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FIRST AFRICAN BEAN YIELD AND ADAPTATION NURSERY (AFBYAN I): PART II. PERFORMANCE ACROSS ENVIRONMENTS

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No. 14. Proceedings of the First Meeting of the SADCC/CIAT Working Group on Drought in Beans, Harare, Zimbabwe, 9-11 May 1991

No. 15. First Pan-African Working Group Meeting on Anthracnose of Beans, Ambo, Ethiopia, 17-23 February, 1991.

No. 16. Cinquieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Bujumbura, Burundi, 13-17 Novembre, 1989.

No. 17. Sixieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 21-25 Janvier, 1991.

No. 18. Conference sur Lancement des Varietes, la Production et la Distribution de Semaines de Haricot dans la Region des Grands Lacs, Goma, Zaire, 2-4 Novembre 1989.

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P R E F A C E

Research on common bean conducted by national programmes in Africa in coordination with CIAT is documented in three series of publications containing: the proceedings of workshops; reports of regional activities; and reprints of journal articles.

Here (CIAT African Occasional Publications Series No. 3B), we present our summary and interpretion of the results from the first African Bean Yield and Adaptation Nurseries, carried out between 1986 and 1989. The nurseries were initiated with several objectives: foremost was to establish the basis of an international trials network to facilitate the exchange of common bean cultivars among national programmes; important also was to attempt to classify environments to develop more efficient evaluation strategies and interpret genotypic performance in terms of environmental features.

The data from individual trials were reported in Part 3A of this document. In Part 3B various methods of analysis are applied to the combined data.

The trial series was conducted by national programme staff. Regional organisation was due to: the CIAT Regional Programme on Beans in Eastern Africa, Debre Zeit, Ethiopia; the Southern African Development Community/Centro Internacional de Agricultura Tropical (SADC/CIAT) Regional Programme on Beans in Southern Africa, Arusha, Tanzania (the bean component of the Grain Legume Improvement Programme of the Southern African Centre for Cooperation in Agricultural Research and Training (SACCAR)); and the Programme Regional pour l'Amelioration du Haricot dans la Region des Grands Lacs, Butare, Rwanda. Funding was provided by: national programmes; the Canadian International Development Agency (CIDA); the Swiss Development Cooperation (SDC); and the United States Agency for International Development (USAID).

Further information on research activities on bean in Africa that are part of these projects is available from:

Pan-Africa Co-ordinator, CIAT, P.O. Box 23294, Dar es Salaam, Tanzania.

Coordinateur Regional, CIAT, Programme Regional pour l'Amelioration du Haricot dans la Region des Grands Lacs, B.P. 259, Butare, Rwanda.

ACKNOWLEDGEMENTS

The efforts of those who allocated time and resources to conduct the trials reported in this document are gratefully acknowledged.

The institutions and addresses are listed below and in Appendix 3 of Part 3A.

Melkassa	I.A.R. Station, Melkassa, P.O. Box 103, Nazret, Ethiopia.
Antsirabe	Fifamanor, B.P. 198, Antsirabe 110, Madagascar.
Kachwekano, Kawanda, Kisindi	Kawanda Research Station, P.O. Box 7065, Kampala, Uganda.
Rubona	ISAR Station, Rubona, B.P. 138, Butare, Rwanda.
Mulungu	INERA, Mulungu, DS Bukavu, Kivu, Zaire.
Msekera, Mbala	EPAD Project, Msekera Regional Research Station, P.O. Box 510089, Chipata, Zambia.
Selian, Irente	TARO Station, Lyamungu, P.O. Box 3004, Moshi, Tanzania.

Acknowledgements are also due to Mr. Thadeus Chikoti for assistance with data analysis and table preparation and to Ms. Eva Ngalo for word processing.

CONTENTS

GLOSSARY

Abbreviations

Environments

MEL87	Melkassa, 1987
FIF88	Antsirabe, 1988
KAC7F	Kachwekano, first season, 1987
KAW6S	Kawanda, second season, 1986
KAW7F	Kawanda, first season, 1987
KIS7F	Kisindi, first season, 1987
MUL7F	Mulungu, first season, 1987
MSK87	Msekera, 1987
MSK88	Msekera, 1988
MBA88	Mbala, 1988
SEL89	Selian, 1989
SEL89B	Selian, inoculated, 1989
IRE89	Irente, 1989

Plant characters

CH	Canopy height (cm)
CW	Canopy width (score)
DFF	Days to 50% flowering
DM	Days to 85% maturity
STH	Stand at harvest
PM2	Pods/m^2
SPP	Seeds/pod
SW	Weight of 100 seeds (g)
SY	Seed yield (kg/ha)

Diseases

Anth	Anthracnose
ALS	Angular leaf spot
ALT	Alternaria blight
AB	Ascochyta blight
RR	Root rots
WB	Web blight
FLS	Floury leaf spot
WM	White mould
CBB	Common bacterial blight
HB	Halo blight
BCMV	Bean common mosaic
BR	Black root
PSB	Pod sucking bugs

INTRODUCTION

The performances of entries in the African Bean Yield and Adaptation Nursery (AFBYAN) in individual environments were summarized by Smithson (1990). The objectives of the AFBYAN I were:

1. to establish the basis of a regional nursery network;

2. to facilitate exchange of promising materials;

3. to aid in classification of ecological zones; and

4. to interpret variation in performance of genotypes in terms of physical and biotic factors.

In order to achieve objectives 3 and 4, collaborators were requested to collect and provide data on various plant and environmental characters and seed yields. For the original entry set (AFBYAN I), there are data from 14 trials. Following similar studies, entries are termed genotypes (G) and trials, environments (E), so that the interaction between them is the G x E interaction.

Changes in relative rankings appear to be an inevitable consequence of growing a set of plant genotypes in even a few locations or seasons. This is especially true in tropical, economically developing regions where not only are environmental fluctuations greater but also crops lack the protection conferred by purchased inputs. The phenomenon, termed G x E interaction, is a major problem for plant breeders and growers. For plant breeders, large G x E interactions impede progress from selection and have important implications for testing and cultivar release programmes. Although many different statistical procedures have been employed to measure and characterise G x E interaction in breeding trials, there have been few attempts to explore its nature and causes.

Pooled analysis of variance partitions the total variation into components due to E, G, their interaction and the residual, thus quantifying the proportion that each contributes and providing tests of their statistical significance. However, the analysis helps little in the interpretation of the main effects and interactions, the latter becoming complex where more than just a few environments and genotypes are concerned.

An important aspect of G x E interaction is stability of performance. Stability can be measured simply in terms of small among-environment variance but a more fashionable method has been to regress the yields of individual genotypes on environment mean yields. This method was first proposed by Yates and Cochrane (1938) more than half a century ago; applied to barley trials in Australia by Finlay and Wilkinson (1963); and extended to include deviations from regression as well as regressions on environment mean yields as stability parameters for maize trials in the U.S.A. by Eberhart and Russell (1966). Regression methods have since been applied by Jinks and others (see, Freeman, 1973) to examine the inheritance of stability and their bases have been discussed recently by Lin *et al.* (1986).

Regression methods suffer from problems of interpretation and concept (Lin et al. 1986; Smithson and Gridley, 1991). One important danger is that a large proportion of genotypes of similar origin and performance may weight the environmental index to the extent that other genotypes appear less stable when, in fact, they merely differ in stability characteristics. Another is that a simple linear regression response is often assumed which, in the biological context, is improbable. Lin et al. (1986) advocated the use of cluster analysis, which does not suffer from this restriction, for the study of genotype response characteristics.

Though both approaches can assist the planning of breeding, testing and cultivar release programmes, neither provides information that enables breeders to properly quantify the factors contributing to variation in performance across a series of environments and the nature of genotypic responses to these factors. To do this will require a multiple regression approach involving those features of the environment and the plant characteristics known to be important in determining bean yields.

Resources did not permit complete measurement of most plant and environment characteristics, so those requested were a compromise between comprehensiveness and feasibility. The plant characters recorded were all associated with seed yields: either directly (such as stand count and yield components); or indirectly, through the adaptation of genotypes to environments (crop growth, time to flowering and maturity and disease reactions). Canopy height and width were measured to provide an easily recordable but objective estimate of crop growth, as an alternative to vigour scores which are subjective and not comparable across environments.

Soil moisture and fertility, temperature, photoperiod, diseases, insects and weeds probably exert most influence on crop development, growth and yield. Rainfall in presowing, vegetative and reproductive periods were used as indicators of soil moisture. However, soil moisture is also a function of land conformation, soil texture and depth and rainfall intensity. Information on these factors were not available. Also, because actual records were not available across all environments, long term averages of both rainfall and temperature were used in some cases. While less than ideal, long term averages should provide a first approximation of actual weather conditions. Soils were classified using available knowledge of chemical composition, CEC and pH. The photoperiod at sowing variable was derived using sowing date and latitude information.

The disease index was the average of the largest genotype mean score for each of the five most severe diseases in each environment. Insect damage was seldom rated and was thus omitted, even though insects, especially bean stem maggots, are known to be important causes of crop loss of bean in Africa. Weed cover was also not rated but may be an important variable because management differed across the environments studied.

Presumably, any of these factors may contribute to differences in yield and other plant characters across a set of environments, with their relative importance changing with circumstances. Provided that important environmental variables influencing plant performance can be measured with sufficient accuracy, it should be possible to quantify their relative importance by regressing seed yields (and other plant characters) on them.

Further, G x E interactions presumably occur because genotypes react differently to one or more of the features of the environments in which they are grown. For example, if Genotype A differs from B only in its ability to tolerate drought stress then A should outperform B in drought environments but behave similarly in non-drought environments and will be reflected in an interaction between the two genotypes and their environments. The regression of the yields (and other characters) of the two genotypes separately on appropriate measures of the environment including drought stress should result in different coefficients for drought stress. This argument can obviously be extended to other genotype:environment relationships.

Here, we examine ways of providing such information using data from the AFBYAN I trial series. First, we apply conventional methods of analysis including: pooled analyses of variance to estimate the E, G, G x E and residual components of the total variance of each variable to assess the importance of G x E interaction; two-way pattern analysis to group environments and genotypes according to seed yields; and stability analysis. We then use less conventional methods to examine the nature of G x E interaction including: partitioning the variations among environments, genotypes and their interaction in various ways; and regressing plant characters on environmental features considered to be important in determining crop growth and yield.

MATERIALS AND METHODS

Genotypes

Some of the 25 genotypes were included due to problems of providing adequate amounts of seed of all the entries originally proposed. Several were 'Calima' types, determinate with medium to large red seed with cream flecks. Four entries were not grown in all trials, so were omitted from combined analyses. These were: BAC 76 (replaced by a local check at Antsirabe in Madagascar); Nain de Kyondo (replaced by Canadian Wonder in the inoculated trial at Selian and at Irente in Tanzania); and Mbala local (replaced by Masai Red in all three Tanzanian trials). The remaining 21 genotypes are listed in Table 1, together with their countries of origin and seed and plant types.

Environments

The environments from which data were obtained are listed in Table 2, together with selected environmental features considered to be important for bean growth, development and yield. They include: sowing dates, latitudes, photoperiods and altitudes (all of possible phenological importance); soil classes (SC) (on a scale of 1-9, where 1 is the least and 9 the most fertile); and disease index (DI) (mean of five largest mean disease scores in each environment, to provide a measure of disease severity).

Rainfall and temperature data during the vegetative (sowing to mid-flower) and reproductive (mid-flower to maturity) periods and rainfall during one month prior to sowing are given in Table 3. Except for Antsirabe, Mulungu, Msekera in 1987 and the two trials at Selian in 1989, these data are based on long term means and thus may diverge from conditions during the actual growing seasons considered here.

Experimental design and layout and data collection

The experimental design and layout and the data collected were described in Part A. Briefly the trials were 5 x 5 triple lattices with three replicates and plot sizes of 4 rows of 4 m length, the centre two of which were used for data collection. The crops were grown according to local practice, including time of sowing, spacing and fertilizer application.

The plant character data requested were: canopy height and per cent ground cover at flowering (the latter was converted to cm of canopy width to derive the variable canopy size, which is canopy cross-sectional area); the number of days to flowering and to maturity; stand at harvest; and disease scores (on a 1-9 scale). Seed yields were recorded and the yield components (pods/m^2, seeds/pod and seed size) were estimated from a sample of 30 pods from each plot.

Data analysis

The methods used to investigate the performances of genotypes across environments were:

Pooled analysis of variance. Pooled analysis of variance was computed for each variable in the form of a split plot analysis with replicates as main plots and genotypes as sub-plots. Because their error variances were heterogeneous, seed yields in kg/ha were also weighted by the reciprocals of their standard errors. The denominator for the F test of the E mean square was the pooled reps and reps x E terms. The G mean square was tested against the G x E mean square and the G x E mean square against the sub-plot error term.

Cluster analysis. Environments and genotypes were clustered by two-way classificatory analyses of seed yields using Ward's (1963) agglomerative, hierarchical minimum variance method and the E, G and G x E interaction sums of squares were partitioned into components due to the variation among and within clusters in the manner of Byth *et al.* (1976). See Everitt (1980) for a summary of methods of cluster analysis.

Stability analysis. The stability of seed yields was explored using the method of Eberhart and Russell (1966) by which the mean yield of each genotype in each environment is regressed on indices derived from the environment mean yields. The significance of the divergence of each regression coefficient (b) from unity is determined by comparison with the standard error of the deviations from regression by standard 't' tests. The significance of the deviation from regression is tested by comparison of their deviation mean squares with the pooled error mean square by means of 'F' tests.

Hierarchical partitioning. Plant characters and environmental features determining seed yields were examined by partitioning the G and G x E sums of squares into components due to plant type (I, II and III) and seed size (S, M and L) and the E and G x E sums of squares according to altitude and latitude or rainfall and temperature.

Multiple regression. Multiple regressions of plant characters on various combinations of environmental features were investigated using the model:

$$Y = a + B_1X_1 + B_22X_2 + \ldots + B_nX_n + e$$

where: Y represents an individual plant character variable; a is the Y axis intercept; B_1-B_n are the regression coefficients of the environmental variables X_1-X_n; and e is the error. The dependent and independent variables are identified below in the section on multiple regression.

RESULTS

Pooled analysis of variance

Mean squares were significantly greater than zero for all variables in the case of environments and for all except anthracnose score, in the case of the G x E interactions (Table 4). The genotypes mean squares were significantly greater than zero except for stand at emergence and anthracnose scores.

Environments accounted for the major part of the total variation of all plant characters except seeds/pod and seed size and of the disease scores for anthracnose, rust and BCMV (Table 5). In general, the proportion contributed by genotypes was similar to or less than that of the G x E interactions except for seeds per pod, seed size and BCMV score.

The weighting of seed yields by the reciprocals of the individual environment standard errors tended to inflate the environmental component at the expense of the others but did not materially change the overall pattern.

Variable means

Tables 6-20 are two-way tables of environment and genotype means for the different variables. In this section, we will consider only the environment and genotype means as interactions are difficult to interpret with 21 genotypes grown in up to 14 environments and will be described in a subsequent section.

Days to flower. Days to flower were recorded in 11 environments (Table 6). They ranged between 35.2 in MSK88 and 60.2 in KAC7F. Kilyumukwe (38.2 days) and Muhinga (38.8) flowered earliest and Carioca (47.5) and G 13671 (46.5) were latest to flower.

Canopy heights. Canopy heights were measured in 11 environments (Table 7). They ranged between 19.2 cm in MBA88 and 43.2 cm in MEL87. G 2816 (30.8 cm) and Black Dessie (31.2) were the shortest genotypes and G 2470 (41.2 cm) and A 197 (37.3) were the tallest.

Canopy widths. Canopy widths were recorded in 13 environments (Table 8). They were least in MUL7F (23.3 cm) and greatest in FIF88 (44.8). Among genotypes, Calima and PVA 1272 produced the narrowest canopies (29.9 cm) and Red Wolaita and G 13671 (39.9 cm) were the widest.

