COMBINING ABILITY, HETEROTIC GROUPING OF EARLY GENERATION LINES AND YIELD STABILITY OF DROUGHT TOLERANT MAIZE HYBRIDS

A THESIS SUBMITED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING IN THE UNIVERSITY OF NAIROBI

TITUS KIPLIMO KOSGEI

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

P.O BOX 29053- 00625

KANGEMI, NAIROBI

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DECLARATION

This thesis presented for an award of Master of Science in Genetics and Plant Breeding at University of Nairobi is my original work and has not been previously submitted in part or totality in any university for an award of any degree.

Name: Titus Kosgei

Sign ……………………………………. **Date ……………………………….**

Examiners

Dr Kiarie Njoroge

Sign ……………………………………… **Date …..**

Prof. Solomon Shibairo

Sign ……………………………………. **Date ……………………………….**

Dr. Dan Makumbi

Sign ……………………………………. **Date ……………………………….**

DEDICATION

This work is dedicated to my cheerful son and wife, parents and brothers.

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AD-	Days to Anthesis
AMMI-	Additive Main effects and Multiplicative Interactions
ASI-	Anthesis to Silking Interval
DTP-	Drought Tolerant Population
EPZ-	Export Processing Zone
GCA-	General Combining Ability
GEI-	Genotype-Environment Interaction
GLS-	Gray Leaf Spot
OPV-	Open pollinated varieties
SCA-	Specific Combining Ability
SD-	Days to Silking

ABSTRACT

Maize (*Zea mays* L) is an important food and feed crop in sub-Saharan Africa whose demand has continually increased pushing farmers to grow the crop in less suitable areas. Breeders have developed new germplasm that can withstand drought and other stresses offered by the variable environmental conditions on the farmers' fields. The objectives of this study were to determine the general and specific combining abilities of the early generation materials, classify them into their heterotic groups and to determine yield stability of the new hybrids across different locations. In the first part of this study, one hundred and six selected early generation lines were crossed to two single cross testers (CML312 x CML 442 and CML395 x CML444) which belong to heterotic groups A and B respectively, and the results evaluated in 6 environments. In the second part, 46 new drought tolerant hybrids were evaluated across 17 environments. Good performing hybrids were identified on both the early generation hybrids and regional hybrid trials test varieties. Results also revealed significant differences ($P < 0.001$) for grain yield among early generation hybrids where entries 74, 25, 35 and 32 were identified as good performers at Kakamega, Kiboko and Embu trials. Entries 35, and 74 showed good performance across all environments, with entry 74 being the best yielder overall. Lines 1, 4, 14, 16 and 37 showed favourable and significant general combining ability (GCA) for grain yield in all sites, and across sites. In addition, line 37 showed significant and favourable GCA for days to anthesis anthesis to silking interval and gray leaf spot indicating that it was a potentially good parent in formation of new hybrids. Specific combining abilities for lines classified 55 lines into heterotic group B, and 51 lines into heterotic group A. Stability analysis using 6 models revealed entry 74 having above average performance and stability when all stability analysis models were used, but for ecovalence and stability variance measures. Entries 100, 126, 116 and 23 showed above

average stability and yield performance across different locations, when Eberhart and Russell, and Finlay and Wilkinson were used. The GGE biplot technique provided a much better tool for analyzing genotype by environment interaction. Entries 27 and 74 (Early generation 3 way hybrids), and entries 29 and 42 (regional hybrids) were shown to be closest to the most ideal genotypes across all environments. The general, specific combining abilities and heterotic groups were determined and showed that these genotypes had potential hybrids for advanced yield testing and subsequent release. Stability analysis on the early generation hybrids and regional hybrids revealed entries that were stable across locations.

CHAPTER 1: INTRODUCTION

1.1 Background information

Maize (*Zea mays* L.) is an important cereal crop in both the developed and developing countries of the world, ranking third after rice and wheat. It is one of the most productive species of food plants (Aldrich. *et al.,* 1975) and is widely adapted. It has a wide geographical reach, being grown from sea level to elevations above 3000 meters above sea level, and from the equator to areas well beyond the subtropics (Dowswell *et al.*, 1996). It is a major source of energy and nutrients for both humans and livestock (Morris, 1998). The cereal in addition to rice and wheat provide at least 30% of the food calories to more than 4.5 billion people in 94 developing countries (von Braun *et al.*, 2010). Of the global maize production, about 21% is used directly as human food, but consumption and utilization varies greatly around the world.

The importance of maize is even greater in Africa. About 85% of the maize grown in sub-Saharan Africa is used directly as human food. It solely provides about 50% of dietary calories in Southern Africa, 30% in Eastern Africa and 15% in West and Central Africa (Pandey, 1998).The demand for maize is continually increasing and is expected to surpass that of rice and wheat by the year 2020. This increase is expected to be as a result of doubling of the maize demand from the 1995 level of 558 million tons to 837 million tons (IFPRI, 2000). A larger part of this increase is expected to come from the developing countries. Of the total 140,000 ha of maize grown worldwide, 96,000 ha is grown in developing countries (CIMMYT, 2000).

