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Genotype by Environment Interaction for Cowpea Seed Yield and Disease Reactions in the Forest and Derived Savanna Agro-Ecologies of South-West Nigeria

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Abstract: Eight cowpea varieties were evaluated for two years in two locations within the south-western Nigeria. The locations are Ibadan (forest) and Ilora (derived guinea savanna). The cowpea varieties were evaluated for their field reactions to cercospora leaf spot and brown blotch fungal diseases. The effect of genotype x environment (g x e) interaction on seed yield was also investigated with the aim of identifying location specific genotypes for each of the two environments. Significant location, genotype and g x e interaction effects were observed for seed yield, days to 50% flowering and the cowpea reactions to the two diseases. Significantly higher seed yield was obtained at Ilora with average yield advantage of 64.87% over Ibadan. Average grain yield at Ilora was 1.22 t ha^{-1} while that of Ibadan was 0.74 t ha^{-1}. Incidence and severity of the two diseases were significantly higher at Ibadan than Ilora. Using AMMI analysis, suitable cowpea varieties were identified for each of the two environments. It was observed that cowpea varieties found to be adapted to Ibadan (forest) environment had low yield potential, this calls for the development of high yielding and disease resistant cowpea genotypes suitable for the forest environment.

Key words: Cowpea · genotype · environment · fungal diseases · Nigeria

INTRODUCTION

Genotype by environment interaction is an important consideration in crop improvement since relative performance of genotypes often changes from one environment to another. Genotype x environment interaction reduces association between phenotypic and genotypic values and thus, plant that performs well in one environment may not necessarily perform well in another environment [1]. Year, location and the climatic factors of a place such as rainfall, temperature and soil properties often affect crop production by interacting with disease causing organisms.

Cowpea is an important component of the food intake of the less developed countries of the world because of its high protein content [2]. The crop is susceptible to a range of pathogens whose importance varies with ecological zone. Brown blotch and cercospora leaf spot diseases are the most important fungal diseases limiting cowpea production in south-west Nigeria [3]. Brown blotch is caused by *Colletotrichum capsici* (Syd) Butler and Bisby. The disease is characterized by purple brown discoloration on the pods. Discoloration may also be observed on petioles, leaf veins and peduncles. Pod infections leads to distortion and maldevelopment of the pods [4, 5]. Cercospora leaf spot disease is caused by two fungi namely *Cercospora canescens* Ellis and martia and *Mycospharella cruenta* Lanthanus. It is characterized by irregular reddish lesions scattered all over the foliage. It can lead to severe premature defoliation [6].

Many of the improved cowpea varieties currently cultivated in the country are highly susceptible to these two diseases [3]. For high productivity, a crop variety being considered for recommendation in a particular environment should be resistant or tolerant to the prevailing diseases in that environment. The g x e interaction studies is of paramount importance in the specific environments in which the genotypes are to be grown [7]. Hence the objectives of this study were: (i) to evaluate the field reactions of the eight cowpea genotypes to cercospora leaf spot and brown blotch fungal diseases (ii) to investigate the effect of g x e interaction on seed yield in order to identify suitable

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high yielding cow pea varieties for each of the two environments.

MATERIALS AND METHODS

Eight cowpea varieties were planted in two locations within the south-western Nigeria for two years (2003 and 2004). The two locations are Ibadan and Ilora. Ibadan lies within the humid rainforest zone with latitude/longitude 7° 22' N/3 55'E, while Ilora falls within derived savanna agro-ecology with latitude/longitude 7° 45 'N/3° 55 'C. The cowpea varieties evaluated are IT90K-277-2, IT96D-610, IT84S-2246 and TVx 3236 [all from the International Institute of Tropical Agriculture (IITA)]; others are Ife brown, Ife-BPC and Ife-98-12 [from the Institute of Agricultural Research and Training (IAR and T)] and Erushu which is a local variety.

At each location, each of the eight cowpea varieties was planted in a five-row plot of 3 x 3m, replicated three times at a spacing of 60 x 30 cm. The trials were protected from insect attack by the application of cypermethrin + dimethoate (Sherpa plus) insecticide which was applied at the rate of 50g a.i. /ha three weeks after seedling emergence and twice after anthesis to control insect attack. No fungicide was applied and the fields were kept clean through manual weeding.