Canopy size. Canopy sizes were calculated for 11 environments (Table 9). They were largest in FIF88 (1.70 m^2), MEL87 (1.67) and SEL89A (1.64) and significantly smaller than all other environments in MBA88 (0.47 m^2), MSK88 (0.55) and MUL7F (0.72).

Days to maturity. Days to maturity were recorded in seven environments (Table 10). They were shortest in MEL87 (68.4 days) and longest in FIF88 (120.8 days). PVA 1272 (85.4 days) matured earliest and Black Dessie (91.6 days) was latest.

Yield components. Yield components were estimated for 11 environments (Table 11).

Pods/m^{-2} were fewest in MSK88 (23.4 m^{-2}) and most in SEL89A (260.2) (Table 11). Among genotypes, G 2470 (72.3 $^{-2}$) and PVA 563 (79.6) produced the fewest pods and Carioca (160.6) and Black Dessie (158.3) produced the most.

Seeds/pod were fewest in MBA88 (2.08) and most in FIF88 (3.85) (Table 12). T 23 (2.61) and Kabanima (2.69) produced the fewest seeds/pod and T 3 (4.76) and Carioca (4.57) produced the most.

Seeds were smallest in MBA88 (293 g/1000 seeds) and largest in SEL89B (511 g) (Table 13). Among genotypes, Black Dessie (216 g/1000 seeds) and Carioca (224 g) produced the smallest seeds and A 197 (519 g) and G 2470 (516 g) produced the largest.

Seed yields. Seed yields were recorded in all 14 environments (Table 14). They were heaviest (3447 and 3032 kg/ha) in the two trials at Selian in 1989 and smallest in MSK88 (169 kg/ha) and MBA88 (270 kg). G 2816 (1638 kg/ha) and Carioca (1601 kg) produced the heaviest yields and Muhinga (1056 kg/ha), PVA 880 and Kabanima (1163 kg) were the poorest yielders.

Disease scores. Although anthracnose was recorded in five out of the 11 environments where diseases were rated, it was never severe and differences among genotypes were not significant (Table 15).

Angular leaf spot was most severe and second most prevalent (eight environments) of the diseases rated (Table 16). It was worst at KAC7F (6.32), KAW6S ((5.73) and MUL7F (5.37). There were significant differences among genotypes with Carioca (3.13) showing the smallest mean score and Urubonobono (5.13) and Red Wolaita (5.04) the most severe disease.

Rust was recorded in seven environments but was not severe except in certain environment:genotype combinations (Table 17). Severity ranged between 1.10 in IRE89 and 3.25 in KAW6S. Red Wolaita (3.52), T-3 (3.38) and T-23 (3.05) showed the most severe scores and Carioca (1.29) appeared most resistant with a maximum score of 2.33 in KAW6S.

Common bacterial blight was the most prevalent disease, occurring in nine environments, but was severe only in individual genotypes in KAW6S (mean 4.94), KAC7F (3.83) and MEL87 (3.33) (Table 18). Among genotypes, PVA 880 (2.33) and Carioca (2.44) were least affected and G 2816 (3.74) and T-3

(3.59) showed most severe symptoms.

BCMV was recorded in five environments but was severe only in certain genotypes in the three trials in Zambia (MSK87, MSK88 and MBA88) (Table 19). T-3 (4.87) and Red Wolaita (4.60) were rated most severely affected and A 197 and ZPv 292 (1.13) expressed the least symptoms.

Ascochyta blight was recorded in four environments but was severe only in KAC7F (4.32), MUL7F (3.30) and MBA88 (4.02) (Table 20). Overall, G 13671 had the largest score (4.42) and ZPv 292 (1.92) was least affected.

Other diseases (floury leaf spot, white mould, alternaria blight, root rots and halo blight) were only locally severe.

Cluster analysis

Cluster analysis of seed yields distinguished four environment (ECGs) and eight genotype clusters (GCGs) (Figures 1 and 2; Table 21). Their means are shown in Table 22.

Clustering accounted for 96.1% of the variation among environments but only 31.1% of the G x E interaction. Differences within clusters were still highly significant for ECG 3 and ECG 4 (Table 23). Environment mean yield accounted totally for the separation. Apart from two trials sown a few days apart in the same field at Selian in 1989, which occurred together in ECG 4, there was little sensible about the composition of the environmental clusters. Trials at the same location in different years or seasons fell in separate clusters and there was little obvious association between climatic and other features of environments and their grouping.

The genotype clustering accounted for 83.5% of the variation among genotypes and, in contrast with the environment clustering, 77.1% of the G x E interaction. As expected from the method used, clusters tended to be related to genotype mean yields. The major discontinuity involved GCGs 1 (1519 kg/ha), 7 (1601 kg) and 8 (1638 kg) and the remaining clusters (1218-1302 kg/ha). In the heavy yielding group, GCG 1 and 7 fused earlier than GCG 8. Among the poor yielding clusters, grouping was not so obviously associated with mean yields, so must have also reflected differential responses to environments. GCGs 4 (1224 kg/ha), 5 (1218 kg) and 6 (1302 kg) fused first, followed by GCG 2 (1231 kg/ha) and then GCG 3 (1272 kg). Moreover, there was near complete overlap of the yields of the genotypes in most clusters.

The genotype cluster composition was quite closely related to plant type, seed size and origin. All genotypes in GCGs 2 and 5 were Plant type (PT) I with medium to large seeds and in GCG 3 were all PT IIIb with small seeds, two of which (Black Dessie and Red Wolaita) are from Ethiopia and the third (T 3) is so similar in morphology to Red Wolaita that they are probably identical. GCGs 7 and 8 each comprised a single genotype (Carioca and G 2816), which were the overall second and largest yielders, respectively. GCGs 1, 4 and 6 each comprised genotypes of varying plant type and seed size, though groups 1 and 4 involved genotypes grown or performing well in the Great Lakes Region. The two genotypes in GCG 6 (K 20 and ZPv 292) were bred in or originated from the same area of Uganda.

Stability analysis

The regression coefficients, coefficients of determination (r^2) and standard errors of deviations from regression (s_b) for the 25 entries are shown in Table 24.

Various responses were exhibited among genotypes in AFBYAN I. Most had b values not significantly different from unity and deviations from regression not significantly greater than zero - for example, PVA 563 (Figure 3). Two genotypes (PVA 1272 and Muhinga), exhibited b values significantly smaller than unity (Figure 4). G 13671 had a b value greater than unity (Figure 5) and two genotypes (G 2816 and Carioca) had deviations from regression greater than zero (Figures 6 and 7). Since ten of the 21 entries were PT I and eight of these Calima types, the environmental indices must be heavily weighted by their reactions to environments and it is not surprising that only one of that particular group (PVA 1272) diverges significantly from the index.

The results conform nicely with the genotype groupings produced by the cluster analysis. GCGs 1 and 6 genotypes were characterised by b values tending to be greater than unity; GCG 2 genotypes showed b values tending to be less than unity; and GCG 3 and 5 had b values near unity. Carioca (GCG 7) and G 2816 (GCG 8) differed from the other genotypes by their larger deviations from regression. GCG 4 was most diverse, involving three genotypes with b values close to unity and Muhinga, with a b value less than unity. Interestingly, GCG 4 was also one of the more diverse in plant character and showed the largest within group variation for seed yields.

Components of E and G x E interactions mean squares

Partitioning of environments according to rainfall, temperature and soil class revealed that most of the variation among environments was among the low, medium and high rainfall groups (38.9%) and within the medium rainfall group (52.5%), the latter arising principally from variation among soil classes in the medium temperature group (34.3%) (Table 25). Similar partitioning of the G x E sums of squares did not distinguish major sources of variation, which appeared to be spread evenly across environments.

Components of G and G x E interactions mean squares

The mean squares from the partitioning of the G and G x E sums of squares for seed yields according to plant type and seed size confirmed the importance of plant type and seed size apportioning most of the G component among rather than within groups (Table 26).

Although there were no significant differences in seed yields among the three plant types (I, II and III), there were very highly significant interactions among plant types and environments. These were mainly due to the comparison of Plant Type (PT) I genotypes with PT II and PT III, PT I genotypes yielding worse than PT II and PT III genotypes in KAW6S, KAW7F, SEL89A and SEL89B and better in RUB7F (Table 27).

There were also highly significant differences among PT I genotypes, arising mainly from among the large-seeded genotypes. The interactions among

PT I genotypes and environments were highly significant; in this case arising entirely from within the group with large seeds. Most of these interactions arose from among rather than within cluster groups.

The two PT II genotypes (Carioca and Kilyumukwe) did not differ significantly in seed yield but displayed highly significant interactions with environments; Carioca yielding better than Kilyumukwe in FIF88, KAW7F, SEL89A and SEL89B and less well in KAC7F, KIS7F, RUB7F and IRE89.

Differences among PT III genotypes were highly significant, with the majority of the variation occurring among the medium-size seeded group comprising G 2816 and Muhinga, the largest (1638 kg/ha) and smallest (1056 kg) yielders in the trials. Differences among seed sizes and within the small and large-seeded groups were not significant. There were also highly significant interactions with environments, arising from comparisons of the response of the small with the medium and large-seeded groups and within the medium and large-seeded groups. There were no significant interactions of environments within the small-seeded group (Red Wolaita, Black Dessie and T-3), which formed GCG 3.

Multiple regression

Among the environmental variables, there were large correlations between total seasonal rainfall and rainfall during other periods, among the different measures of temperature and with some combinations involving photoperiod (Table 28), so the regression variables were confined to presowing, vegetative and reproductive period rainfall, mean temperature, soil class and disease index.

The R^2 values from the multiple regressions of seed yield and its components (pods/m^2, seeds/pod and seed size) and canopy size of each of the 21 genotypes on these six environmental variables are shown in Table 29 and the individual regression coefficients in Tables 30-35. The genotypes are arranged according to clusters and the order in which they fused to facilitate inspection for similarities in environmental responses. In oder to more easily examine the relationships between yield and its components, the regression coefficients are presented by independent (environmental) variable. Thus, the coefficients for the regressions of seed yield on the six environmental variables are found in the first column of Tables 30-35. Similarly for canopy size and the components of yield.

The regressions accounted for up to 79% of the variation in seed yields and 89% of that in pod numbers (Table 29). Although there was no clear association of R^2 values with GCGs for seed yields, in the case of pod number, the R^2 values tended to be largest in members of GCGs 1, 3 and 5 and least in GCGs 2, 4, and 8. R^2 values were less for other plant characters. For seeds/pod they ranged from 0.31 to 0.79 and for seed size from 0.27 to 0.79, there being two genotypes not significantly greater than zero for both characters. There was no obvious relationship between R^2 values and GCG. For canopy size, R^2 values were significant in only four genotypes.

Soil class. Seed yields increased from 172-415 kg/ha for each unit increase in soil class (Table 30). Although all genotypes responded significantly, there were differences among them. Notably, G 2816 displayed a significantly larger b coefficient than most other genotypes while Carioca, the second largest yielder in the trial, and G 13671 (the fourth), also exhibited large b coefficients. The latter two genotypes also showed the largest b values in the stability analysis. Similarly, the members of GCG2 (PVA 1292, T-23, Calima and PVA 880) exhibited consistently small coefficients for soil class and in the stability analysis.

The effects of soil fertility on yields appeared to be mainly through pod number, which increased by 19.4-48.7 pods/m^2 for every unit increase in soil class. The response was greatest in Carioca (48.7 pods/m^2) and G 13671 (39.4 pods) and other members of GCG1. For seeds/pod, coefficients were significant in eight genotypes (0.18-0.35 seeds/pod for each unit increase in soil class) and, for seed size, in ten genotypes (17-50 g/1000 seeds).

These results suggest that soil fertility was an important determinant of crop yield (and thus environment index) and a contributor to G x E interaction in these trials.

Presowing rainfall. Seed yields were apparently unrelated to presowing rainfall except for G 2816, in which they fell significantly (40 kg/ha for every mm) with increasing rainfall (Table 31). The pods/m^2, seed weights and canopy sizes of all genotypes decreased with increasing presowing rainfall, the decreases in pod numbers and seed sizes being significant in most genotypes. Reductions in canopy size were significant in only four genotypes - Black Dessie, Red Wolaita (both members of GCG3), G 12470 and G 2816. Presowing rainfall might *a priori* be expected to benefit crop growth and yield by increasing the quantity of water in the soil profile but excessive rainfall could also be detrimental to emergence and early crop growth.

Vegetative period rainfall There was little association between rainfall during the vegetative period and any of the crop characteristics recorded (Table 32). The exception was seeds/pod, which fell significantly (by 0.42-1.05/pod for every mm of rainfall) with increasing rainfall, except in G 2816 and members of GCG3.

Reproductive period rainfall. Seed yields fell 0.77-7 kg/ha for every mm of rainfall recorded during the reproductive period (Table 33). The fall was significant in all but three genotypes - these were Kilyumukwe and A 197 (both members of GCG4) and G 2816, which appeared least affected. The coefficients for other characters were rarely significant, except for pod number, where they were all positive. G 2816 was also conspicuous by a large increase in canopy size (31 cm^2) and a large decrease in seeds/pod (1.03) for every mm increase in reproductive rainfall. Increasing rainfall during the reproductive period may be expected to reduce yields by producing conditions less favourable for pod ripening and more favourable for disease development.

Mean temperature. Seed yields fell significantly with increasing mean temperature (99-144 kg/ha with every ^{o}C) in only four genotypes, associated with significant decreases *in pod numbers (86-189 pods/m^2) in all genotypes* and in seed size (9-34 g/1000 seeds) in 11 genotypes (Table 34). These decreases were countered by largely significant increases in seeds/pod. Canopy sizes decreased significantly with increasing temperatures in two genotypes (Black Dessie and G 2816) from 7.4-12.5 cm^2 for every ^{o}C. G 2816 was *again conspicuous, its seed yield* and canopy size falling and its seeds/pod increasing with increasing temperature more than those of other genotypes.

Disease index. Disease index was rarely significantly associated with any of the plant characters recorded (Table 35). The seed yields of Kirundo and A 197 increased significantly by 167 and 176 kg/ha per unit increase in disease index, respectively. Both were in GCG4, the other two members of which also displayed large, positive coefficients, accompanied by large, positive coefficients for pod number and seeds/pod. Positive associations between seed yields and disease pressure are obviously spurious, perhaps due to the disease index behaving as a proxy for other factors. Over all, there is little evidence for diseases being important causes of crop loss in common bean in these trials. Whatever the factors involved, the large swings in coefficients from positive to negative could have made important contributions to G x E interaction.

DISCUSSION

Environments

Combined analyses of variance revealed that environments and the interactions due to G x E interaction accounted for much larger proportions of the variation in seed yields and other plant characters than genotypes. Partitioning of the environment sums of squares showed that rainfall and soil class (in the medium rainfall zone) accounted for most of the variation in yields among environments. The results of the multiple regression estimates were in agreement, with yields increasing significantly with soil class and decreasing with increasing reproductive period rainfall. Clustering environments according to seed yields substantially reduced the E component: however, inspection of the groups revealed no obvious relationship with environmental features. Furthermore, clustering removed only a small proportion of the E x G component and partitioning identified no major source of variation, so these data provide no basis for stratifying environments for testing purposes.

Genotypes

Clustering genotypes according to seed yields substantially reduced the G and G x E variations and distinguished groups differing principally in plant type and seed size. Partitioning of the G and G x E components showed that plant type accounted for most of the variation. Stability characteristics were also related to plant type. Genotypes diverging most from environmental indices fell in the PTII and PTIII groups and so their responses differed from PTI genotypes. Because environmental indices would have been heavily weighted by PTI genotypes we can conclude only that the two groups differed in stability and not that the PTI group was more stable than PTII and PTIII genotypes.