In Kenya, maize is the main staple food, and is an important source of energy and nutrients. A large proportion of the population, both in the urban and rural areas consume the cereal. Its consumption is estimated to be about 98 kilograms per person per year in Kenya. This converts to about 2.7 to 3.1 million metric tons per year (Jayne *et al.*, 2001). Therefore, food self-sufficiency is inextricably linked with maize in Kenya and East Africa (Karugia *et al.*, 2003), since it supplies about 40% of dietary calorie intake (Karanja and Oketch, 1990).

The long term goal of food self-sufficiency in Kenya and East Africa has remained unmet since production falls below the amount demanded in some years. Importation of maize, as a temporary measure to bridge the deficit, has been inevitable (EPZ, 2005). Various factors including biotic, abiotic and socioeconomic factors in the maize production environment can be attributed to the reduced production and short supply of maize.

i) Low soil fertility

Low soil fertility is among the most important yield reducing constraint in East and central Africa region. It contributes to production losses of up to 30% of the expected yield, valued at USD500 million (Edmeades *et al.*, 1995). Tropical soils have been known to be low in soil fertility. According to Kumwenda *et al.*, (1995) poor agronomic practices by the farmers like continuous cropping, removal and burning of crop residues and low or no use of fertilizer and soil amendments have led to soil depletion. These factors combined with intensive land use and subsequent decline in fallow periods has facilitated and worsened this problem. In addition, population pressure has pushed agriculture into les fertile areas, and even worse, the high costs of inputs have forced farmers to grow the crop unfertilized. Heisey and Mwangi (1996) reported that fertilizer use in Sub-Saharan Africa was less than 10Kg N per ha, mainly because farmers were not able to break even.

ii) Diseases

There are a range of diseases in maize, caused by fungal, bacterial and viral pathogens. The most important diseases in Africa are leaf blight (caused by *Exserohilum turcicum*), gray leaf spot (caused by *Cercospora zeamaydis*), ear rots (caused by diplodia and Fusarium), common leaf rust (caused by *Puccinia sorghii*), maize streak virus and head smut (caused by *Sphalotheca reiliana*) (Vivek *et al.*, 2004). Control of these diseases using chemicals is unaffordable, environmentally degrading and time consuming (M'mboyi *et al.*, 2010) and therefore host plant resistance is more appropriate.

iii) Weeds

Weeds equally cause severe maize yield losses because of the competition they put up to the maize crop. Parasitic weeds such as *Striga* are of very high importance and have caused annual losses estimated at USD7 million, regionally (M'mboyi *et al.*, 2010).

iv) Insect pests

Insect pest in maize are a major constraint to production due to direct yield losses and reduction in grain quality they cause. A large area key in production of maize have been found to have up to 60% infestation by lepidopteran pests (James, 2003). The most prominent borers in East Africa are the spotted stem borer (*Chilo partelus*) and African stem borer (*Busseola fusca*). It is estimated that global annual losses stand at USD 5.7 billion and pest control pesticides valued at 550 million are spent in control of insects (M'mboyi *et al.*, 2010).

v) Drought stress in maize

Drought is ranked as the most important constraint to maize productivity in East and Central Africa, and leads to a significant yield reduction (Edmeades *et al.*, 1989). It contributes to production losses of about 17% annually, valued at USD 280 million (Diallo *et al.*, 2004). Drought causes reduced yield and reduced establishment or complete crop failure if it occurs during the flowering through grain filling stage and early development or seedling stages respectively. Occurrence of drought during flowering and grain filling stages has been shown to result in maximum yield reduction (Bänziger *et al.*, 2000; Grant *et al.*, 1989). Production of maize in exclusively rain fed systems in Kenya has predisposed farmers to crop losses due to drought and erratic weather patterns. In addition, an increase in the population has led to a shift in maize cultivation into marginal and semiarid areas characterized by drought and poor soils. An increase in frequency and unpredictability of drought conditions over time and space (Campos *et al.*, 2004) has necessitated development of drought tolerant varieties for the moisture stressed areas. Great efforts have been put in the recent past towards development of high yielding stress tolerant inbred lines for hybrid development. Pedigree selection and backcrossing strategies have been used widely since selfing materials from lines with desirable attributes increases the probability of deriving superior lines, as compared to selfing of heterogenous materials (Pandey, 1998). Lines developed from these strategies have been selected based on their per se performances for yield and other secondary traits as well as combining abilities, under drought and other stresses, from extended top cross experiments data. This selection has led to development of elite inbred lines through combination of genes from elite backgrounds (Hallauer, 1990)

Breeding for drought tolerance through selection for earliness would mainly target development of cultivars that can complete their life cycles sufficiently within the season so that they are not significantly affected by terminal drought. Therefore selection for earliness is focused at developing materials whose growth pattern matches the availability of water/ moisture. Selection for tolerance to drought that targets the critical stages is ideal in developing hybrids for areas with variable precipitation, and whose rainfall pattern cannot be predicted. Materials that show increased production under drought are more preferred over those that show mere survival in the same conditions.