Between 6 and 7 weeks after planting the cowpea varieties were observed for the natural development of symptoms of cercospora leaf spot and brown blotch diseases. Incidence of each of the diseases on each cowpea variety was assessed by counting the number of plants showing symptoms of each of the two diseases and expressed as percentages. Disease severity scores used for the two diseases were based on a scale of 1-5. For cercospora leaf spot, 1 = no symptom, 2 = scattered leaf spots not more than 3 spots per leaf on few leaves, 4 = many spots on few leaves, 5 = many spots on most leaves with yellowing and defoliation occurring. For brown blotch disease, 1 = no symptoms, 2 = mild symptoms confined either to the stem or to the base and tip of the peduncle, 3 = stems, leaf veins and pods with moderate blotching but without distortion, 4 = heavy blotching of pods with some distortion, 5 = severe pod damage. Number of days to 50% flowering was also recorded for each variety. At harvest, dry pods from the middle three rows of each plot were harvested together, threshed and seed yield per plot was determined from which seed yield per hectare was estimated.

Data collected were subjected to analysis of variance, Duncan Multiple Range Test and simple linear correlation. In addition, yield data from the two environments (location by year combined) of the eight cowpea varieties were subjected to Additive main effects and multiplicative interaction model (AMMI) analysis using MATMODEL version 2.0 computer package [8] and biplot drawn for the identification of specific genotypes for each of the two environments.

RESULTS AND DISCUSSION

The results of the analysis of variance are shown in Table 1. Number of days to 50% flowering, incidence and severity of cercospora leaf spot disease varied between the two years. Significant location and variety effects were observed for all the parameters. Year x genotype interaction effect was significant for number of days to 50% flowering and the incidence of brown blotch disease indicating that the degree of susceptibility of the cowpea varieties to brown blotch disease differed between the two years. Location x genotype interaction effect was significant for all the parameters except for the number of days to 50% flowering. Year x location x genotype effect was also significant for number of days to 50% flowering, seed yield and incidence and severity of cercospora leaf spot disease. Differential behaviour of cowpea genotypes to varying environments have been reported previously [9, 10].

Average performance of the cowpea varieties and their reactions to the two diseases across the two locations are shown in Table 2. Number of days to 50% flowering ranged between 37.72 to 44.92 days with the local variety (Erushu) being the earliest to flower. The variety IT84S-2246 had the highest seed yield of 1.18 t ha^{-1} with Ife-98-12 having the least seed yield of 0.83 t ha^{-1}. The most susceptible varieties to cercospora leaf spot were Ife BPC and IT84S-2246. The most resistant variety to the disease appeared to be IT90K-277-2 with disease incidence of 5.75% and severity score of 1.67. The cowpea varieties Ife BPC and Ife brown were the most susceptible to brown blotch disease with the percentage incidence of 19.0% and 18.75% respectively.

Number of days to 50% flowering and seed yield in each of the two locations are shown in Table 3. Number of days to 50% flowering ranged between 37.67-44.83 days at Ibadan and from 38.17-45.30 days at Ilora. Seed yields of the cowpea varieties were significantly higher at Ilora than at Ibadan and it ranged between 0.98-1.52 t ha^{-1} at Ilora and 0.61 to 0.93 at Ibadan. The best yielding variety at Ilora was IT84S-2246 while the highest yielding variety

Table 1: Mean square values for cowpea seed yield and disease reactions in two locations

Source of variation	Days 50% flowering	Yield	Cecospora incidence	Cercospora severity	Brown blotch incidence	Brown blotch severity
Year	26.04**	0.00003	2271.76**	10.01**	42.67	0.38
Location	12.04	5.49**	490.51**	7.59**	1107.04**	20.17**
Genotype	63.00**	0.15**	349.7**	2.02**	396.31**	2.45**
Year x Loc	54.96**	0.12	82.51	0.26	9.38	0.04
Year x Gen	15.85**	0.11	36.74	0.44	107.33**	0.35
Loc x Gen	1.23	0.17**	219.20**	1.92**	168.52**	1.05**
Y x L x G	14.76*	0.14**	99.58**	0.55**	13.94	0.16

*, **, Significant at $p<0.05$ and 0.01 respectively

Table 2: Average performance and disease reactions of the 8 cowpea varieties

Variety	Days to 50% flowering	Yield (t ha^{-1})	Cercospora incidence (%)	Cercospora severity	Brown blotch incidence (%)	Brown blotch severity
1 Erushu	37.92e	0.91bc	6.5d	1.58c	9.92c	2.00c
2 IT90K-277-2	44.92a	0.99ab	5.75d	1.67bc	1.58d	1.25d
3 Ife brown	42.75c	0.92bc	16.75ab	2.42a	18.75a	2.75a
4 IT96D-610	43.00bc	1.10ab	17.83ab	2.5a	15.83ab	2.08c
5 IT84S-2246	44.17ab	1.18a	19.00a	2.42a	17.08ab	2.25bc
6 Ife-98-12	41.17d	0.83cd	12.00cd	1.75bc	13.83ab	2.08a
7 TVx 3236	44.67a	0.95bc	13.58bc	2.00b	13.00bc	2.33bc
8 Ife BPC	43.42bc	0.95bc	19.33a	2.58a	19.00a	2.58ab
Mean	42.75	0.98	13.84	2.11	13.63	2.17
SEM	0.24	0.03	0.86	0.06	0.63	0.05