The genotype, G 2816, diverged most conspicuously from the other genotypes. G 2816 is PTIII with a medium-size seed: it yielded heaviest overall, appeared alone in GCG 8 and deviated significantly from the environmental index. Carioca was the second most divergent. It is PTII with a small seed: it was the second largest yielder overall, it occurred alone in GCG 7 and, like G 2816, its yields deviated significantly from the environmental index. The genotypes in GCG 3 (Red Wolaita, Black Dessie and T-3) were also clearly distinguishable from those of other groups. They were the only genotypes combining semi-climbing growth habit with small seed size and they produced similar, smaller than average yields.

Do the multiple regressions on environmental variables offer any explanation for the genotypic responses to environments? The regressions accounted for large and significant proportions of the variation in yield and its components (though not in canopy size) of most genotypes. Seed yields increased with increasing soil class (as a measure of soil fertility) and decreased with increasing reproductive period rainfall. The effects of soil fertility appeared to be mainly associated with pods/m^2 though seeds/pod and canopy and seed size were also increased in some genotypes. The relationships between reproductive period rainfall and components of yield were inconsistent and usually not significant: as rainfall increased, pod numbers tended to increase and seed numbers decrease.

Only in a few genotypes was there evidence of a relationship between seed yields and rainfall in the presowing and vegetative periods, mean temperature or disease index, although some yield components were affected. Pod numbers and seed sizes tended to fall with increasing presowing rainfall and the number of seeds/pod became fewer with increasing vegetative rainfall: there was no obvious explanation for these relationships. Pod numbers and seed sizes also fell with increasing temperature, which conforms with accepted knowledge of the adaptation of common bean, compensated by increases in seed numbers.

But it is the differences among the reponses of the genotypes to the environmental variables that are important in relation to G x E interaction. Again G 2816 exhibited the greatest divergence. Its seed yield and canopy size responded more to improving soil fertility than other genotypes and were depressed to a larger extent by increasing presowing rainfall and mean temperature: its canopy size responded more and its seed yield was much less affected by reproductive period rainfall. Carioca was also conspicuous. Its seed yields tended to respond more to improving soil fertility than other genotypes and its seed yields were among those most depressed by reproductive period rainfall. Carioca's response to soil fertility was associated with more pods and seeds/pod than other genotypes.

The members of GCG3 (Black Dessie, Red Wolaita and T 3) also responded differently to environments than other genotypes. Canopy sizes increased with improving soil fertility and decreased with increasing presowing rainfall - among other genotypes, only G 2816 behaved similarly. Their seed sizes increased more with improving soil fertility, increasing disease pressure and increasing vegetative rainfall; and fell less with increasing temperature and presowing rainfall. Also, seeds/pod fell less with increasing vegetative period rainfall than those of other groups.

GCG4 (Kirundo, Kilyumukwe, A 197 and Muhinga) was another group with noticeably different responses to environments. This was the most diverse group morphologically, including genotypes of all three growth habits and with medium and large seeds. Their seed yields and pod numbers tended to increase more than those of other genotypes with increasing disease potential, though this relationship is probably spurious. There are several other instances of individual genotypes with differing responses to the environmental variables. For example, the canopy size of G 12470 was smaller with increasing presowing rainfall than those of other genotypes; and its seeds/pod were fewer with increasing presowing and reproductive period rainfall.

CONCLUSIONS

It would be imprudent to draw a general set of conclusions from these results. The environments studied are an inadequate sample of environments in which beans are produced in Africa. The genotypes include land races and improved lines and cultivars that are commonly grown or have performed well in tests in Africa, but they are few in number. Attention has already been drawn to the inappropriateness or imprecision of the environmental data. Another possible deficiency is the omission of environmental features which also determine crop growth and yield. One of these is insect damage, notably due to bean stem maggot, which is known to cause yield loss of common bean in Africa. Weed cover was also not recorded though standards of trial management differed and may have affected yields. Apart from other statistical considerations, omission of any factor with large effects in any environment may invalidate the analysis.

For the multiple regressions to be meaningful, the estimates should account for significant proportions of the variation across environments; the results should be repeatable; and the effects of the environmental factors should not diverge too widely from expectation. Repeatability yet remains unproven but the regressions did account for significant proportions of the variation in yield and the effects of the environmental variables were within reason.

The importance of environments and G x E interaction in these trials is beyond doubt. The results provide no basis for a classification of environments. Seed yields improved with soil fertility and deteriorated with rainfall during the reproductive period. Genotypes and genotype groups differed in their responses to environments. From the results of the multiple regression analysis, it is tempting to suggest that the genotypic differences arose mainly from responses to soil fertility and reproductive period rainfall but this needs further confirmation.

The results of the AFBYAN II series are now being assembled and data have been received from 22 trials. Not all the data are complete but they are much more comprehensive than the data from the AFBYAN I series. A few trials remain outstanding. Once these have been received, it is proposed to examine environment and genotype responses in these data. Not only will this provide a better sample of environments than AFBYAN I, but also a more diverse set of genotypes. In addition, it is proposed to combine the data from the ten genotypes that are common to AFBYANs I and II across all environments. Hopefully, analysis of these larger data sets will produce more meaningful interpretations of G x E interaction than have been so far achieved.

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Table 1. Contributing countries, sources and characteristics of genotypes in AFBYAN 1 between 1986 and 1989.

Genotypes	Other identities	Contributing countries	Sources	Seed types Sizes	Seed types Colours	Plant type
Black Dessie	-	Ethiopia	Ethiopia	S	Black	3b
Red Wolaita	-	Ethiopia	Ethiopia	S	Red	3b
PVA 1272	-	Rwanda	CIAT	L	Red/white fleck	1
G 13671	Japones	Rwanda	Mexico	L	Cream/black fleck	3
G 2816	Flor de Mayo	Rwanda	Mexico	M	Cream	3
T 3	-	Tanzania	Tanzania	S	Red	3b
T 23	Lyamungu 85	Tanzania	Tanzania	L	Red/white fleck	1
Kabanima	-	Uganda	Uganda	M	Red/white fleck	1
K 20	-	Uganda	Uganda	L	Red/white fleck	1
ZPV 292	Gayaza 8	Zambia	Uganda	M	Purple mottle	3b
Carioca	-	Zambia	Brazil	S	Brown/cream striped	2b
Urubonobono	-	Burundi	Burundi	M	White/black fleck	3
Kirundo	-	Burundi	Burundi	L	Yellow	3
Calima	-	Burundi	Colombia	L	Red/cream fleck	1
Rubona 5	-	Rwanda	Colombia	L	Red/cream fleck	1
Kilyumukwe	-	Rwanda	Rwanda	L	Purple	2
A 197	-	Rwanda	CIAT	L	Cream	1
Muhinga	-	Zaire	Zaire	M	White/black striped	3
PVA 880	-	Rwanda	CIAT	L	Red/white fleck	1
PVA 563	-	Rwanda	CIAT	L	Red/white fleck	1
G 12470	Peru 14-2	Rwanda	Ecuador	L	Purple/white fleck	1

S, M and L indicates weight of seeds/100 g less than 25, 25-40 and greater than 40, respectively

Table 2. Environments in which AFBYAN I was grown between 1986 and 1989.

Environments	Countries	Latitudes	Altitudes (masl)	Soil class	Sowing date	Day length (hours) At sowing	Change first month
MEL87	Ethiopia	$8^{\circ}25'$	1550	5	30 Jun	12.60	-0.12
FIF88	Madagascar	19°	1500	7	1 Mar	12.48	-0.53
KAC7F	Uganda	$1^{\circ}14'$	2123	3	25 Apr	12.08	+0.02
KAW6S	Uganda	$0^{\circ}34'$	1196	5	mid Oct	12.10	0
KAW7F	Uganda	$0^{\circ}34'$	1196	5	9 Apr	12.12	+0.02
KIS7F	Uganda	$0^{\circ}25'$	1146	3	mid Mar	12.12	0
RUB7F	Rwanda	$2^{\circ}29'$	1706	3	8 Oct	12.15	+0.05
MUL7F	Zaire	$2^{\circ}18'$	1731	7	mid Oct	12.15	+0.07
MSK87	Zambia	$13^{\circ}39'$	1025	5	8 Jan	12.88	-0.27
MSK88	Zambia	$13^{\circ}39'$	1025	5	10 Jan	12.87	-0.27
MBA88	Zambia	$8^{\circ}51'$	1673	1	13 Jan	12.58	-0.18
SEL89A	Tanzania	$3^{\circ}20'$	1387	9	30 Mar	12.08	-0.08
SEL89B	Tanzania	$3^{\circ}20'$	1387	9	4 Apr	12.07	-0.08
IRE89F	Tanzania	$4^{\circ}50'$	1400	2	15 Apr	12.02	-0.15

Table 3. Rainfall and temperature data for environments where AFBYAN I was grown between 1986 and 1989.

	Rainfall (mm)				Temperature ^{o}C								
					Maximum			Minimum			Mean		
Environments	Pre sowing	Veg. period	Reprod. period	Total	Veg. period	Reprod. period	Full season	Veg. period	Reprod. period	Full season	Veg. period	Reprod period	Full season
MEL87	80	300	200	580	22.0	26.0	24.0	15.4	15.0	15.2	20.4	20.0	20.2
FIF88	156	139	39	345	27.3	23.5	25.4	8.1	3.8	6.0	17.7	14.6	16.2
KAC7F	150	120	40	310	-	-	-	-	-	-	15.1	15.0	15.1
KAW6S	110	200	150	460	27.3	27.5	27.4	16.2	16.0	16.1	21.7	21.6	21.6
KAW7F	115	230	70	415	26.8	26.0	26.4	16.7	16.0	16.4	21.8	20.8	21.3
KIS7F	100	230	170	500	28.5	28.0	28.3	17.5	17.3	17.4	23.1	22.6	22.9
RUB7F	110	180	160	450	25.0	25.0	25.0	13.9	13.9	13.9	18.5	19.0	18.4
MUL7F	123	371	267	761	24.6	24.0	24.3	13.4	13.6	13.5	18.0	18.8	18.9
MSK87	242	229	202	673	28.8	28.8	28.8	18.4	17.3	17.8	23.6	23.1	23.4
MSK88	280	360	190	730	27.0	27.6	27.3	18.0	17.0	17.5	21.8	21.6	21.7
MBA88	240	340	300	880	23.0	24.2	23.6	14.6	14.8	14.7	17.9	18.2	18.1
SEL89A	142	369	48	559	24.2	21.8	24.2	16.0	13.7	14.8	20.1	17.8	19.0
SEL89B	142	376	35	553	22.9	21.7	22.3	16.0	13.6	14.8	19.5	17.8	18.7
IRE89	85	190	60	335	24.5	22.0	23.2	13.5	10.5	12.0	18.5	16.0	17.2

Table 4. Mean squares for plant characters and disease scores in AFBYAN in 4-14 environments between 1986 and 1989.

Plant characters/ disease scores	Environ- ments (E)	Error (a)	Varieties (V)	V x E	Error (b)
Canopy height (x10^{-1})	403.88***	19.96	20.33***	6.43***	2.10
Canopy width	122.82***	6.72	19.56***	2.52***	1.34
DFF (x10^{-1})	403.26***	6.55	18.14***	1.39***	0.37
Stand (x10^{-2})	836.53***	2.31	4.97	4.95***	1.89
DM (x10^{-2})	196.22***	0.27	1.00***	0.26***	0.06
Pods/m2 (x10^{-3})	307.69***	2.30	16.50***	2.28***	1.01
Seeds/100 pods (x10^{-6})	21.36***	0.35	14.14***	0.66***	0.30
Seed size (x10)	4.02***	0.03	3.35***	0.10***	0.04
Seed yield (x10^{-5})	658.07***	5.86	9.94***	3.05***	0.94
Seed yield (weighted)	1022.00***	4.96	9.62***	3.67***	1.00
Anthracnose	4.36**	0.46	0.67	0.53	0.46
ALS	148.25***	3.42	6.66**	3.19***	0.86
Rust	47.20***	2.06	7.08***	2.95***	0.63
CBB	66.30***	2.53	4.12***	1.99***	1.93
BCMV	68.66***	1.52	13.70***	2.55***	1.00
ASCO	102.31***	6.51	4.73*	2.37***	0.72

Table 5. Percentage contributions of sources of variation to total sums of squares in AFBYAN in 4-14 environments between 1986 and 1989.

Plant characters/ disease scores	Environ- ments (E)	Error (a)	Varieties (V)	V x E	Error (b)
Canopy height	56.9	6.2	5.7	18.1	13.0
Canopy width	44.2	5.2	11.7	18.1	20.8
DFF	81.0	2.9	7.3	5.6	3.3
Stand	81.2	0.5	1.8	9.6	7.9
DM	94.2	0.3	1.7	2.7	1.5
Pods/m^2	70.6	1.2	7.6	10.4	10.2
Seeds/pod	28.2	1.0	37.4	15.9	17.4
Seed size	27.8	0.1	46.3	13.5	11.7
Seed yield	83.6	1.6	1.9	7.7	5.2
Seed yield (weighted)	87.8	0.9	1.3	6.3	3.7
Anthracnose	10.3	2.7	7.9	24.8	54.3
ALS	53.8	2.8	6.8	22.9	14.2
Rust	28.8	2.9	14.4	36.1	17.8
CBB	40.5	3.5	0.3	24.3	25.4
BCMV	28.4	1.6	28.3	21.1	20.7
ASCO	43.2	7.3	13.3	20.0	16.1

Table 6. **Days to flower of 21 genotypes in eleven environments in AFBYAN 1 between 1986 and 1989.**

	Environments											
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	Means
Black Dessie	40.0	58.7	66.0	38.7	37.3	49.0	39.0	37.3	49.3	43.3	42.3	45.5
Red Wolaita	38.3	53.7	61.0	38.3	37.3	51.0	38.0	36.7	45.0	43.0	44.0	44.2
PVA 1272	36.3	52.3	54.0	37.0	35.0	49.0	36.0	35.0	43.0	40.0	42.7	41.8
G 13671	39.0	54.7	66.0	36.7	36.7	51.0	51.7	41.7	49.3	43.0	41.7	46.5
G 2816	35.3	54.0	65.0	36.3	37.3	47.0	33.3	34.0	44.7	41.0	44.0	42.9
T 3	38.7	54.7	63.7	38.0	37.7	47.0	37.7	36.0	45.0	44.3	45.7	44.4
T-23	36.0	53.3	58.7	35.7	37.0	49.0	36.7	35.3	42.3	41.0	40.0	42.3
Kabanima	39.0	55.0	59.7	37.7	36.7	49.0	38.3	35.3	44.0	42.0	43.7	43.7
K-20	39.3	54.7	57.7	38.0	35.0	49.0	37.3	35.7	44.7	41.7	43.3	43.3
ZPV-292	39.7	54.0	60.0	36.7	36.3	49.0	34.7	32.3	44.3	40.3	44.3	42.9
Carioca	41.3	58.7	70.0	42.0	39.0	53.0	40.3	37.3	50.0	48.0	43.0	47.5
Urubonobono	38.0	52.3	59.7	33.7	36.7	39.0	34.0	34.7	40.0	41.0	40.3	40.8
Kirundo	36.3	53.0	58.3	34.3	36.7	42.0	32.0	31.0	40.0	39.0	42.3	40.5
Calima	30.0	52.3	57.3	34.3	36.3	42.0	34.7	35.0	42.0	39.3	38.0	40.1
Rubona 5	35.3	51.7	58.3	35.7	36.7	49.0	38.3	35.7	42.3	40.0	39.7	42.1
Kilyumukwe	31.0	52.0	55.0	34.0	36.0	34.0	32.3	31.0	40.0	39.0	35.7	38.2
A 197	34.3	52.7	58.7	34.3	36.7	42.0	34.7	33.0	43.3	39.7	39.7	40.8
Muhinga	32.7	51.7	59.7	32.7	34.7	34.0	32.0	31.0	40.0	41.0	38.0	38.8
PVA 880	39.3	53.0	55.0	37.7	36.7	47.0	38.3	36.7	44.7	41.7	38.7	42.6
PVA 563	37.7	54.3	58.7	37.3	37.7	47.0	38.7	37.0	44.7	41.7	44.3	43.5
G 12470	38.0	54.7	61.0	37.7	37.3	47.0	40.3	37.7	45.0	43.0	43.0	44.1
S.E.(±)						1.11						0.35
Mean	36.9	53.9	60.2	36.5	36.7	46.0	37.1	35.2	44.0	41.6	41.6	
S.E.(±)						1.02						
C.V. (%)						4.5						

Table 7. Canopy heights (cm) of 21 entries in eleven environments in AFBYAN 1 between 1986 and 1989.