These drought tolerant hybrids should have stable grain yield over time and across the target environments (Becker and Leon, 1988; Piepho, 1996). Differences in yield stability are a result of genotype and environment interaction (GEI). Genotype x environment interaction (GEI) results in differential response of cultivars across different environments (Kang *et al.*, 2004). Some varieties can perform relatively better than others in one environment and become the worse off at another environment.

1.2 Statement of the problem and justification

Maize is the most important food crop in Eastern Africa and is the staple food in Kenya. More so, it is widely grown by small holder farmers, mainly under rain fed conditions. A decline in soil fertility and declining availability in water resources (Beck *et al.*, 1997) has necessitated development of stress tolerant hybrid varieties. However, the environments in which the new varieties are planted in exposes them to many environmental stresses due to the dynamic conditions resulting from changing climatic conditions, with rains becoming more erratic and production shifting to less reliable areas. The production environment is also changing due to escalating costs of inputs making them unaffordable to many small scale farmers. This has resulted in reduced yields, frequent crop failures and subsequent food shortages, owing to the high dependence on maize for food in Kenya. Maize breeding, until recently, focused on developing new maize varieties that have better yields and agronomic traits, for different environments under the prevailing farmer conditions. The International Maize and Wheat Improvement Center (CIMMYT) has developed and released maize inbred lines with tolerance to abiotic stresses of primary importance under farmers' conditions. Newer maize inbred lines with different genetic background are also being developed. However, information about the combining ability and heterotic groups of the new lines is not available, and the best hybrid combinations have not been identified. Some of the older stress tolerant lines have been used to develop hybrids that have been tested in several countries in East and Central Africa. The GEI interaction of the new hybrids has not been studied to determine which hybrids are more stable in the target environments.

1.3 General objective

To determine the combining abilities, classify early generation maize lines into their respective heterotic groups and assess the stability of performance of drought tolerant maize hybrids for mid altitude areas of Eastern Africa.

1.3.1 Specific objectives

i. To identify good hybrids by utilizing general combining ability estimates of early generation lines.

ii. To estimate the specific combining ability of the early generation lines and classify them in their respective heterotic groups.

iii. To asses grain yield stability of early generation hybrids and new drought tolerant hybrids, to determine the best varieties and testing sites using mathematical models.

1.4 Hypothesis

i. General combining ability estimates can reliably be used to identify good hybrid combinations from early generation lines.

ii. Specific combining ability can reliably be used to assign maize lines into their specific heterotic groups and to identify lines with good combining ability that can be used as parents in hybrid combinations.

iii. Mathematical models can reliably be used to identify varieties whose yields are predictable across target environments as well as ideal testing sites.

CHAPTER 2: LITERATURE REVIEW

2.1 Breeding for drought tolerance

Drought is an important source of stress in maize production systems in the tropics, and continually causes losses because of the shifting climatic patterns (Hillel and Rosenzweig, 2002; Lobell *et al.*, 2011) and production of maize in less arable areas due to population pressure (Bänziger and Cooper, 2001). Therefore selection for good performing germplasm under drought is a priority objective in many breeding programs (Castleberry and Lerette, 1980). The global climate change underway (Hillel and Rosenzweig, 2002) is expected, in the long term to result in increased drought among other effects. Climate-yield predictions have been carried out for many of the important crops, using simulation models (Lobell *et al.*, 2011). Results from these analyses have indicated the need for investment in breeding for crop adaptation to mitigate catastrophic losses in yield and to enable sufficient production of food to meet demand from the fast growing human population.

The International Centre for Maize and Wheat Improvement Center started improvement of tropical maize for drought tolerance, having identified drought as an important factor limiting maize productivity in low income countries (Edmeades *et al.*, 1989) in the 1980s. Breeding for drought tolerance is complex since the trait is controlled quantitatively and often confounded by differences in plant phenology (Barnabas *et al.*, 2008). It is therefore critical to understand the physiological and genetic basis of this response. This would enable them to apply appropriate breeding strategies to maximize on genetic gain made (Reyazul *et al.*, 2012).

CIMMYT scientists used recurrent selection techniques in elite populations since they had low frequencies of genes conferring drought tolerance. They evaluated improved populations for drought tolerance using controlled irrigation during rain free periods, and simulated drought (Bolaños and Edmeades, 1993). Severe drought stress imposed at flowering and grain filling led to a yield reduction of 30% relative to yields observed under optimum moisture conditions. A selection index that considered yields under optimal and drought conditions, anthesis to silking interval, barrenness, leaf senescence and leaf rolling was developed from information generated from these experiments (Edmeades *et al.*, 1999). Drought tolerant versions of the initial lowland tropical populations were developed from this method. Two drought tolerant populations of maize, DTP1 and DTP2, were developed at CIMMYT through recurrent selection using known sources of drought tolerance (Edmeades *et al.*, 1997).

2.2 Combining ability

The concept of combining ability was first described by Sprague and Tattum in 1942. They described general combining ability (GCA) and specific combining ability (SCA) as a way of determining the genetic value of a population (Sprague and Tatum, 1942). The mathematical models of these parameters were set out by Griffing in 1956 in his classical paper (Griffing, 1956). Information generated when GCA and SCA values are calculated is of great importance to breeders since it is indicative of the relatedness of their breeding materials. They also enables breeders to identifying the type of gene actions responsible for quantitative traits, and thereby assist in identifying lines that exhibit heterosis in hybrid combinations, without necessarily making all possible crosses. Breeders in CIMMYT maize program have been keen to make use of these parameters in their developmental activities.