Numbers in the same column followed by the same letter(s) are not significantly different at $p<0.05$

Table 3: Number of days to 50% flowering and cowpea seed yield in each of the two locations Ilora and Ibadan

	Days to 50% flowering		Yield (t ha^{-1})	
Variety	1	2	1	2
1 Erushu	38.17c	37.67d	1.15ab	0.67^{ns}
2 IT90K-277-2	45.00a	44.83a	1.38ab	0.61
3 Ife brown	43.00ab	42.50bc	1.06bc	0.78
4 IT96D-610	43.33ab	42.67abc	1.44a	0.76
5 IT84S-2246	44.83a	43.50abc	1.52a	0.83
6 Ife-98-12	41.00bc	41.33cd	1.05bc	0.61
7 TVx 3236	45.33a	44.00ab	1.17ab	0.74
8 Ife BPC	44.17ab	42.67abc	0.98c	0.93
Mean	43.10	42.40	1.22	0.74
S.E.M	0.39	0.25	0.04	0.03

Numbers in the same column followed by the same letter(s) are not significantly different at $p<0.05$. 1 = Ilora, 2 = Ibadan, ^{ns} = not significantly different at $p<0.05$

at Ibadan was Ife-BPC. The incidence and severity of the two diseases were however higher at Ibadan (Table 4). Average incidence of cercospora leaf spot at Ilora and Ibadan were 11.58 and 16.0% respectively while those of brown blotch disease were 10.23 and 17.02% respectively. The most susceptible varieties to cercospora leaf spot disease at Ilora were Tvx 3236 and Ife-BPC, while IT84S-2246, Ife-BPC and Ife brown varieties were the most susceptible at Ibadan (Table 4). The most susceptible variety to brown blotch disease at Ilora was Ife-BPC while Ife brown, IT96D-610 and IT84S-2246 were the most susceptible varieties to the disease at Ibadan. Ife brown had the highest disease severity score of 3.67 at this location (Table 4). In this study, environment 1 (Ilora) appeared to be higher yielding compared with Ibadan having seed yield advantage of 64.87% with less incidence and severity of the two diseases which favoured cowpea production (Tables 3 & 4).

Although IT84S-2246 was found to be susceptible to the two diseases at the two locations, it was still highly productive; the seed yield potential of this variety reduced the effects of the diseases on the yield. The variety, IT90K-277-2 appeared to possess field resistance to both cercospora leaf spot and brown blotch diseases at the two locations. The actual level of resistance has to be ascertained with artificial inoculation. The local variety Erushu also combined early maturity with high level of field resistance to the two diseases. It would be incorporated into further breeding programme to improve

Table 4: Reactions of the cowpea varieties to cercospora leaf spot and brown blotch diseases in each of the two locations Ilora and Ibadan

	Cercospora incidence (%)		Cercospora severity		Brown blotch incidence (%)		Brown blotch severity	
Variety	1	2	1	2	1	2	1	2
1 Erushu	7.33^{ns}	5.67c	1.66^{ns}	1.50b	9.17bc	10.67c	1.83ab	2.16c
2 IT90K-277-2	7.17	4.33c	1.67	1.67b	1.33c	1.83d	1.17b	1.33d
3 Ife brown	11.00	22.50ab	1.83	3.00a	11.67ab	25.83a	1.83ab	3.67a
4 IT96D-610	13.33	22.33ab	2.17	2.83a	6.33bc	25.33a	1.50ab	2.67bc
5 IT84S-2246	9.83	28.17a	1.67	3.17a	10.50b	23.67a	1.67ab	2.83bc
6 Ife-98-12	10.50	13.50bc	13.50	1.50b	2.00ab	14.67bc	1.83ab	2.33c
7 TVx 3236	17.50	9.66c	2.33	1.67b	10.67b	15.33bc	2.00ab	2.67bc
8 Ife BPC	16.00	22.67ab	1.83	3.33a	19.17a	18.83ab	1.83ab	3.33ab
Mean	11.58	16.10	1.83	2.40	10.23	17.02	1.71ab	2.62
SEM	1.32	1.10	0.09	0.09	0.97	0.81	0.06	0.08

Numbers in the same column followed by the same letter(s) are not significantly different at $p<0.05$, 1 = Ilora, 2 = Ibadan, ^{ns} = not significantly different at $p<0.05$

Table 5: Correlation coefficients of the incidence and severity of the diseases with seed yield

S/N		1	2	3	4	5	
1	Days to 50% flowering	x					
2	Yield	0.16	x				
3	Cercospora incidence	0.02	-0.0	-0.01	x		
4	Cercospora severity	-0.01	-0.10	-0.09	84.0**	x	
5	Brown blotch incidence	-0.07	-0.20*	0.38**	0.43**	x	
6	Brown blotch severity	-0.05	-0.31**	0.40**	0.53**	0.78**	x

*, **, Significantl at $p<0.05$ and 0.01 respectively

its yield potential. Traditional varieties are known to be good sources of desirable characters such as disease resistance.