	Environments											
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	Mean
Black Dessie	43.3	31.7	31.7	35.0	41.7	27.7	26.7	21.7	15.0	33.3	35.0	31.2
Red Wolaita	43.3	35.0	36.0	36.7	35.0	40.3	25.0	21.7	21.7	33.3	31.7	32.7
PVA 1272	36.7	38.3	45.0	45.0	41.7	25.7	40.0	25.0	21.7	43.3	31.7	35.8
G 13671	48.3	41.7	33.3	35.0	36.7	33.0	26.7	18.3	18.3	31.7	30.0	32.1
G 2816	45.0	28.3	31.7	38.3	30.0	45.3	21.7	21.7	16.7	30.0	30.0	30.8
T-3	43.3	33.3	36.7	40.0	36.7	35.0	28.3	20.0	20.0	31.7	31.7	32.4
T-23	43.3	41.7	48.3	43.3	43.3	15.7	43.3	26.7	20.0	43.3	35.0	36.7
Kabanima	38.3	36.7	37.3	40.0	47.7	12.7	35.0	21.7	18.3	35.0	31.7	32.2
K-20	40.0	38.3	46.0	40.0	41.7	16.3	41.7	26.7	18.3	45.0	31.7	35.1
ZPV 292	43.3	41.7	38.3	45.0	41.7	17.7	35.0	23.3	18.3	38.3	35.0	34.3
Carioca	45.0	30.0	33.3	38.3	40.0	36.3	35.0	25.0	21.7	36.7	36.7	34.4
Urubonobono	45.0	35.0	35.0	38.3	35.0	27.7	33.3	25.0	20.0	35.0	31.7	32.8
Kirundo	40.0	41.7	41.7	46.7	43.3	23.7	30.0	25.0	20.0	38.3	31.7	34.7
Calima	40.0	41.7	38.3	40.0	41.7	22.0	36.7	20.0	21.7	41.7	31.7	34.1
Rubona 5	46.7	41.7	43.3	40.0	43.3	22.7	38.3	26.7	21.7	45.0	35.0	36.8
Kilyumukwe	40.0	35.0	41.7	48.3	35.0	30.0	28.3	25.0	18.3	36.7	31.7	33.6
A 197	43.3	43.3	43.3	41.7	50.0	21.7	43.3	26.7	20.0	41.7	35.0	37.3
Muhinga	45.0	30.0	36.7	41.7	35.0	27.0	33.3	18.3	13.3	36.7	33.3	31.8
PVA 880	45.0	36.7	41.7	43.3	45.0	21.3	41.7	20.0	18.3	45.0	31.7	35.4
PVA 563	45.0	43.3	40.0	45.0	46.7	21.3	43.3	20.7	20.0	43.3	33.3	36.5
G 12470	46.7	41.7	50.0	45.0	48.3	37.7	53.3	26.7	20.0	48.3	35.0	41.2
S.E. (±)						2.65						0.80
Mean	43.2	37.5	39.5	41.3	40.9	26.7	35.2	23.1	19.2	38.7	32.9	
S.E. (±)						1.78						
C.V. (%)						13.3						

Table 8. Canopy widths (cm) of 21 entries in thirteen environments in AFBYAN 1 between 1986 and 1989.

	Environments													
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	IRE 89F	Means
Black Dessie	40.0	45.0	40.0	36.7	50.0	43.3	30.0	30.0	31.7	25.0	50.0	45.0	20.0	37.4
Red Wolaita	41.7	43.3	40.0	35.0	45.0	45.0	33.3	48.3	30.0	26.7	50.0	45.0	35.0	39.9
PVA 1272	33.3	46.7	30.0	31.7	35.0	38.3	20.0	26.7	16.7	18.3	38.3	30.0	23.3	29.9
G 13671	43.3	46.7	36.7	43.3	40.0	41.7	23.3	50.0	31.7	30.0	48.3	38.3	45.0	39.9
G 2816	43.3	46.7	30.0	30.0	30.0	31.7	40.0	30.0	28.3	23.3	48.3	40.0	30.0	34.7
T-3	33.3	43.3	46.7	40.0	48.3	43.3	30.0	36.7	28.3	26.7	46.7	41.7	36.7	38.6
T-23	40.0	43.3	40.0	31.7	35.0	25.0	13.3	33.3	20.0	23.3	40.0	35.0	35.0	31.9
Kabanima	33.3	45.0	36.7	33.3	45.0	36.7	13.3	23.3	15.0	23.3	40.0	31.7	30.0	31.3
K-20	43.3	45.0	43.3	28.3	31.7	31.7	13.3	33.3	20.0	23.3	40.0	35.0	26.7	31.9
ZPV 292	33.3	46.7	30.0	40.0	35.0	28.3	16.7	36.7	26.7	26.7	41.7	35.0	16.7	31.8
Carioca	41.7	48.3	33.3	33.3	46.7	46.7	30.0	43.3	28.3	28.3	50.0	43.3	40.0	39.5
Urubonobono	40.0	46.7	36.7	41.7	36.7	43.3	20.0	45.0	36.7	28.3	43.3	36.7	40.0	38.1
Kirundo	36.7	43.3	36.7	35.0	38.3	33.3	20.0	33.3	28.3	25.0	40.0	30.0	21.7	32.4
Calima	36.7	41.7	33.3	33.3	31.7	36.7	23.3	25.0	15.0	21.7	35.0	30.0	25.0	29.9
Rubona 5	41.7	48.3	46.7	31.7	38.3	35.0	20.0	28.3	23.3	23.3	40.0	33.3	38.3	34.5
Kilyumukwe	36.7	40.0	36.7	33.3	31.7	33.3	23.3	26.7	23.3	23.3	40.0	33.3	23.3	31.2
A 197	38.3	43.3	36.7	30.0	40.0	31.7	23.3	26.7	21.7	23.3	38.3	31.7	25.0	31.5
Muhinga	31.7	43.3	33.3	36.7	33.3	33.3	16.7	26.7	18.3	25.0	48.3	33.3	30.0	31.5
PVA 880	41.7	41.7	33.3	31.7	36.7	40.0	23.3	23.3	16.7	20.0	40.0	30.0	26.7	31.2
PVA 563	36.7	46.7	33.3	35.0	43.3	41.7	23.3	28.3	13.3	21.7	38.3	36.7	26.7	32.7
G 12470	41.7	46.7	40.0	36.7	38.3	38.3	33.3	45.0	21.7	25.0	41.7	38.3	45.0	37.8
S.E. (±)							3.36							0.93
Mean	38.5	44.8	36.8	34.7	38.6	37.1	23.3	33.3	23.6	24.4	42.8	35.9	30.5	
S.E. (±)							1.63							
C.V. (%)							16.9							

Table 9. Canopy sizes (m^2) of 21 entries in eleven environments in AFBYAN 1 between 1986 and 1989.

	Environments											
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	Means
Black Dessie	1.72	1.48	1.27	1.28	2.08	0.83	0.80	0.68	0.38	1.67	1.58	1.25
Red Wolaita	1.80	1.52	1.44	1.29	1.58	1.35	1.21	0.65	0.57	1.67	1.43	1.32
PVA 1272	1.23	1.79	1.40	1.43	1.48	0.57	1.10	0.42	0.40	1.67	0.95	1.13
G 13671	2.09	1.98	1.23	1.52	1.52	0.80	1.33	0.58	0.56	1.53	1.15	1.30
G 2816	1.95	1.35	0.95	1.17	0.93	1.81	0.65	0.62	0.39	1.45	1.20	1.13
T-3	1.45	1.44	1.72	1.60	1.77	1.17	1.02	0.57	0.53	1.47	1.33	1.28
T-23	1.74	1.81	1.95	1.37	1.55	0.22	1.45	0.55	0.47	1.73	1.23	1.28
Kabanima	1.28	1.66	1.39	1.33	2.14	0.19	0.82	0.32	0.43	1.40	1.00	1.09
K-20	1.74	1.76	2.00	1.13	1.33	0.25	1.38	0.53	0.43	1.80	1.12	1.23
ZPV-292	1.47	1.97	1.15	1.80	1.46	0.31	1.32	0.63	0.49	1.59	1.25	1.22
Carioca	1.88	1.47	1.10	1.28	1.88	1.25	1.52	0.71	0.62	1.83	1.59	1.38
Urubonobono	1.84	1.63	1.28	1.60	1.30	0.58	1.50	0.93	0.57	1.52	1.17	1.26
Kirundo	1.48	1.80	1.52	1.64	1.68	0.57	1.00	0.72	0.50	1.53	0.95	1.22
Calima	1.47	1.75	1.28	1.33	1.42	0.53	0.93	0.30	0.47	1.47	0.95	1.08
Rubona 5	1.94	2.02	2.03	1.27	1.68	0.50	1.09	0.63	0.51	1.80	1.17	1.33
Kilyumukwe	1.43	1.42	1.53	1.63	1.10	0.71	0.78	0.60	0.43	1.47	1.05	1.11
A 197	1.68	1.89	1.60	1.26	2.00	0.61	1.19	0.57	0.47	1.59	1.10	1.27
Muhinga	1.43	1.32	1.25	1.53	1.17	0.48	0.90	0.34	0.33	1.77	1.11	1.06
PVA 880	1.88	1.57	1.37	1.40	1.68	0.62	0.98	0.34	0.37	1.80	0.95	1.18
PVA 563	1.65	2.03	1.35	1.58	2.03	0.61	1.27	0.27	0.43	1.67	1.22	1.28
G 12470	1.95	1.96	2.03	1.65	1.85	1.24	2.40	0.57	0.52	2.03	1.35	1.60
S.E. (±)						0.169						0.051
Mean	1.67	1.70	1.47	1.43	1.60	0.72	1.17	0.55	0.47	1.64	1.18	
S.E. (±)						0.105						
C.V. (%)						23.6						

Table 10. Days to maturity of 21 entries in seven environments in AFBYAN 1 between 1986 and 1989.

	Environments							
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 7F	MUL 7F	MSK 87	SEL 89A	Means
Black Dessie	67.7	133.0	89.0	73.3	90.0	86.3	101.7	91.6
Red Wolaita	62.7	118.0	91.0	73.3	88.3	86.3	101.7	88.8
PVA 1272	63.0	118.0	88.0	70.3	85.0	79.0	94.7	85.4
G 13671	71.0	120.0	90.7	75.0	89.0	91.3	104.3	91.6
G 2816	65.7	125.7	93.3	74.3	90.0	78.3	100.7	89.7
T-3	63.7	118.0	90.0	73.3	85.0	86.0	100.0	88.0
T-23	69.3	118.0	90.0	70.0	89.0	82.0	94.0	87.5
Kabanima	71.0	121.7	91.3	73.0	89.0	77.0	99.7	89.0
K-20	70.0	121.7	91.0	68.7	89.0	87.3	100.7	89.8
ZPV-292	68.7	116.0	91.0	71.0	89.0	74.0	93.0	86.1
Carioca	67.3	133.0	91.0	76.3	97.3	80.7	104.3	92.9
Urubonobono	70.3	118.0	86.0	73.0	89.0	86.7	102.0	89.3
Kirundo	71.7	116.0	90.0	70.0	86.3	79.7	97.7	87.3
Calima	66.0	116.0	89.0	72.0	85.0	79.0	96.0	86.1
Rubona 5	70.0	118.0	90.0	71.7	89.0	83.0	99.3	88.7
Kilyumukwe	66.0	114.3	87.0	70.7	85.0	80.7	102.3	86.6
A 197	70.0	122.0	93.3	74.0	89.0	80.0	100.3	89.8
Muhinga	69.7	120.0	87.0	72.3	85.0	74.0	101.7	87.1
PVA 880	69.7	120.0	93.3	74.3	89.0	82.0	102.0	90.0
PVA 563	71.3	123.7	91.3	77.0	89.7	81.0	100.7	90.7
G 12470	71.3	125.7	92.7	75.0	90.0	92.0	104.3	93.0
S.E.$^{+}$				1.65				0.55
Mean	68.4	120.8	90.3	72.8	88.5	82.2	100.0	
S.E. (±)				0.66				
C.V. (%)				2.8				

Table 11. Pods m^{-2} of 21 genotypes in eleven environments in AFBYAN 1 between 1986 and 1989.

	Environments											
Genotypes	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	IRE 89F	Means
Black Dessie	209.0	130.4	132.9	177.4	71.8	117.7	49.4	74.1	358.1	315.4	104.5	158.3
Red Wolaita	152.0	95.1	110.7	84.2	43.8	62.1	16.7	42.8	275.0	235.2	85.8	109.4
PVA 1272	128.1	127.9	79.2	70.2	31.5	101.7	28.5	59.3	290.0	171.7	81.8	106.4
G 13671	169.6	154.1	149.3	61.7	48.9	56.5	22.0	41.6	270.6	208.7	78.8	114.7
G 2816	133.5	111.5	153.2	78.6	31.7	82.6	44.9	75.0	287.1	213.0	106.4	119.8
T-3	174.8	155.2	144.1	73.6	41.9	86.2	21.0	33.8	235.7	199.9	100.6	115.1
T-23	149.8	130.4	92.8	46.8	34.8	82.9	28.6	66.6	268.4	140.1	69.9	101.0
Kabanima	157.5	144.8	160.5	33.3	54.3	70.8	16.5	53.0	217.8	206.2	82.5	108.8
K-20	146.0	78.2	58.0	17.3	32.9	140.4	16.9	67.9	311.7	273.9	59.5	109.3
ZPV-292	110.0	113.3	91.3	29.4	46.8	91.2	34.5	47.4	203.6	148.3	36.9	86.6
Carioca	267.1	131.5	160.4	226.1	51.7	101.3	17.5	66.4	390.5	280.9	73.7	160.6
Urubonobono	171.5	141.9	146.7	79.0	58.3	55.9	24.2	45.2	260.2	212.5	92.8	117.1
Kirundo	100.3	124.6	80.2	63.7	40.3	82.2	22.7	67.3	234.5	150.8	44.4	91.9
Calima	118.2	103.3	93.0	63.9	56.6	91.8	14.7	55.4	226.7	115.5	54.3	90.3
Rubona 5	184.6	162.8	112.5	55.8	55.7	87.9	34.5	50.3	237.1	218.9	72.5	115.7
Kilyumukwe	70.3	97.5	103.0	27.3	62.7	81.0	18.8	59.3	276.4	166.5	51.8	92.2
A 197	88.0	110.8	97.9	76.5	27.0	78.9	31.7	60.0	192.4	138.5	57.8	87.2
Muhinga	109.0	102.6	102.6	97.1	30.7	69.7	13.9	48.2	280.6	187.3	52.8	99.5
PVA 880	113.5	99.6	80.8	35.3	40.6	86.1	13.0	31.2	252.2	129.8	55.3	85.2
PVA 563	101.0	84.6	68.8	51.8	27.5	71.8	11.4	35.3	221.1	150.1	52.7	79.6
G 12470	108.8	75.5	73.0	45.7	40.5	44.4	9.9	19.7	174.5	140.3	63.4	72.3
S.E. (±)						18.34						5.54
Mean	141.1	117.9	109.1	71.2	44.3	83.0	23.4	52.4	260.2	190.6	70.4	
S.E. (±)						6.04						
C.V. (%)						30.1						

Table 12. Seeds/100 pods of 21 genotypes in eleven environments in AFBYAN 1 between 1986 and 1989.