In late 1960s, the CIMMYT maize program worked on collection and evaluation of various sources of maize germplasm. This culminated in successful release of many open pollinated varieties (Vasal *et al.*, 1992b). They later began the development of hybrid maize to suit the demands of hybrid oriented farms and markets (Beck *et al.*, 1997). Therefore studies to investigate heterotic groups and patterns were started (Vasal *et al.*, 1992b; Vasal *et al.*, 1992a). This task culminated with the identification and release of 10 pairs of subtropical, mid altitude and highland populations in 1990s. They were subjected to reciprocal recurrent selection to increase the genetic distance between partner groups (Fan *et al.*, 2009). One hundred and thirty four subtropical, 38 mid altitude and 26 highland inbred maize lines were thus produced from this work.

A heterotic group is a set of lines that can be traced back to a common origin and display similar combining ability when crossed with lines from different genetic backgrounds (Dubreuil *et al.*, 1996). Crossing maize lines from different heterotic groups would offer a breeder better chances of obtaining potentially good hybrids (Fan *et al.*, 2009). Conventionally, a breeder makes many crosses between maize lines selected based on pedigree information (Smith *et al.*, 1997). This does not provide enough information for breeders to decide which materials to be included in crosses. The classification of inbred lines into heterotic groups is therefore of very high importance in hybrid maize breeding.

There are two major methods of heterotic group classification. In the traditional method, breeders assign the germplasm into the different heterotic groups based on the estimates of the combining ability patterns obtained using information from testcross trials (Fan *et al.*, 2001; Fan *et al.*, 2004). The second method utilizes molecular markers to compute genetic similarity or genetic distance to assign maize inbred lines to different heterotic groups (Barata and Carena, 2006).

Tropical maize germplasm is generally classified into two main heterotic groups: A and B. These groups enable breeders to place tropical maize inbred lines into the respective heterotic groups and thus avoid making unnecessary crosses and subsequently evaluation of hybrids. When two genetically diverse parents are crossed, the resultant F1 generation will often exhibit heterosis in various magnitudes (Hallauer and Miranda, 1988). The best combinations of hybrids result from a cross between lines from different heterotic groups (L´opez *et al.*, 2003). Even with the recent history of hybrid maize development in tropical regions, tropical maize germplasm classification into heterotic groupings has not been extensively done and thus it is one of the major constraints in the development of superior hybrids for the tropical areas.

2.4 Stability in plant breeding

Genetic stability is important in plant breeding as it helps in improving the efficiency of cultivar selection across a wide environment, using cultivar means. A significant amount of G x E interaction reduces this efficiency (Hopkins *et al.*, 1995). It is important that multi-environmental field experiments are done to ascertain the stability of a variety before it is released. Breeders can then generate information important in cultivar evaluation and recommendation in plant breeding programs and agriculture.

Phenotypic stability is the ability of a genotype to express itself in a way that it does not fall outside the expected values in different environments. A lot of GEI is disadvantageous to breeding since it reduces progress from selection and also makes cultivar recommendation difficult (Kang and Magari, 1996). Some genotypes maintain similar phenotypic values in different environments, while others do change with a change in the environments but in a positive and predictable way. Both of these scenarios are an expression of stability. According to Becker and Leon (1988) there are two concepts of stability: static and dynamic.

Static stability is present when a variety maintains its performance with a change in the environmental conditions. This means that a variety would not respond to a change in factors in the environment, for example, a high level of inputs. This type of stability would not be useful to farmers, if a variety is a low yielding genotype. But for traits such as resistance to diseases, it would be very important.

Dynamic stability is present when a variety's performance changes with a change in the environmental conditions, but in a positive and predictable way. Most genotypes respond to a variation in the environmental conditions. This therefore results in a variation in the trait levels. Therefore, a deviation from this variation can be considered as a source of instability. Approaches of measuring dynamic stability include those that are based on GxE quantification like rank ordering.

2.6 Measurement of stability

Three main approaches have been used in the past to measure stability of various crops. These are a)parametric, b) non-parametric and c) multivariate approaches, which are briefly reviewed below.

i) Parametric and non-parametric

These methods are based on the distributional assumptions about genotypic effects, environmental effects and G x E effects. Assumptions such as normality, genotype additivity and variance homogeneity are made (Yue *et al.*, 1997). Univariate parametric methods include simple and bi segmental linear regression; nonlinear regression models variance components with mixed models and descriptive statistics.

The use of non-parametric methods may be necessary when data has a ranking but no clear numerical interpretation, such as when assessing preferences; in terms of levels of measurement, for data on an ordinal scale. These models give a modified interaction concept because interaction is only in those environments that are of significant importance in breeding (Yue *et al.*, 1997). Non parametric methods include variance of genotype rank values. Non-parametric methods are widely used for studying populations that take on a ranked order. These methods relate to environments and phenotypes relative to biotic and abiotic environmental factors.

