.7	3.7	5.8	3.9
ICGV 92088	6.0	6.7	4.3	5.8	5.7
ICGV 92092	2.3	4.0	5.3	5.8	4.4
ICGV 92093	2.7	6.0	4.3	5.5	4.6
ICGV 92095	3.0	6.0	4.3	5.8	5.0
ICGV 92099	6.0	6.7	4.3	5.8	5.7
55-437 (Check)	9.0	8.7	8.7	8.2	8.6
SE (±)	0.52	0.41	0.36	0.30	
Mean	5.1	6.4	4.9	6.0	
CV (%)	18	11	13	9	

with some genotypes and variable with others. For example, ICGV 92081, ICGV 92086 and ICGV 92092 had low scores across locations and years, while 55-437 showed the highest score. Averaged over years and locations, ICGV 92081 and ICGV 92093 produced the highest pod as well as high haulm yields and were resistant to leafspot. ICGV 92088 and ICGV 92102 combined high yields with moderate resistance to late leafspot

DISCUSSION

The main effect years was significant indicating differences between years for late leafspot resistance. It is common to have wide differences in late leafspot reaction depending on the year or location (Waliyar, 1993). The significant G x Y interaction observed for late leafspot, indicated that the reaction of genotypes changed significantly from year to year. Similarly, the significant G x L interaction indicated that some genotypes reacted differently to late leafspot at the two locations. The significant three-way interaction (G x Y x L) for late leafspot indicated a differential response to environmental variation that is not accounted for by either year or location. Some genotypes such as ICGV 92102 showed a susceptible reaction at Gaya but moderately resistance at Bagauda in both years (Table 5). On the other hand, some genotypes such as ICGV 91231 were resistant at both locations in 1995 but susceptible in 1996. Disease resistance levels, differences in temperature, rainfall distribution and sowing date can induce conditions that are unique to each year-location combination and may explain in part the causes of the interactions observed. The relative importance of the G x Y and GxYx L interactions for late leafspot indicate that a number of different locations should be used for evaluation of genotypes for resistance to avoid selecting unstable genotypes.

The disease pressure at all locations was high as indicated by the consistent high scores for the susceptible check. Under less disease pressure the magnitude of G x E variance could be different, as the more susceptible genotypes could be rated as stable and the less resistant genotypes could be rated as unstable under less intense disease pressure. However, intense disease pressure is preferable to obtain a true assessment of the level of late leafspot resistance of breeding lines.

The moderate heritability of resistance to late leafspot suggested that G x E interaction for disease severity can be a source of bias in selecting for resistance. However, testing in several environments can increase the ability to select resistant genotypes.

The most resistant genotype (ICGV 92086) produced the lowest pod yield, but ranked second for haulm yield. Such a genotype would be useful in a hybridization program along with genotypes with intermediate levels of resistance that are higher yielding.

The visual rating system used in this study did not allow for identification of specific components of resistance but it proved effective in identifying genotypes combining resistance to late leafspot and high pod yield. This is in agreement with results obtained by Smith *et al.* (1994). The lines used in this study attained physiological maturity in 100 to 115 days from sowing. This combination of leafspot resistance, early maturity and reasonable yield is a significant achievement. Such genotypes will contribute to an integrated disease management (IDM) program.

Overall, the high yielding genotypes averaged 26-36 % greater yield advantage than 55-437. Although there is a need for further improvement, significant progress has been made in the combination of early maturity, leafspot tolerance and high yield performance. Similar results have been reported by Branch and Culbreath (1995) in United States of America. Further sources of resistance to foliar diseases, however, still need to be found to achieve the goal of creating stable higher levels of resistance.

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