	Environments											
Genotypes	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	MSK 87	MSK 88	MBA 88	SFL 89A	SFL 89B	IRE 89F	Means
Black Dessie	527	383	431	497	467	440	352	221	443	494	433	426
Red Wolaita	510	414	521	537	488	424	434	377	441	449	377	452
PVA 1272	331	290	387	301	336	288	266	119	215	266	178	271
G 13671	426	422	436	474	449	302	190	234	361	320	301	356
G 2816	396	396	323	419	436	357	348	128	390	421	303	356
T-3	542	493	456	507	488	423	342	434	501	580	472	476
T-23	293	338	270	331	279	286	238	116	208	275	233	261
Kabanima	306	329	336	317	314	286	166	150	267	284	201	269
K-20	343	406	333	370	358	292	214	105	227	284	243	289
ZPV-292	410	344	463	407	429	443	383	180	377	415	225	371
Carioca	554	486	452	491	533	507	406	307	498	467	331	457
Urubonobono	416	437	339	422	406	358	351	171	399	393	291	362
Kirundo	343	364	389	380	367	409	287	157	267	382	235	325
Calima	317	353	266	290	316	329	210	165	211	286	299	276
Rubona 5	340	377	372	363	347	327	325	200	260	284	298	318
Kilyumukwe	356	367	349	380	323	354	164	134	265	245	235	288
A 197	341	344	280	318	264	311	316	198	285	278	295	294
Muhinga	309	391	320	369	347	388	314	200	343	327	245	323
PVA 880	316	358	330	404	359	310	256	224	275	324	247	309
PVA 563	356	350	343	361	382	328	179	131	286	336	265	301
G 12470	347	357	339	380	364	234	184	418	346	302	245	320
S.E. (±)						32						10
Mean	385	381	368	396	383	352	282	208	327	353	283	
S.E. (±)						7						
C.V. (%)						16.2						

Table 13. Weights of 1000 seeds (g) of 21 genotypes in eleven environments in AFBYAN 1 between 1986 and 1989.

	Environments											
Genotypes	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	IRE 89F	Means
Black Dessie	200	322	329	157	239	185	151	161	225	231	174	216
Red Wolaita	249	428	277	230	243	234	168	190	259	315	222	256
PVA 1272	520	422	409	398	538	432	276	354	472	546	572	449
G 13671	407	344	360	294	350	352	277	268	443	593	393	371
G 2816	400	364	329	279	338	317	243	231	398	436	351	335
T-3	238	192	282	229	227	226	173	183	228	289	215	226
T-23	567	525	465	396	543	432	342	402	536	663	566	494
Kabanima	484	349	348	326	454	342	253	292	517	483	459	392
K-20	472	585	435	421	589	373	259	322	499	414	522	445
ZPV-292	497	420	393	377	341	351	239	279	446	599	392	394
Carioca	201	253	254	197	189	229	162	199	243	307	227	224
Urubonobono	350	377	456	268	381	294	251	285	380	407	405	350
Kirundo	537	485	375	386	424	333	251	299	556	522	465	421
Calima	642	521	549	510	524	447	273	367	672	679	521	519
Rubona 5	499	383	390	357	439	387	276	332	589	547	622	438
Kilyumukwe	609	549	508	473	459	393	312	376	580	655	643	505
A 197	630	529	583	463	526	493	375	383	638	709	480	528
Muhinga	468	384	378	293	475	282	196	230	335	419	469	357
PVA 880	551	493	493	368	505	394	266	301	521	550	553	454
PVA 563	557	506	547	411	415	373	269	292	567	588	578	464
G 12470	588	533	537	342	413	446	259	402	579	769	812	516
S.E. (±)						36.0						11.0
Mean	460	427	414	342	410	348	251	293	461	511	459	
S.E. (±)						7.0						
C.V. (%)						15.6						

Table 14. Seed yields (kg/ha) of 21 genotypes in fourteen environments in AFBYAN 1 between 1986 and 1989.

	Environments														
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	RUB 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89A	SEL 89B	IRE 89F	Means
Black Dessie	509	2204	1567	1633	1363	738	1252	403	957	260	242	3542	3587	778	1359
Red Wolaita	815	1961	1517	1600	1018	502	1265	399	614	121	292	3125	3293	713	1231
PVA 1272	613	2243	1500	1150	845	550	1730	242	1257	216	255	2929	2407	822	1197
G 13671	938	2902	2167	2275	845	767	1484	313	553	114	264	4001	3548	939	1508
G 2816	926	2104	1550	1650	908	467	1828	2543	928	355	221	4360	3896	1193	1638
T-3	399	2256	1454	1700	836	403	1362	509	823	125	267	2686	3324	1022	1226
T-23	690	2502	2150	1125	615	525	1600	34	1046	243	309	2922	2498	920	1227
Kabanima	369	2321	1575	1475	345	771	2008	22	685	71	236	2965	2681	766	1163
K-20	430	2356	1842	817	271	688	2400	43	1580	97	218	3533	2924	756	1282
ZPV-292	679	2241	1617	1642	440	671	1954	76	1397	289	226	3307	3615	344	1321
Carioca	742	2989	1575	1692	2176	521	1362	703	1175	116	395	4663	3777	528	1601
Urubonobono	810	2500	2292	2192	888	900	1852	280	584	210	212	3837	3344	1107	1501
Kirundo	333	1852	2117	1150	967	621	1815	223	1093	167	305	3374	2989	488	1250
Calima	855	2423	1867	1400	931	817	2152	323	1333	84	343	3141	2238	826	1338
Rubona 5	807	3132	2325	1483	738	842	1887	231	1109	311	325	3591	3366	1151	1521
Kilyumukwe	452	1552	1950	1750	488	888	1830	165	1122	109	298	3597	2655	789	1260
A 197	421	1908	1933	1575	1118	354	1812	661	1196	375	-448	3415	2685	732	1331
Muhinga	343	1569	1533	1200	928	500	1528	72	762	86	217	2908	2532	607	1056
PVA 880	570	2030	1675	900	515	729	1626	297	1025	90	209	3563	2292	766	1163
PVA 563	536	2003	1467	1292	778	433	1820	308	869	60	115	3474	2954	811	1209
G 12470	298	2231	1433	1317	593	617	2165	653	464	59	277	3446	3074	1306	1281
S.E. (±)								177.2							96.4
Mean	597	2251	1767	1477	838	633	1749	405	980	169	270	3447	3032	827	
S.E. (±)								47.4							
C.V. (%)								23.3							

Table 15. Anthracnose reactions of 21 entries in 5 environments in AFBYAN 1 between 1986 and 1989

Genotypes	FIF 88	KAC 7F	KAW 6S	KIS 7F	MUL 7F	Means
Black Dessie	1.00	1.00	1.33	1.33	2.67	1.47
Red Wolaita	1.00	1.67	1.67	1.67	2.67	1.73
PVA 1272	1.33	2.00	1.00	1.67	1.67	1.53
G 13671	1.33	1.00	1.67	1.00	2.00	1.40
G 2816	1.33	1.00	1.67	1.67	2.00	1.53
T-3	1.00	1.00	2.00	1.67	1.67	1.47
T-23	1.67	1.67	1.00	1.00	2.33	1.53
Kabanima	1.33	1.00	1.33	1.00	1.67	1.27
K-20	1.33	1.00	1.00	1.67	1.33	1.27
ZPV-292	1.33	2.00	1.33	1.00	2.33	1.60
Carioca	1.00	1.00	1.33	1.00	2.00	1.27
Urubonobono	1.00	1.00	1.33	1.33	1.67	1.27
Kirundo	1.67	1.00	1.00	1.33	1.33	1.27
Calima	2.33	3.33	1.00	1.33	1.33	1.87
Rubona 5	1.33	1.00	1.00	1.00	1.67	1.20
Kilyumukwe	1.00	1.00	1.33	1.00	1.33	1.13
A 197	1.00	1.00	1.33	1.00	2.00	1.27
Muhinga	1.00	1.00	1.67	1.00	1.33	1.20
PVA 880	1.67	2.33	1.67	1.33	2.00	1.80
PVA 563	2.00	1.67	1.33	1.33	2.00	1.67
G 12470	1.00	1.00	1.00	1.33	3.00	1.47
S.E.$^{+}$			0.392			0.175
Mean	1.32	1.37	1.33	1.27	1.90	
S.E.$\pm$			0.085			
C.V. (%)			47.2			

Table 16. Angular leaf spot reactions of 21 entries in 8 environments in AFBYAN 1 between 1986 and 1989.

Genotypes	KAC 7F	KAW 6S	KIS 7F	MUL 7F	MSK 88	MBA 88	SEL 89A	IRE 89	Means
Black Dessie	7.33	7.67	1.67	5.67	3.33	3.67	3.67	3.67	4.58
Red Wolaita	6.33	5.67	1.33	7.00	5.33	4.00	5.67	5.00	5.04
PVA 1272	5.33	4.33	1.67	5.67	2.33	2.00	2.67	4.00	3.50
G 13671	4.67	4.67	1.00	3.67	5.33	5.67	1.00	3.00	3.63
G 2816	5.67	7.00	3.33	5.33	4.33	5.67	1.67	2.00	4.38
T-3	6.67	4.00	1.33	5.67	5.67	2.67	4.67	4.67	4.42
T-23	6.67	5.67	1.00	5.00	3.00	3.00	5.67	4.67	4.33
Kabanima	6.67	7.67	1.00	4.33	4.33	3.00	3.67	3.00	4.21
K-20	7.33	5.67	1.67	4.67	4.33	2.33	2.67	4.00	4.08
ZPV-292	7.00	5.33	1.67	5.00	2.00	3.67	3.00	4.67	4.04
Carioca	4.67	4.00	1.00	5.67	2.00	3.33	1.00	3.33	3.13
Urubonobono	7.00	7.00	2.33	5.33	4.33	6.00	5.33	3.67	5.13
Kirundo	7.00	6.67	2.33	5.33	3.00	2.67	7.00	4.00	4.75
Calima	7.00	6.00	1.67	6.00	4.67	3.00	6.33	5.00	4.96
Rubona 5	6.67	6.67	1.00	5.67	3.00	3.00	6.33	4.00	4.54
Kilyumukwe	5.33	5.00	1.33	5.67	2.67	2.67	4.67	4.00	3.92
A 197	6.67	5.33	1.00	5.33	4.67	3.00	6.67	4.67	4.67
Muhinga	4.67	5.67	1.67	5.00	2.00	4.00	3.67	4.00	3.83
PVA 880	6.33	6.67	1.00	5.00	4.67	2.67	6.00	4.33	4.58
PVA 563	7.33	5.00	1.00	6.00	4.67	2.67	4.67	3.67	4.38
G 12470	6.33	4.67	1.00	5.67	4.00	2.00	2.00	4.00	3.71
S.E.±					0.536				0.190
Mean	6.32	5.73	1.48	5.37	3.79	3.37	4.19	3.97	
S.E.±					0.233				
C.V. (%)					21.7				

Table 17. Rust reactions of 21 entries in 7 environments in AFBYAN 1 between 1986 and 1989

Genotypes	KAC 7F	KAW 6S	KIS 7F	MUL 7F	MBA 88	SEL 89A	IRE 89	Means
Black Dessie	1.67	2.00	1.33	1.67	1.00	3.00	1.00	1.67
Red Wolaita	7.00	4.67	1.33	2.67	1.33	6.33	1.33	3.52
PVA 1272	1.00	3.00	2.00	2.33	1.33	2.67	1.00	1.90
G 13671	3.33	2.33	1.33	2.00	1.00	1.00	1.00	1.71
G 2816	4.67	3.00	1.67	3.00	1.00	1.00	1.00	2.19
T-3	7.33	2.33	1.33	2.67	2.67	5.00	2.33	3.38
T-23	1.00	4.00	2.00	4.00	2.00	7.00	1.33	3.05
Kabanima	1.00	3.33	1.33	2.00	1.00	2.67	1.00	1.76
K-20	2.33	5.00	1.67	1.67	1.00	2.00	1.00	2.10
ZPV-292	3.67	3.67	1.00	3.00	1.67	5.00	1.00	2.71
Carioca	1.00	2.33	1.00	1.67	1.00	1.00	1.00	1.29
Urubonobono	3.67	3.67	1.33	2.33	1.00	1.67	1.00	2.10
Kirundo	2.33	3.00	1.33	2.00	1.00	3.00	1.00	1.95
Calima	1.00	3.00	1.67	3.33	1.00	2.00	1.00	1.86
Rubona 5	1.00	2.67	1.00	3.00	1.00	1.33	1.00	1.57
Kilyumukwe	2.00	2.67	1.67	3.00	1.00	2.67	1.00	2.00
A 197	1.00	5.00	1.00	2.00	1.33	3.00	1.00	2.05
Muhinga	1.00	3.00	3.00	3.00	1.00	3.33	1.00	2.19
PVA 880	1.00	4.33	1.00	1.67	1.00	2.67	1.00	1.81
PVA 563	1.00	2.67	1.33	2.00	1.33	2.33	1.00	1.67
G 12470	1.67	2.67	1.33	3.33	1.00	3.67	1.00	2.10
S.E.$\pm$				0.457				0.173
Mean	2.37	3.25	1.46	2.49	1.22	2.97	1.10	
S.E.$\pm$				0.181				
C.V. (%) ..				37.3				

Table 18. Common bacterial blight reactions of 21 entries in 9 environments in AFBYAN 1 between 1986 and 1989.

Genotypes	MEL 87	KAC 7F	KAW 6S	KIS 7F	MSK 87	MSK 88	MBA 88	SEL 89A	IRE 89	Means
Black Dessie	4.00	4.33	5.67	2.33	2.33	3.00	1.00	1.67	4.00	3.15
Red Wolaita	4.00	4.00	6.00	3.67	2.33	4.33	1.00	1.67	2.67	3.30
PVA 1272	3.33	2.00	3.33	2.67	1.67	2.67	1.67	1.67	3.67	2.52
G 13671	3.00	6.67	5.00	2.33	2.00	2.67	1.67	2.33	2.67	3.15
G 2816	2.67	6.33	6.00	3.33	2.67	4.67	1.33	3.33	3.33	3.74
T-3	4.33	5.33	5.67	3.33	2.67	4.33	1.67	1.67	3.33	3.59
T-23	3.33	3.00	5.00	2.67	1.67	2.67	1.67	1.00	3.67	2.74
Kabanima	4.00	4.00	6.33	2.00	2.00	4.00	2.00	2.67	2.67	3.30
K 20	3.00	4.00	5.00	2.00	2.00	3.33	2.33	2.00	3.00	2.96
ZPV 292	4.00	3.00	5.00	3.33	2.33	3.67	2.33	2.00	4.00	3.30
Carioca	3.33	3.67	4.33	1.67	1.00	2.67	1.00	2.00	2.33	2.44
Urubonobono	3.33	3.00	6.67	3.67	2.00	2.67	1.00	2.67	3.00	3.11
Kirundo	3.00	3.00	5.33	2.33	2.33	3.67	2.00	1.33	4.00	3.00
Calima	3.67	2.33	5.00	1.33	1.67	3.33	1.67	1.33	4.00	2.70
Rubona 5	3.00	2.33	5.00	3.00	1.33	2.67	2.00	1.00	3.67	2.67
Kilyumukwe	3.00	4.00	5.00	4.00	3.00	3.33	1.33	3.00	4.00	3.41
A 197	2.67	3.33	3.33	1.00	1.33	2.00	1.00	6.67	3.00	2.70
Muhinga	3.00	3.33	4.67	2.67	2.00	2.00	1.00	2.33	3.33	2.70
PVA 880	3.00	4.67	3.67	1.00	1.33	1.67	1.67	1.33	2.67	2.33
PVA 563	3.33	6.00	3.67	2.67	1.67	3.00	2.67	2.33	3.00	3.15
G 12470	3.00	2.00	4.00	2.00	1.67	2.67	2.67	2.00	2.67	2.52
S.E.±					0.555					0.185
Mean	3.33	3.83	4.94	2.52	1.95	3.10	1.65	2.19	3.27	
S.E.±					0.200					
C.V. (%)					32.3					

Table 19. BCMV reactions of 21 entries in 5 environments in AFBYAN 1 between 1986 and 1989.