Non-parametric models differed from parametric models in that the model structure is not specified initially, but is instead determined from data. The number and nature of the parameters are flexible and not fixed in advance. Non-parametric models also do not require assumptions such as those made in parametric models (Hühn, 1990; Nassar and Hühn, 1987). Most breeding programs incorporate some elements of both parametric and non-parametric approaches (Becker and Leon, 1988) because these classifications are complementary rather than being mutually exclusive.

ii) Multivariate

Multivariate methods include additive main effects and multiplicative interactions (AMMI) analysis (Crossa, 1990). In AMMI, interaction effects are modeled through a principal component model (Johnson and Wichern, 1998). (The AMMI model is discussed in some detail below) Applicability and application of these models has been of considerable concern to breeders. The choice of the models has always been dependent on the researchers understanding and method of approach of stability (Lin *et al.*, 1986). In all the models, scientists focused on the means of genotypes estimated, for a given environment. Therefore a linear model may be considered to come up with a graphical representation. For example:

$$Y_{ij} = \mu + g_i + e_j + ge_{ij} + \bar{\varepsilon}_{ij}$$

Where Y_{ij} is the i^{th} genotype mean as observed in the j^{th} environment, for the different varieties and the different environments respectively, μ is the overall constant, g_i is the fixed effect of the i^{th} environment. e_j is the sum of the effect of the interaction between the i^{th} genotype and the j^{th} environment, ge_{ij} is the interaction effect between the genotype and the environment for the i^{th} genotype for j^{th} environment and $\bar{\varepsilon}_{ij}$ is the mean error related to the observed Y_{ij} which is assumed to be 0 and normally distributed.

2.7 Methods of measuring phenotypic stability

Genotype and environment interaction (GxE) is the differential reaction of different genotypes when they are exposed to different environmental conditions (Kang *et al.*, 2004). This interaction can therefore be used in genetic stability analysis. Ferreira *et al.*,(2006) proposed that phenotypic stability be measured by modeling GxE interactions (Ferreira *et al.*, 2006). There are five broad methods to measure these interactions as follows;

i. Variance of genotypes;
ii. Ecovalence and stability variance measure;
iii. Regression of coefficients; and
iv. Multivariate methods

i) Variance of genotypes

The variance of genotypes method has been used for almost 100 years. Phenotypic stability can be estimated using an analysis of variance of each of the genotypes over the environments in which it was tested (Roemer, 1917). This estimation of variance can be described by the formula below:

$$s_i^2 = \frac{\sum_{j=1}^{q} \left(Y_{ij} - \overline{Y}_{i.}\right)^2}{q-1}$$

Where s_i^2 is the variance of the i^{th} genotype, Y_{ij} is the yield of a cultivar i in the j^{th} environment, $\overline{Y}_{i.}$ is the mean yield of variety i and q is the number of environments being tested.

This model is an application of the static concept of phenotypic stability. A genotype would be considered stable if its estimated variance is not significantly different from 0. In this case, the genotype will not show a variation in yields with a change in the environments. However, varieties that have such a high phenotypic stability across environments have low yields. This method of measuring phenotypic stability can be important in measuring the stability of genotypes that would desirably be constant across different environments, for example, resistance to diseases or resistance to environmental stresses. This type of stability can be important if the geographical range could be restricted.

ii) Regression of coefficients

The regression approach was first suggested by Yates and Cochran (Yates and Cochran, 1938). They proposed partitioning the G x E interactions by calculating the regression of the means of yields of the different genotypes in their respective environments. This approach was then used by other scientists, and modifications added on to the approach. Three types of models developed as a result of modifications; the simple linear regression model (Finlay and Wilkinson, 1963), the unisegmented linear regression model and the bisegmented linear regression model.

iii) Simple linear regression model

Finlay and Wilkinson (1963) proposed the use of a simple linear regression model of analysis which could be described as below;

$$Y_{ij} = \beta_{0i} + \beta_{1i}\overline{Y}_{.j} + \delta_{ij} + \overline{\varepsilon}_{ij}$$

Where Y_{ij} is the yield of the i^{th} genotype in the j^{th} environment, β_{0i} is the coefficient for the regression of the i^{th} genotype in environment o, β_{1i} is the coefficient of regression for the i^{th} genotype in environment *1* and $\overline{Y}_{.j}$ is the average yield of all genotypes in environment *j*. δ_{ij} is the coefficient of G x E interaction of the i^{th} genotype in the j^{th} environment and $\overline{\varepsilon}_{ij}$ is an error term.