The results of the correlation analysis are shown in Table 5. All the disease parameters are highly positively correlated ($p<0.01$) with one another. This significant positive correlation between brown blotch and cercospora leaf spot diseases indicate that selection for resistance to either of the disease could result in progress in resistance to the other. Although, the incidence and severity of cercospora leaf spot disease were negatively correlated with seed yield, the correlation was not significant. However, there were significant negative correlations between seed yield and incidence and severity of brown blotch disease indicating that high susceptibility of cowpea to this disease would significantly reduce seed yield. This calls for the cultivation of brown blotch disease resistant varieties in the endemic areas to alleviate yield loss due to the disease. Yield loss incurred from brown blotch disease in northern guinea savannah of Nigeria was estimated to range from 46-75% [11, 12]. The identified resistant variety IT90K-277-2 could be recommended to farmers in the endemic areas. The negative correlation between cowpea seed yield and incidence and severity of the two diseases evaluated was partly responsible for the low seed yield of the cowpea varieties obtained at Ibadan as these diseases were more prevalent in that environment. Other factors that could be responsible for low yield in the forest environment may include rainfall distribution temperature and soil properties.

Table 6: AMMI analysis of variance for cowpea seed yield evaluated in two environments

Source of variation	Degree of freedom	Sums of square (SS)	Mean square	SS%
Total	47	4.55	0.97	
TRT	15	3.83	0.25**	
Gen	7	0.45	0.06*	9.89
Env	1	2.79	2.79**	61.32
G x E	7	0.60	0.09**	13.19
IPCA1	7	0.60	0.09**	
Error	32	0.73	0.02	

*, **, Significant at $p<0.05$ and 0.01 respectively

The results of the AMMI analysis are shown in Table 6. Only one Interaction Principal Component Axis (IPCA) was produced as there were only two environments involved in the analysis. The result showed

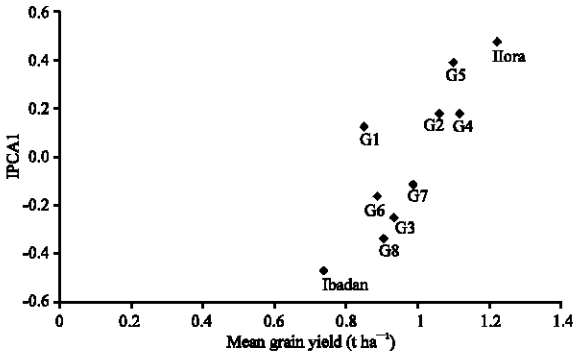

Fig. 1: Distribution of the 8 cowpea varieties between the two sties

that environment (obtained as location by year combined), genotype and genotype x environment interaction were significant for seed yield (Table 6). Environment alone accounted for 61.32% of the total sums of square indicating that differences in yield potential of the two environments was responsible for most of the observed variation in seed yield. While genotype and g x e interaction were responsible for 9.89% and 13.19% of the total sums of square respectively (Table 6). Similar observations have been reported in the past [13, 14]. Each of the two sites exhibited distinct effects on the performance of the cowpea varieties. From Fig. 1, Ilora (derived savannah) was high yielding with positive interaction while Ibadan (forest) appeared to be low yielding for cowpea production with negative interaction. High yielding cowpea varieties IT84S-2246 (G5), IT96D-610 (4), IT90K-277-2 [3] with mean seed yield above the grand mean were more suited to the Ilora environment, while cowpea varieties Ife BPC (G8) and Ife brown (G3) were more adapted to the Ibadan environment. The cowpea variety TVx 3236 (G7), though high yielding, had negative interaction while the local variety (G1) had positive interaction but low yielding. It was observed that the cowpea varieties identified to be adapted to Ibadan environment had low yield potentials. Continuous efforts have to be made to breed for high yielding genotypes with high level of resistance to the prevailing diseases in the forest environment. Although forest environment has low yield potential for cowpea production, farmers in the area still cultivate the crop either as catch crop after the harvest of the main crops such as maize, yam, cassava, etc. or planted in intercrop with the main crops.

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