Genotypes	KAW 6S	KIS 7F	MSK 87	MSK 88	MBA 88	Means
Black Dessie	1.33	1.33	5.33	2.33	2.33	2.53
Red Wolaita	1.67	2.33	7.33	5.67	6.00	4.60
PVA 1272	1.00	1.33	2.67	1.00	1.00	1.40
G 13671	1.00	1.67	5.67	1.67	3.67	2.73
G 2816	1.00	1.00	4.33	3.00	4.33	2.73
T-3	2.00	2.33	6.67	6.00	7.33	4.87
T-23	1.00	1.67	3.33	1.00	3.00	2.00
Kabanima	1.00	1.33	3.67	1.00	2.33	1.87
K-20	1.00	1.33	3.33	1.00	1.33	1.60
ZPV-292	1.33	1.33	1.00	1.00	1.00	1.13
Carioca	1.33	1.00	3.33	3.00	2.00	2.13
Urubonobono	1.67	2.33	6.33	1.67	2.00	2.80
Kirundo	1.00	1.67	3.33	1.00	3.33	2.07
Calima	1.00	2.67	3.00	1.00	1.00	1.73
Rubona 5	1.33	1.00	3.00	1.33	2.00	1.73
Kilyumukwe	1.00	2.00	3.33	1.00	1.00	1.67
A 197	1.00	1.33	1.33	1.00	1.00	1.13
Muhinga	1.00	2.00	3.00	1.00	1.67	1.73
PVA 880	1.00	1.67	4.00	1.67	2.33	2.13
PVA 563	1.00	1.67	4.33	1.00	3.33	2.27
G 12470	1.00	2.67	3.33	2.67	1.67	2.27
S.E.±			0.578			0.258
Mean	1.17	1.70	3.89	1.90	2.56	
S.E.±			0.155			
C.V. (%)			44.6			

Table 20. Ascochyta blight reactions of 21 entries in 4 environments in AFBYAN 1 between 1986 and 1989.

Genotypes	KAC 7F	MUL 7F	MBA 88	IRE 89	Means
Black Dessie	3.67	3.33	2.33	1.00	2.58
Red Wolaita	4.33	3.00	4.00	1.67	3.25
PVA 1272	3.67	3.33	5.00	1.33	3.33
G 13671	6.67	5.00	3.67	2.33	4.42
G 2816	5.67	6.00	3.33	1.33	4.08
T-3	4.67	3.00	4.33	1.00	3.25
T-23	2.67	3.00	3.33	1.33	2.58
Kabanima	3.67	2.00	4.33	1.00	2.75
K-20	4.00	2.33	4.33	1.00	2.92
ZPV-292	2.67	2.33	1.67	1.00	1.92
Carioca	3.33	5.67	4.33	1.00	3.58
Urubonobono	5.00	3.00	3.00	1.33	3.08
Kirundo	4.33	2.33	5.33	2.33	3.58
Calima	6.33	2.67	4.00	3.00	4.00
Rubona 5	4.33	3.33	4.67	1.00	3.33
Kilyumukwe	2.33	3.00	3.67	1.33	2.58
A 197	4.67	3.00	5.00	3.67	4.08
Muhinga	4.00	3.00	4.00	1.00	3.00
PVA 880	6.33	3.33	5.33	1.33	4.08
PVA 563	4.67	3.00	5.00	1.00	3.42
G 12470	3.67	3.67	3.67	1.00	3.00
S.E.±			0.488		0.244
Mean	4.32	3.30	4.02	1.48	
S.E.±			0.322		
C.V. (%)			25.8		

Table 21. Environment and genotype clusters formed from two-way classification of seed yields.

Clusters	Environments/genotypes
Environments	
1	Mulungu 1987F, Msekera 1988, Mbala 1988
2	Melkassa 1987, Kawanda 1987F, Kisindi 1987F, Msekera 1987, Irente 1989
3	Antsirabe 1988, Kachwekano 1987F, Kawanda 1986S, Rubona 1987F
4	Selian 1989A, Selian 1989B
Genotypes	
1	G 13671, Urubonobono, Rubona 5
2	PVA 1272, T 23, Calima, PVA 880
3	Black Dessie, Red Wolaita, T 3
4	Kirundo, Kilyumukwe, A 197, Muhinga
5	Kabanima, PVA 563, G 12470
6	K 20, ZPv 292
7	Carioca
8	G 2816

Table 22. Means of clusters formed by two-way classification of seed yields in AFBYAN I.

Genotype clusters	Environment clusters 1	2	3	4	Means
1	251	865	2207	3614	1510
2	220	812	1755	2749	1231
3	291	766	1648	3259	1272
4	260	710	1692	3019	1224
5	200	643	1759	3099	1218
6	158	725	1859	3345	1302
7	405	1028	1904	4220	1601
8	1040	884	1783	4128	1638
Means	281	775	1811	3239	

Table 23. Environment (E) and genotype (G) cluster components of E, G and G x E sums of squares for seed yields (kg ha^{-1} x 10^{-2}).

Sources of variation	df	MS	%SS
Environments (E)	13	658100***	
Among E groups	3	2741358***	96.1
Within E groups	10	33093***	3.9
Within E group 1	2	8784	0.2
2	4	15806	0.7
3	3	65360***	2.3
4	1	54054**	0.6
Error	28	5856	
Genotypes (G)	20	9938***	
Among G groups	7	23700***	83.5
Within G groups	13	2528	16.5
Within G group 1	2	46	0.0
2	3	2409*	3.6
3	2	2399	2.4
4	3	5826**	8.8
5	2	1474	1.5
6	1	317	0.2
G x E	260	3047***	
Among E groups x G	60	4101***	31.1
Within E groups x G	200	2731***	68.9
In E group 1 x G	40	2712***	13.7
2	80	2384***	24.1
3	60	3145***	23.8
4	20	2911**	7.3
Among G groups x E	91	6711***	77.1
Within G groups x E	169	1074	22.9
In G group 1 x E	26	1251	4.1
2 x E	39	879	4.3
3 x E	26	872	2.9
4 x E	39	944	4.6
5 x E	26	1093	3.6
6 x E	13	2057	3.4
Among E groups x among G groups	21	9639***	25.6
Remainder	239	2468***	74.4
Error	560	944	

Table 24. Stability parameters for seed yields (kg/ha) of 25 genotypes in AFBYAN I grown between 1986 and 1989.

Genotypes	b	r^2	s_b
Genotype cluster 3			
Black Dessie	1.04	0.94	0.074
Red Wolaita	0.94	0.95	0.064
T 3	0.91	0.92	0.075
Genotype cluster 2			
PVA 1272	0.83**	0.96	0.047
T 23	0.89	0.93	0.073
Calima	0.85	0.92	0.073
PVA 880	0.92	0.94	0.066
Genotype cluster 5			
Kabanima	0.95	0.95	0.064
PVA 563	1.01	0.99	0.030
G 12470	1.04	0.95	0.066
Genotype cluster 4			
Kirundo	0.99	0.96	0.059
Kilyumukwe	0.96	0.93	0.078
A 197	0.90	0.96	0.056
Muhinga	0.85**	0.98	0.038
Genotype cluster 6			
K 20	1.07	0.90	0.101
ZPv 292	1.08	0.94	0.079
Genotype cluster 1			
G 13671	1.20*	0.95	0.083
Urubonobono	1.13	0.96	0.070
Rubona 5	1.11	0.96	0.069
Genotype cluster 7			
Carioca	1.25	0.88	0.132**
Genotype cluster 8			
G 2816	1.06	0.75	0.177***

Table 25. Mean squares for seed yields (kg ha^{-1} x 10^{-2}) from partitioning of environments in AFBYAN I according to rainfall, temperature and soil class.

Sources of variation	df	Mean squares	Sums of squares (%)
Environments	13	658100***	100.0
Among rainfall groups (RFG)	2	140584***	38.9
Within RFG1	4	250092***	11.7
Among temperature groups (TG) in RFG1	1	339321**	3.9
Within TG1 in RFG1	3	330523**	7.7
Among soil classes (SC) in TG1	1	382658***	4.4
Within SC3 in TG1	2	278389***	3.3
Within RFG2	4	1123823***	52.5
Among TG in RFG2	1	128421***	15.0
Within TG2 in RFG2	2	1493416***	34.9
Among SC in TG2	1	2932778***	34.3
Within SC1 in TG2	1	54054**	0.6
Within TG3 in RFG2	1	224179***	2.6
Within RFG3	3	82651***	2.9
Among TG in RFG3	1	35413***	0.4
Within TG2 in RFG3	1	5704	0.1
Within TG3 in RFG3	1	206836***	2.4
Error	28	5856	
Environments x genotypes	260	3047***	100.0
Among RFG x G	40	3581***	18.1
Within RFG1 x E	80	3284***	33.2
Among temperature groups (TG) in RFG1	20	4267***	21.5
Within TG1 in RFG1	60	2301***	11.6
Among soil classes (SC) in TG1	20	2732***	6.9
Within SC3 in TG1	40	1871*	4.7
Within RFG2	80	2730***	27.6
Among TG in RFG2	20	2957**	7.5
Within TG2 in RFG2	40	2989***	15.1
Among SC in TG2	20	3067**	7.7
Within SC1 in TG2	20	2911**	7.4
Within TG3 in RFG2	20	1985	5.0
Within RFG3	60	2798***	21.2
Among TG in RFG3	20	2903**	7.3
Within TG2 in RFG3	20	4253***	10.7
Within TG3 in RFG3	20	1238	3.1
Error	560	942	

Table 26. Plant type (PT) and seed size (SS) components of genotypes (G) and G x environments (E) sums of squares for seed yields (kg ha^{-1} x 10^{-2}) in AFBYAN I.

Sources of variation	df	Mean squares	Per cent SS
Genotypes	20	9938***	100.0
Among PT	2	11120	11.2
Within PT I	9	4918**	22.2
Between SS in PT I	1	5422*	2.7
Among LSS in PT I	8	4855**	19.5
Among LSS groups in PT I	2	8562	8.6
Within CG2 in PT I	3	2409	3.6
Within C65 in PT I	1	1101	0.5
Within rest in PT I	2	6694	6.7
Within PT II	1	24380	12.3
Within PT III	8	13490***	54.3
Among SS in PT III	2	4782	4.8
Within SSS in PT III	2	2399	2.4
Within MSS in PT III	3	26523***	40.0
Within LSS in PT III	1	13990	7.0
G x E	260	3047***	100.0
Among PT x E	26	6396***	21.0
PT I v. PT II and III x E	13	10279***	16.9
PT II v. III x E	13	2514**	4.1
Within PT I x E	117	1690***	25.0
Between SS in PT I x E	13	1130	1.9
Among LSS in PT I x E	104	1760***	23.1
Among LSS groups in PT I x E	26	2562***	8.4
Within GG2 in PT I x E	39	879	4.3
Within C65 in PT I x E	13	914	1.5
Within rest in PT I x E	26	2702**	8.9
Within PT II x E	13	7657***	12.6
Within PT III x E	104	3161***	41.5
Among SS in PT III x E	26	6740***	22.1
Within SSS x E	26	872	3.0
Within MSS x E	39	5203***	10.5
Within LSS x E	13	3646***	6.0
Error	560	942	

SSS, MSS, LSS = small, medium and large seed size groups, respectively; GC2, GC3, GC5, GC6 = genotype clusters 2, 3, 5 and 6, respectively (Table 24)

Table 27. Mean seed yields (kg/ha) of plant type and seed size genotype groups in fourteen environments in AFBYAN 1 between 1986 and 1989.

	Environments														
Genotypes	MEL 87	FIF 88	KAC 7F	KAW 6S	KAW 7F	KIS 7F	RUB 7F	MUL 7F	MSK 87	MSK 88	MBA 88	SEL 89	SEL 89B	IRE 89	Means
Plant type I	559	2315	1777	1253	675	633	1920	281	1056	161	273	3298	2712	885	1271
Plant type II	597	2270	1763	1721	1332	704	1596	434	1149	113	346	4130	3216	658	1431
Plant type III	639	2177	1757	1671	910	619	1593	535	857	192	249	3460	3348	799	1343
Plant type I															
Medium seeds	369	2321	1575	1475	345	771	2008	22	685	71	236	2965	2681	766	1163
Large seeds	580	2314	1799	1229	711	617	1910	310	1098	170	278	3335	2715	899	1283
GC2	682	2299	1798	1144	726	655	1777	224	1165	158	279	3139	2359	833	1231
GC5	417	2117	1450	1304	685	525	1992	480	667	60	196	3460	3014	1058	1245
Remainder	533	2465	2033	1292	709	628	2033	311	1295	261	330	3513	2992	880	1377
Plant type II															
Carioca	742	2989	1575	1692	2176	521	1362	703	1175	116	395	4663	3777	528	1601
Kilyumukwe	452	1552	1950	1750	488	888	1830	165	1122	109	298	3597	2655	789	1260
Plant type III															
Small seeds	574	2140	1513	1644	1072	548	1293	437	798	169	267	3118	3401	838	1372
Medium seeds	690	2104	1748	1671	791	634	1791	743	918	235	219	3603	3347	817	1379
Large seeds	635	2377	2142	1713	906	694	1650	268	823	140	284	3688	3268	713	1379
Medium seeds															
G 2816	926	2104	1550	1650	908	467	1828	2543	928	355	221	4360	3896	1193	1638
ZPv-292	679	2241	1617	1642	440	671	1954	76	1397	289	226	3307	3615	344	1321
Urubonobono	810	2500	2292	2192	888	900	1852	280	584	210	212	3837	3344	1107	1501
Muhinga	343	1569	1533	1200	928	500	1528	72	762	86	217	2908	2532	607	1056
Large seeds															
G 13671	938	2902	2167	2275	845	767	1484	313	553	114	264	4001	3548	939	1508
Kirundo	333	1852	2117	1150	967	621	1815	223	1093	167	305	3374	2989	488	1250

Table 28. Correlation coefficients (x 10^2) among environmental variables

	Environmental variables															
	VR	RR	TR	VMXT	RMXT	MMXT	VMNT	RMNT	MMNT	SMXT	SMNT	SMT	SC	PP	CPP	DP
PR	28	33	59	24	27	29	22	16	19	12	17	16	4	76	-54	22
VR		39	78	-52	-25	-37	38	37	38	21	25	27	-44	19	10	27
RR			82	-6	48	20	24	48	38	21	52	40	37	51	10	-10
TR				-24	18	2	35	47	43	23	42	36	-3	53	-5	13
VMXT					67	91	20	14	17	63	49	57	9	19	-21	-18
RMXT						90	55	62	60	78	88	86	34	51	3	-17
MMXT							45	44	45	80	77	80	17	37	-8	-16
VMNT								94	98	81	85	85	7	17	41	49
RMNT									99	71	89	84	22	16	57	48
MMNT										77	89	86	16	17	51	49
SMXT											90	97	-12	33	-4	-25
SMNT												98	7	36	21	-8
SMT													-5	36	10	-16
SC														10	12	-7
PP															-65	-35
CPP																54

PR, VR, RR and TR = preflowering, vegetative and reproductive period and total rainfall; VMXT, RMXT and MMXT = vegetative, reproductive and mean maximum temperature; VMNT, RMNT and MMNT = vegetative, reproductive and mean minimum temperature; SMXT, SMNT and SMT = seasonal maximum, minimum and mean temperature; SC = soil class; PP = photoperiod; CPP = change in photoperiod; DP = disease potential

Table 29. R^2 values ($x10^2$) from multiple regressions of yield and its components on environmental variables.