In this method, the yield of a specific genotype in a given environment is regressed on the measurement of the environment (Yates and Cochran, 1938). The assumption here is that the regression coefficients differ and are specific to the genotypic characteristics. Therefore we need a parameter for the environment as the environmental index which is independent for the specific experiment. Very often, the average of all genotypes is used since an independent measure may not be available.

iv) Unisegmented and bisegmented linear regression models

The unisegmented and bisegmented linear regression models have been used by many workers (Cruz *et al.*, 1989; Eberhart and Rusell, 1966; Freeman and Perkins, 1971; Shukla, 1972). The similarity in these scientists approach was that they regressed the genotypes performance on the different environmental mean yields, through linear or non-linear parameter models.

v) Ecovalence and stability variance measure

Ecovalence is the genotypes ability to respond to environmental change. Wricke (1964) proposed the use of sum of square of the G x E population effects as a measure of this parameter. This is borne out of the logical inference that each genotype in the population contributes to the sum of squares of the interaction between the genotypes and the environment. This is the genotypes ability to answer to an environmental change. This method applies the dynamic concept of stability and uses the following formula:

$$W_i = \sum_{j=1}^{q} \left(Y_{ij} - \overline{Y}_{i.} - \overline{Y}_{.j} + \overline{Y}_{..}\right)^2$$

Where W_i is the total G x E population effects, Y_{ij} is the yield of the i^{th} genotype in the j^{th} environment, $\overline{Y}_{i.}$ is the average yield of the i^{th} genotype in all environments, $\overline{Y}_{.j}$ is the average yield of all genotypes in the j^{th} environment and $\overline{Y}_{..}$ is the average yield of all genotypes in all environments.

This way the GxE interaction sum of squares can be estimated. If W_i is 0, then the genotype is considered stable. But if it is more than 0, then the genotype is considered unstable.

Shukla (1972) modified the ecovalence measure by linear transformation and called it the *stability variance measure.* This parameter could be describe by the equation below;

$$\sigma_i^2 = \left(\frac{p}{(p-2)(q-1)}\right)w_i - \frac{ss(GxE)}{(p-2)}$$

This stability variance measure differs from ecovalence measure only in the linear transformation, but results in a similar rank order of genotypes.

Both regression of coefficients, and ecovalence and stability variance measures are dependent on the genotypes included in the test. Therefore generalization is unnecessary because the mean of all genotypes is used as a standard response in each environment. Therefore breeders must be careful when inferencing using these models of stability. The sample must be representative of the original population.

vi) Cluster analysis

It is a method that determines groups through numerical classification. It is a relatively new concept of analysis. In this approach, the genotypic population is divided into groups of similar genotypes. Cluster methods involve two aspects; the definition of similarity or dissimilarity measure and the algorithm that groups objects. There are two main methods to measure similarity: the *unicriterion* and the *multicriterion.*

For the unicriterion method, there are four groups, which are the Euclidean distance, standardized distance, dissimilarity index and correlation coefficient. In each of the groups there are two types of indexes identified as *A* and *B*. *A* indicates that the similarity is because of genetic effect and G x E interaction, while *B* indicates that the similarity is because of the G x E alone.

Both parametric and non-parametric methods give individual results of stability, but do not give a more generalized picture of the response. For example, a genotype can be considered as stable when tested using the analysis of variance of genotypes, and at the same time it is unstable when analyzed using ecovalence and stability variance measure. In this case it would be difficult to get conclusive results from the analyses. This is because the response of the genotypes to the environments is in a multivariate fashion.

vii) Multivariate methods

This approach uses the mathematical concepts of eigenvalues and eigenvectors. Mathematically, an *eigenvector* is a non-zero value which may be positive or negative and which when applied on a linear transformation, it may change in length, if the transformation is positive or direction if the transformation is negative, but it remains along the same line. The magnitude of change in length is defined by a quantity termed as an *eigenvalue*. Thus an *eigenvalue* is the corresponding scalar value for each eigenvector which determines the amount by which the eigenvector is scaled, under the linear transformation.

Multivariate methods are important in studying phenotypic stability where genotype response to the environment is in a multivariate fashion rather than simple interactions. This includes the additive main effects and multiplicative interactions methods (AMMI). The additive main effects and multiplicative interactions approach is an analysis method that identifies genotype and environment relationship when the two principal components are retained. The main aim of AMMI is to model the interactions through a principal component model

Multivariate methods are important in studying phenotypic stability where genotype response to the environment is in a multivariate fashion rather than simple interactions. This includes the additive main effects and multiplicative interactions methods (AMMI). The additive main effects and multiplicative interactions approach is an analysis method that identifies genotype and environment relationship when the two principal components are retained. The main aim of AMMI is to model the interactions through a principal component model Therefore when plotted on a principal component index axis against mean yield, a stable genotype is located as close as possible to 0 on the environment axis and as furthest as possible to 0 in the yield axis. This method was developed by Gabriel (1971) and Gollob (1968). It has since then been used and advanced by other authors (Crossa, 1990; Gauch and Zobel, 1988; Zobel *et al.*, 1988).

An AMMI model could be defined by the model below;

$$Y_{ij} = \mu + g_i + e_j + \sum_{k=1}^{m} \lambda_k r_{ik} s_{jk} + \delta_{ij} + \bar{\varepsilon}_{ij}$$

And the G x E interaction effect is

$$\sum_{k=1}^{m} \lambda_k r_{ik} s_{jk} + \delta_{ij}$$

Where λ_k is the eigenvalue associated with the k^{th} principal component; r_{ik} is the i^{th} element for the egenvector for λ_k associated with genotypes; S_{jk} is the j^{th} element of the eigenvector for λ_k associated with environments and *m* is the number of retained component axes.

Biplot analysis is an important tool in the multivariate approach of analysis. It is a scatter plot that approximates and displays a two way table in both its row components, column components and an interaction between row and column components. It was first used to analyze agricultural data in 1978 (Bradu and Gabriel, 1978). other workers have then used biplots for analysis of genotype by environment data (Cooper and De Lacy, 1994; Gauch, 1992). Various biplot visualization methods have been developed to address genotype by environment data questions that are relevant in genotype evaluation (Yan *et al.*, 2000) where genotype (G) and Genotype-Environment interactions (GEI) are the main sources of variation.

CHAPTER 3: COMBINING ABILITY AND HETEROTIC GROUPING OF EARLY GENERATION INBRED LINES UNDER STRESS AND NON-STRESS CONDITIONS

3.0 SUMMARY

Drought stress is one of the major abiotic stresses limiting maize production in Kenya. Knowledge of the general and specific combining ability of maize inbred lines in a breeding program is beneficial in development of breeding strategies to be used in the development of stress tolerant germplasm. The objective of this study was to estimate combining ability of the early generation lines and classify the lines into heterotic groups. One hundred and six (106) S3 lines were crossed to two testers; one from heterotic group A and the second from heterotic group B. The resultant 212 three way hybrids and three commercial checks were evaluated under drought stress and optimum moisture conditions at six locations in Kenya, in an alpha lattice design (5 x 43). Analysis of variance revealed significant general and specific combining ability effects ($P<0.01$) for grain yield in both managed drought and well watered conditions. Additive effects were of more importance than non-additive gene effects in the control of grain yield and other traits under drought stress and optimum conditions. Heterotic grouping of maize lines based on their specific combining ability patterns showed that 51 lines could be classified into heterotic group A while 55 lines could be classified into heterotic group B. Good performing hybrids were identified across all locations and in specific locations. Entry 74 was the best yielder overall and in Kakamega optimum and Kiboko drought sites in the first season. Entry 32 was the best in Embu optimum trial while entry 25 and 35 were the best in Kiboko optimum trial. Entries 1, 35 and 74 were the best across all locations.

3.1 INTRODUCTION

3.1.1 Drought stress

It is predicted that by 2030 developing countries will be seriously affected by climate change since most of the effects will be more pronounced in the tropics and in the subtropics. In addition, most of the expected population growth by 2030 will come from developing nations, and a good proportion of this population is directly or indirectly involved in agriculture (Reynolds and Ortiz, 2010). Drought effects resulting from climate change is a major challenge in current agriculture (Reyazul *et al.*, 2012). Breeding for drought tolerance is therefore an important undertaking.

Improvement of source populations for stress has increased the probability of deriving stress tolerant hybrids. CIMMYTs' maize program has stepped up breeding for drought since most maize in the developing world is grown under rain fed conditions. Breeders have put their efforts in alleviation of drought effects during the most susceptible stages of flowering and grain filling (Edmeades *et al.*, 1999). One of the strategies used was selection for early maturity to enable successful reproduction before onset of severe stress (Campos *et al.*, 2004). Occurrence of drought before flowering leads to delayed silk formation and consequently increased anthesis to silking interval (Edmeades *et al.*, 1999) Gains achieved from selection under stress were associated with increased flower synchrony (shorter ASI), fewer barren plants, a smaller tassel size, a greater harvest index including a larger number of ears per plant, and delayed leaf senescence (Edmeades *et al.*, 1999; Ribaut *et al.*, 2009). In the process of developing drought tolerant populations and extracting drought tolerant inbred lines, it is important to understand the relationship of inbred lines, per se performance and the hybrid performance under stressed and non-stressed treatments, and the comparative performance of inbreds in testcrosses.

3.1.2 Combining abilities and heterotic grouping

Information on the genetic value of lines developed in a breeding program is critical during hybrid formation. A maize breeder would be interested in identifying the type of gene actions responsible for quantitative traits, and thereby assisting in identifying lines that would exhibit heterosis in hybrid combinations, without necessarily making all possible crosses (Hallauer and Miranda, 1988). Significant values for general combing ability (GCA) and specific combining ability (SCA), estimated from yield data, may be interpreted as indicating the additive and non-additive gene action, respectively (Sprague and Tatum, 1942). General combining ability (GCA) enables breeders to distinguish relatedness among genotypes and exploit the existing variability in the breeding materials, and to identify individual genotypes conferring desirable attributes (Melania and Carena, 2005). The specific combining ability (SCA) is used to determine heterotic patterns among populations and inbred lines, to identify promising single crosses and to assign inbred lines into heterotic groups (Vasal *et al.*, 1992a).

Information on general and specific combining ability is of fundamental importance in a breeding program aiming to develop high yielding hybrid varieties. It is a rapid way of assaying the genetic value of a line(s). Breeders have been able to exploit the variability in breeding materials, and identified individual genotypes conferring favourable traits, and also distinguished their relationship patterns (Melania and Carena, 2005). Genetic diversity among groups of populations is often found to be associated with lines that possess good GCA and SCA. It is the basis for the expression of patterns among groups of genotypes. Han *et al.,* (1991) evaluated maize inter population crosses using CIMMYT populations and germplasm pools. They observed significant and positive SCA effects on inter population lines crosses leading to the conclusion that crosses from unrelated lines are more likely to show superior yielding performances (Han *et al.*, 1991). Therefore, information on general combining ability GCA of lines has enabled breeders to select good performing lines, and thus avoiding unnecessary costs in establishment of unnecessary hybrids trials. Grouping lines by their combining ability patterns into their respective heterotic groups is therefore a fundamental activity in a plant breeding program.