Genotypes	Seed yields (kg/ha)	Canopy sizes (cm^2)	Pods/ m^2	Seeds/ 100 pods	Weight/ 1000 seeds (g)
GOG 3					
Red Wolaita	77	35^{ns}	77	78	36^{ns}
Black Dessie	76	61	89	31^{ns}	56
T-3	77	45^{*}	83	45^{**}	56
GOG 2					
PVA 1272	72	23^{ns}	65	65	60
T 23	74	17^{ns}	61	79	57
Calima	68	28^{ns}	61	62	73
PVA 880	64	25^{ns}	60	50^{**}	64
GOG 5					
Kabanima	68	24^{ns}	82	60	61
PVA 563	76	30^{ns}	76	66	79
G 12470	76	35^{ns}	85	34^{ns}	59
GOG 4					
Kirundo	73	28^{ns}	68	66	80
Kilyumukwe	58	32^{ns}	58	73	65
A 197	70	27^{ns}	64	39^{*}	67
Muhinga	74	25^{ns}	74	46^{**}	69
GOG 6					
K 20	63	20^{ns}	70	71	59
ZPv 292	68	26^{ns}	69	71	74
GOG 1					
G 13671	73	42^{*}	75	65	42^{*}
Urubonobono	74	24^{ns}	87	59	58
Rubona 5	76	31^{ns}	82	48^{**}	52
GOG 7					
Carioca	75	34^{ns}	77	49^{**}	27^{ns}
GOG 8					
G 2816	79	65	68	69	72

ns denotes not significantly greater than zero; * and ** denote significantly greater than zero at P = 0.05 and 0.01, respectively; all other values significantly greater than zero at P = 0.001

Table 30. Regression coefficients from multiple regressions of yield and its components on the independent variable soil class.

	Dependent variables				
Genotypes	Seed yields (kg/ha)	Canopy sizes (cm^2)	Pods/ m^2 (x10)	Seeds/ 100 pods ($x10^2$)	Weight/ 1000 seeds ($g \times 10^2$)
GCG 3					
Red Wolaita	260***	956*	285***	613	2363*
Black Dessie	220***	654**	312***	1944	2037*
T-3	229***	453	324***	1480	1635**
GCG 2					
PVA 1272	186**	687	255**	2786**	-444
T 23	178**	297	298***	126	1208
Calima	214**	454	261***	-377	4472***
PVA 880	191*	535	278***	856	1976
GCG 5					
Kabanima	206**	383	384***	2713**	1030
PVA 563	219***	645	237***	1822*	2785**
G 12470	189**	399	194***	2530	302
GCG 4					
Kirundo	234***	440	265***	2094*	1933*
Kilyumukwe	218*	484	314***	2172*	1063
A 197	265***	438	217***	-346	5000***
Muhinga	172***	768	315***	977	367
GCG 6					
K 20	208*	326	359***	1144	150
ZPv 292	282***	710	286***	3526***	3039**
GCG 1					
G 13671	303***	401	394***	2688*	1994
Urubonobono	255**	340	347***	922	2160**
Rubona 5	229**	392	337***	295	-511
GCG 7					
Carioca	346***	810	487***	2791*	1399
GCG 8					
G 2816	415***	885**	320***	-271	1739**

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Table 31. Regression coefficients from multiple regressions of yield and components on the independent variable presowing rainfall (mm).

Genotypes	Seed yields (kg/ha x10^2)	Canopy sizes (cm^2 x10^2)	Pods/ m^2 (x10^2)	Seeds/ 100 pods (x10^3)	Weight/ 1000 seeds (gx10^2)
	Dependent variables				
GCG 3					
Red Wolaita	-162	-2565	-456	-150	-514
Black Dessie	-1042	-4165***	-654***	-360	-197
T-3	251	-4252**	-486***	-695*	-506***
GCG 2					
PVA 1272	2214	-1006	-298	-177	-928**
T 23	2710	-2189	-359	354*	-916**
Calima	1127	-1550	-410*	189	-1521***
PVA 880	1243	-3365	-382	-138	-1193***
GCG 5					
Kabanima	1124	-554	-700***	-476	-926***
PVA 563	381	-1939	-353*	-455	-1253***
G 12470	-681	-5607*	-399***	-1107**	-1392*
GCG 4					
Kirundo	1605	-801	-341	109	-799***
Kilyumukwe	-235	-2686	-646*	-188	-1028*
A 197	1167	-1620	-287	573*	-1075**
Muhinga	448	-2640	-558**	388	-1084***
GCG 6					
K 20	4019	-2382	-403	-31	-1000***
ZPv 292	2563	436	-278	110	-687*
GCG 1					
G 13671	-1120	-2301	-677***	-1020**	-599
Urubonobono	-1492	-1359	-686***	332	-1091***
Rubona 5	2356	-2173	-366*	210	-968*
GCG 7					
Carioca	703	-3366	-787**	24	-341
GCG 8					
G 2816	-4007*	-5253***	-634**	276	-422*

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Table 32. Regression coefficients from multiple regressions of yield and components on the independent variable vegetative rainfall (mm).

Genotypes	Seed yields (kg/ha $x10^2$)	Canopy sizes (cm^2 $x10^2$)	Pods/ m^2 ($x10^2$)	Seeds/ 100 pods ($x10^3$)	Weight/ 1000 seeds ($gx10^2$)
	Dependent variables				
GCG 3					
Red Wolaita	230	-199	235	-104	-765**
Black Dessie	767	-3	105	-424	-726***
T-3	-514	-1049	-283*	-6	-132
GCG 2					
PVA 1272	-683	-1788	16	-954**	410
T 23	-1474	-687	-142	-546***	225
Calima	-2374	-1007	-173	-424**	-200
PVA 880	225	-1051	-105	-490**	-148
GCG 5					
Kabanima	-1056	-1058	-330**	-824***	424
PVA 563	803	-751	5	-680**	-201
G 12470	1777	-648	3	-362	687
GCG 4					
Kirundo	-1068	-2416	-118	-827***	225
Kilyumukwe	-1449	-1820	-15	-1053***	205
A 197	-1908	-1205	-133	-260	-364
Muhinga	-80	-771	-19	-548*	-52
GCG 6					
K 20	-550	-780	-250	-938***	-375
ZPv 292	-669	-1152	-211	-831***	-97
GCG 1					
G 13671	-1514	-648	-271	-905***	325
Urubonobono	-1429	-892	-173	-465	-283
Rubona 5	-902	-1427	-236	-613**	836*
GCG 7					
Carioca	379	1049	-109	-703*	-132
GCG 8					
G 2816	1218	-618	9	-234	-81

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Table 33. Regression coefficients from multiple regressions of yield and components on the independent variable reproductive rainfall (mm).

Genotypes	Seed yields (kg/ha $x10^2$)	Canopy sizes (cm^2 $x10^2$)	Pods/ m^2 ($x10^2$)	Seeds/ 100 pods ($x10^3$)	Weight/ 1000 seeds ($gx10^2$)
	Dependent variables				
GCG 3					
Red Wolaita	-702***	-1534	-108	-727**	581
Black Dessie	-522**	1112	392*	322	290
T-3	-479**	122	456*	226	388*
GCG 2					
PVA 1272	-514**	334	261	379	-224
T 23	-546**	124	523	-630**	102
Calima	-388*	7	502*	-490	-723
PVA 880	-528*	1362	422	-89	276
GCG 5					
Kabanima	-501*	-2449	834***	430	8
PVA 563	-601**	-1197	300	-11	282
G 12470	-604**	2355	233	-1310**	-152
GCG 4					
Kirundo	-529**	-204	452*	-85	-2
Kilyumukwe	-437	1215	660*	122	-175
A 197	-335	-78	345	-656*	843
Muhinga	-539**	1341	440	-371	63
GCG 6					
K 20	-670*	1152	489	-315	-12
ZPv 292	-540*	-1232	513*	228	222
GCG 1					
G 13671	-539*	398	688*	587	18
Urubonobono	-568*	545	569**	-720	744*
Rubona 5	-684**	446	484*	-307	-464
GCG 7					
Carioca	-697**	268	581	114	287
GCG 8					
G 2816	-77	3128**	562	-1029**	53

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Table 34 Regression coefficients from multiple regressions of yield and components on the independent variable mean temperature.

Genotypes	Seed yields (kg/ha x10)	Canopy sizes (cm^2)	Pods/m^2 ($x10^2$)	Seeds/100 pods ($x10^2$)	Weight/1000 seeds (g x 10^2)
	Dependent variables				
GCG 3					
Red Wolaita	-10	56	-862***	1441	-144
Black Dessie	-529	-742*	-1545***	682	-683
T-3	-703	-428	-1510***	-1174	-148
GCG 2					
PVA 1272	-451	-337	-1322**	1380*	-817
T 23	-993*	-607	-1705***	1583***	-1762*
Calima	-514	-518	-1055**	915*	-2082**
PVA 880	-668	-617	-1161*	1145*	-1509*
GCG 5					
Kabanima	-667	233	-1894***	533	-1323
PVA 563	-542	-113	-1065**	1109	-1877**
G 12470	-1065*	-709	-980***	-1977*	-3436**
GCG 4					
Kirundo	-443	5	-1214**	1990***	-1925***
Kilyumukwe	-127	-584	-1243*	1190*	-2133*
A 197	-525	-214	-864*	831	-1643*
Muhinga	-216	-553	-1198**	1704**	-1017
GCG 6					
K 20	-694	-997	-1869**	1557**	-449
ZPv 292	-241	315	-1106**	2133***	-1680**
GCG 1					
G 13671	-980	-405	-1876***	272	-1074
Urubonobono	-707	63	-1707***	1588*	-1090*
Rubona 5	-1134*	-948	-1724***	1452*	-1540
GCG 7					
Carioca	-404	-180	-1813**	962	-569
GCG 8					
G 2816	-1444**	-1249**	-1573**	2252***	-876*

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Table 35. Regression coefficients from multiple regressions of yield and components on the independent variable disease index.

Genotypes	Seed yields (kg/ha x10)	Canopy sizes (cm^2)	Pods/m^2 ($x10^2$)	Seeds/100 pods ($x10^2$)	Weight/1000 seeds (g x 10^2)
GCG 3					
Red Wolaita	1041	20	25	-1905*	3218**
Black Dessie	903	-116	263	442	3489***
T-3	648	507	923	-538	411
GCG 2					
PVA 1272	-1299	-597	657	1673	-3510**
T 23	112	-567	687	1146*	-1554
Calima	187	-883	638	-119	-711
PVA 880	282	-536	609	1529*	-1293
GCG 5					
Kabanima	473	-488	1277**	1829*	-2933**
PVA 563	566	-1073	474	665	-347
G 12470	433	-519	112	1416	-3549
GCG 4					
Kirundo	1671*	-544	1291*	1743*	-919
Kilyumukwe	1899	108	1380	1329	-1574
A 197	1755*	-801	1238*	182	258
Muhinga	1153	6	1217	2003*	-2316*
GCG 6					
K 20	-150	-545	-439	1964*	614
ZPv 292	664	-1182	1069	1625	-427
GCG 1					
G 13671	1163	-1514*	1442	1640	-987
Urubonobono	1583	-906	1003*	1297	933
Rubona 5	-8	-702	870	1361	-3961*
GCG 7					
Carioca	722	-362	377	483	1092
GCG 8					
G 2816	1626	-305	937	516	-457

*, ** and *** denote coefficients significantly different from zero at P = 0.05, 0.01 and 0.001, respectively

Figure 1. Dendrogram of environment classification for seed yields.

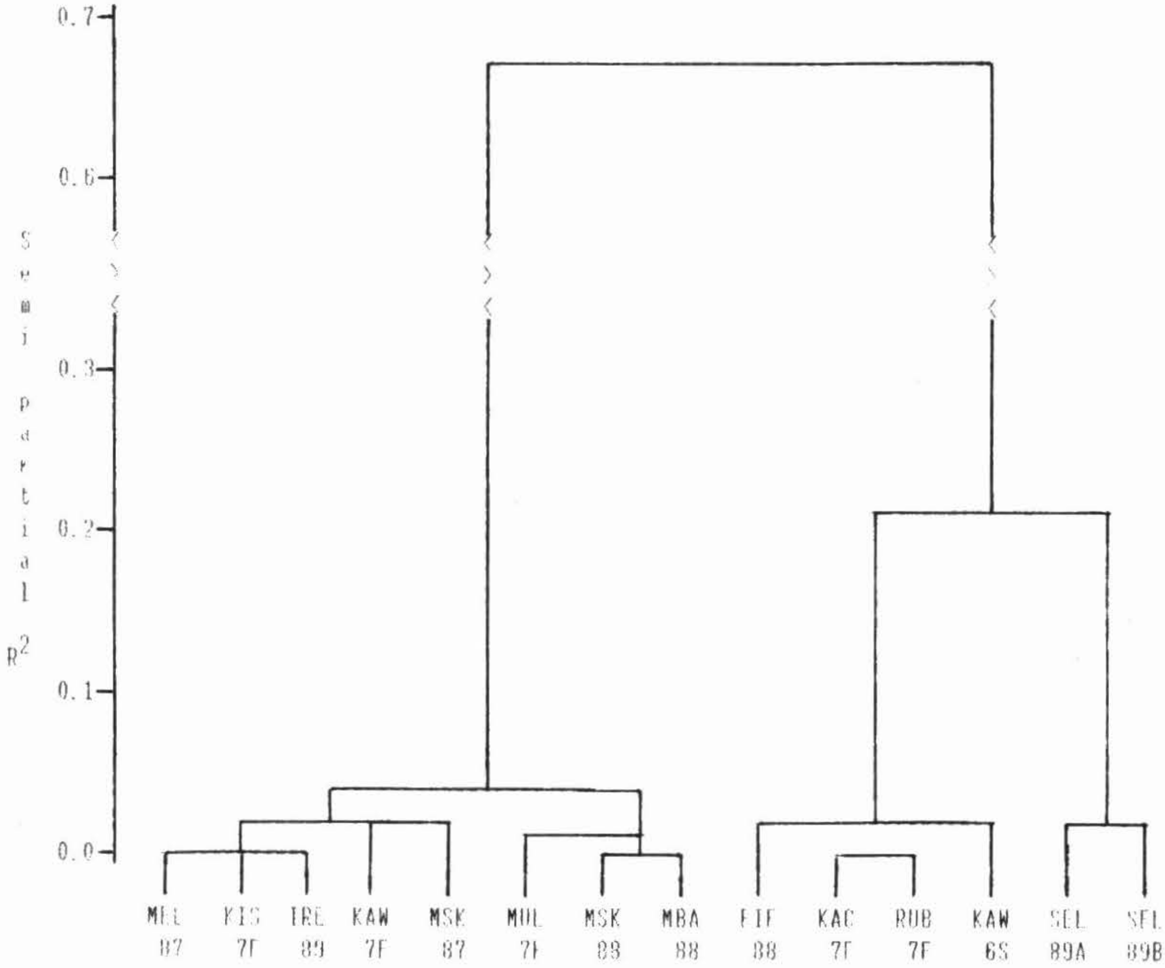

Figure 2. Dendrogram of genotype classification for seed yields.

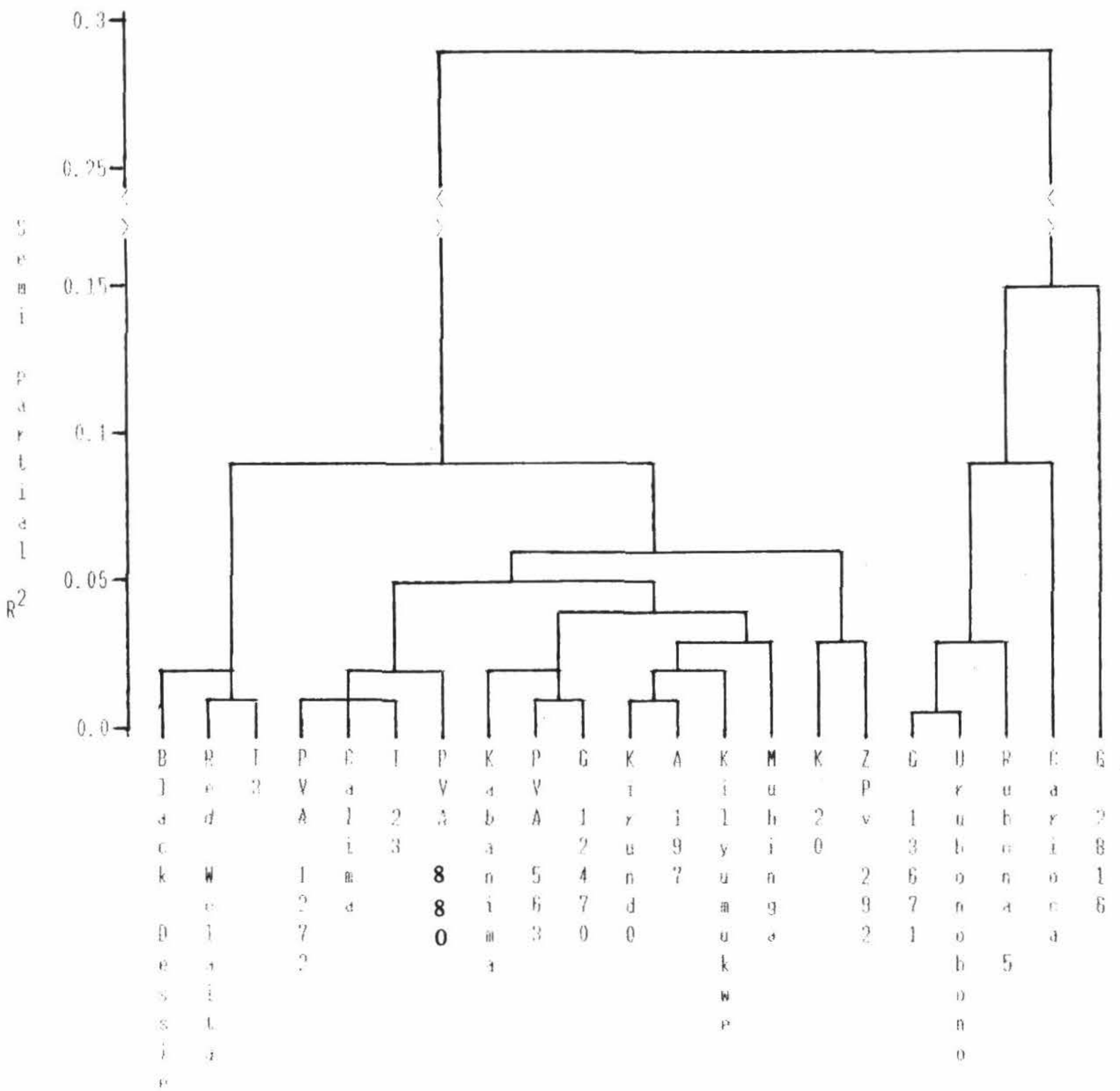

Figure 3. Regression of yield of PVA 563 on environment mean yield.

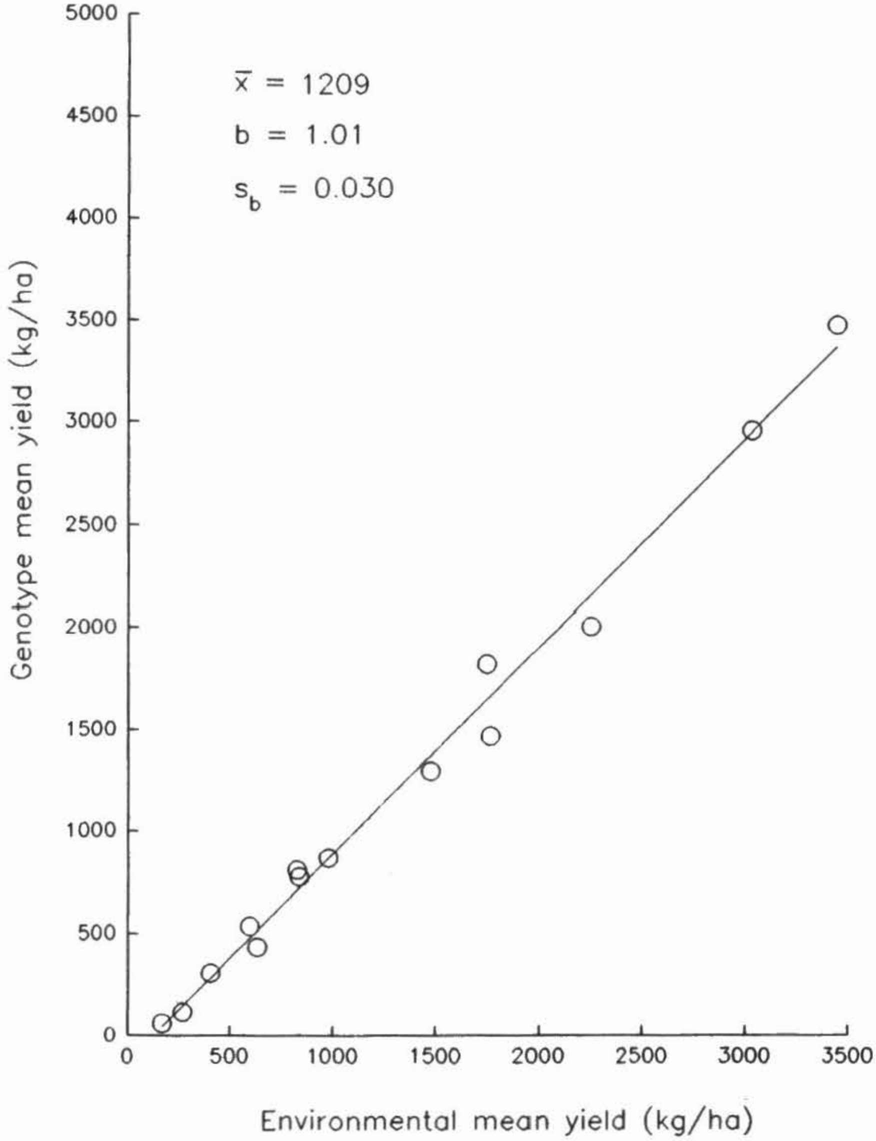

Figure 4. Regression of yield of PVA 1272 on environment mean yield.

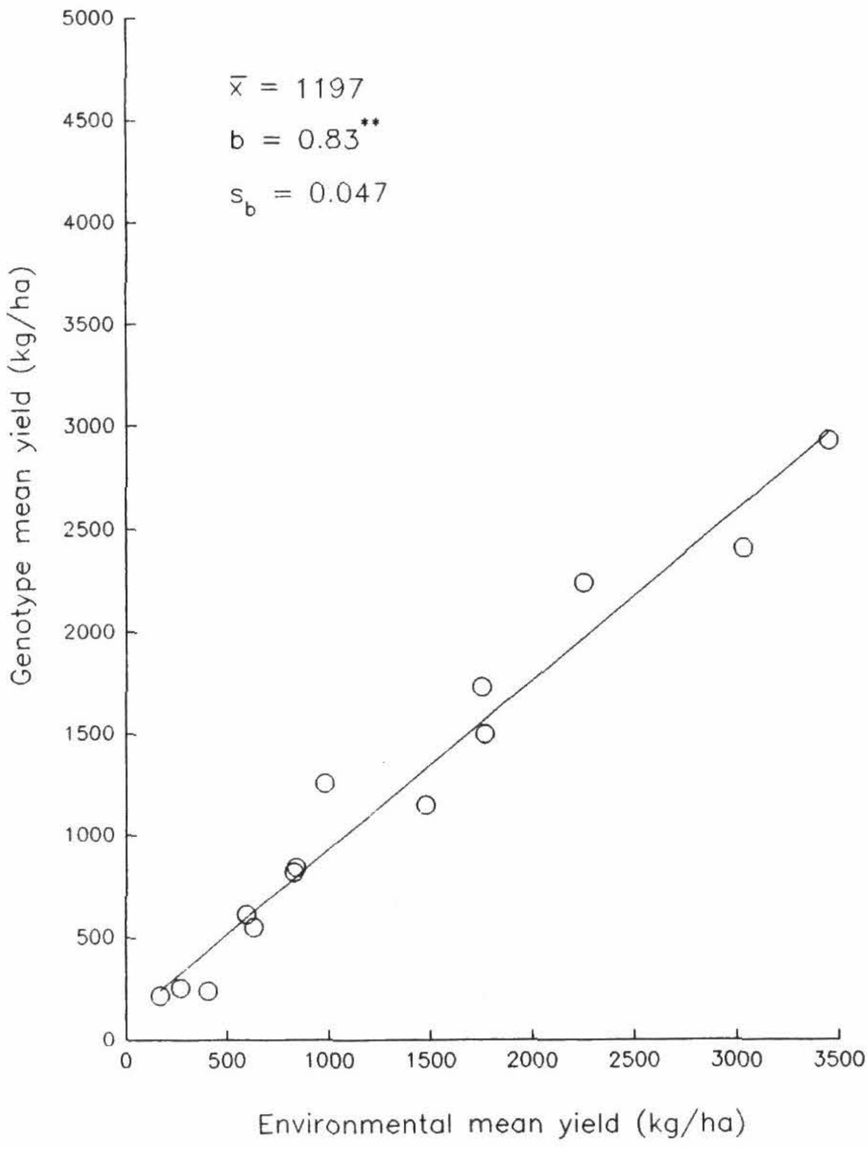

Figure 5. Regression of yield of G 13671 on environment mean yield.

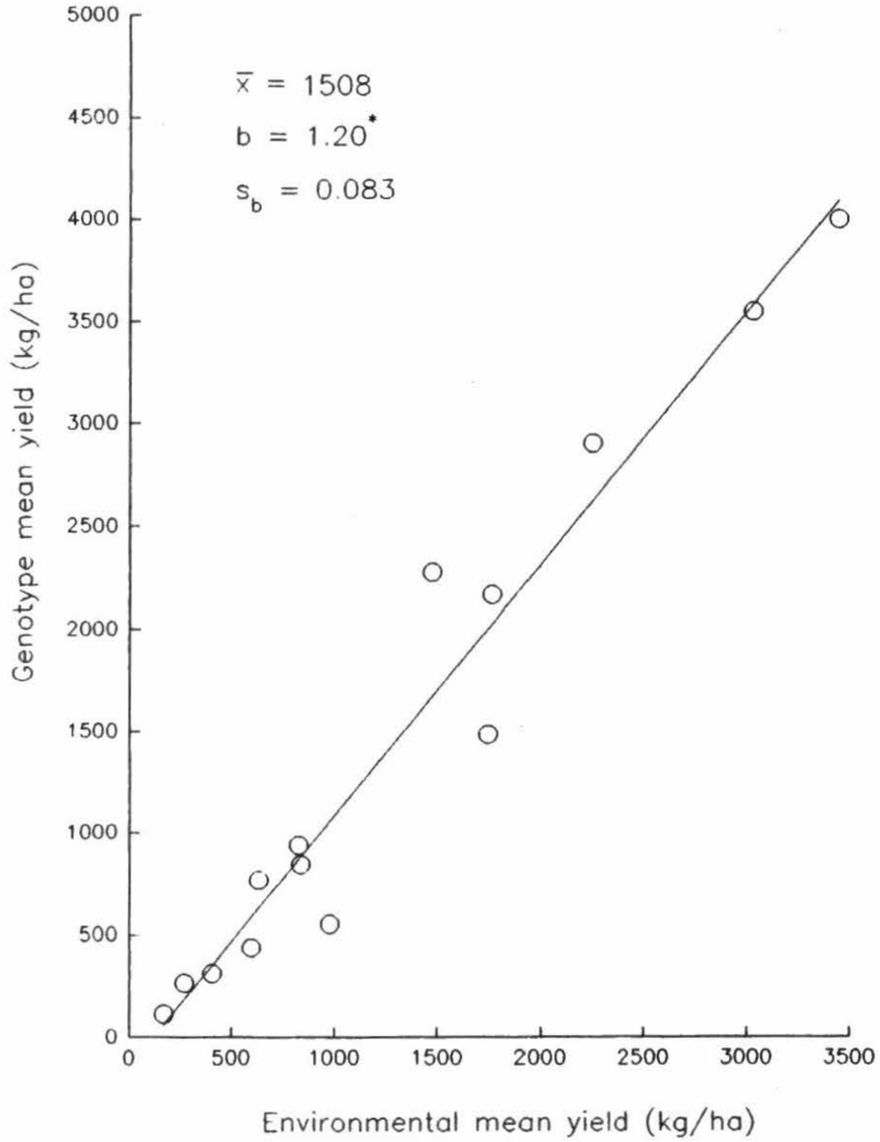

Figure 6. Regression of yield of G 2816 on environment mean yield.

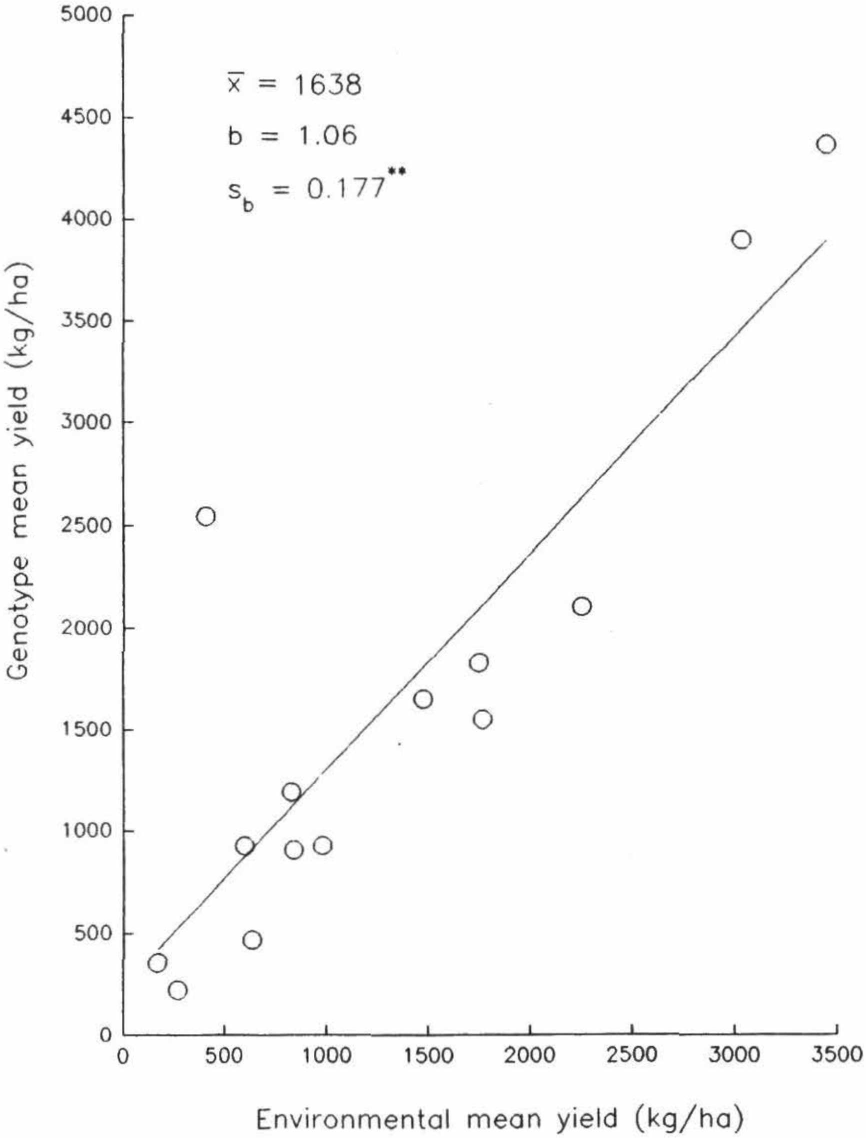

Figure 7. Regression of yield of Carioca on environment mean yield.