A heterotic group is a set of lines that can be traced back to a common origin and display similar combining ability when crossed with lines from different genetic backgrounds (Dubreuil *et al.*, 1996). Vasal *et al.*, (1992a) identified two different tropical heterotic patterns when he studied 92 white tropical maize lines using four testers. These were Tropical Heterotic Group A (THGA) and Tropical Heterotic Group B (THGB). The patterns were based on how they expressed their specific combining ability scores. The hypothesis behind this classification was that positive SCA effects between inbred lines generally indicate that lines are in opposite heterotic groups and lines in the same heterotic group exhibited negative SCA effects when crossed. Combination of lines from different heterotic groups result in hybrids with higher chances in expression of hybrid vigour (Birchler *et al.*, 2003; Ricci *et al.*, 2007; Tollenaar *et al.*, 2004). Tropical maize germplasm heterotic groupings have not been extensively studied and thus lack of this knowledge is a major constraint in quick development of superior hybrids adapted to these tropical conditions.

There are two major methods of heterotic group classification used worldwide. In the traditional method, breeders assign the germplasm into their different heterotic groups based on the estimates of the combining ability scores, from the hybrid yield (Fan *et al.*, 2001; Fan *et al.*, 2007). The second method employs current molecular markers to compute genetic similarity or genetic distance to assign maize to different heterotic groups (Barata and Carena, 2006).

Studies done on CIMMYT maize germplasm have identified two suitable single cross testers CML312/CML442 (A) and CML395/CML444 (B). They were widely adapted and are currently in wide use in these environments (Sebastian, 2007). CML202/CML395 and CML505/CML509 have also been identified as single cross testers for use in breeding programs.

The International Maize and Wheat Improvement Center (CIMMYT) developed inbred lines with tolerance to stresses of primary importance under farmers' conditions. However, information about their combining ability and heterotic groups of these new lines is not available, and the best hybrid combinations have not been identified. This section attempts to the estimate general ans specific combining abilities and classify early generation maize lines into their respective heterotic groups.

3.2 Materials and methods

3.2.1 The Experimental material and hybrid formation

One hundred and six (106) early generation lines at S3 (F4) stage were used in this experiment. These lines were developed from crosses between CIMMYT inbred line CML445 and nine inbred lines from the International Institute of Tropical Agriculture (IITA). Inbred line CML445, in heterotic group AB, is drought tolerant and has resistance to *Exerohilum turcicum* and gray leaf spot. The F1 between CML445 and the 9 IITA lines (formed in 2007) was selfed to form the F2 in 2008A at Kiboko. The F2s were selfed in 2008B at Embu to form the S2s and then advanced to S3 stage under disease pressure at Kibos in 2009A. Selection was done at harvest on individual plants for low ear placement, reduced ear rots, tolerance to *Exerohilum turcicum*, gray leaf spot, and common leaf rust. Each cob harvested was kept as a separate line (ear to row). From this nursery, 106 S3 lines were selected for this study. They were crossed to two single cross testers in a line by tester mating design (Kempthorne, 1957) in a nursery set up in Kiboko research station in October 2009. The testers used were CML312xCML442 (heterotic group A) and CML395xCML444 (heterotic group B). Two nurseries, one for each tester were planted. In each nursery, a line and a tester were planted side by side in single 4 meter row plots spaced at 75 cm between rows and 20 cm between plants in a plot. They were irrigated immediately after planting and further irrigation was applied to avoid moisture stress. Di-ammonium phosphate (DAP) was applied during planting at the rate of 27 Kg N ha^{-1} and 60 Kg P ha^{-1}, to help in root development and proper germination. Regent® (4SC Fipronil: 5-amino-1-(2, 6-dichloro-4-(trifluoromethyl) phenyl)-4((1, R, S)-trifluoromethyl) sulfinyl)-1-H-pyrazole-3-carbonitrile) was applied at a rate of 0.5 g per hill to keep off cut worms and other insects. Calcium ammonium nitrate (CAN) was applied four weeks after emergence at a rate of 60 kg N ha^{-1}.

3.2.2 Pollination and hybrid development

Plants were checked daily just before shoot emergence, for any new shoots and protective polythene bags used to cover emerging shoots, to prevent live pollen in the air from landing on them. The tassels were checked for pollen shed on the main branch and bagged using tassel bags to collect pollen from the tassels. At pollination, reciprocal pollination (each entry was used as a male and as a female) system was carried out, where each line was pollinated by a tester. Pollen was bulked from all plants in a row and manually applied on the respective plants silk.

At harvest, ears from lines and tester plants from each reciprocal cross were carefully harvested and bulked. A total of 212 three way hybrids were formed from the two nurseries. It was assumed that maternal effects were insignificant.

3.2.3 Experimental design and hybrid evaluation

The 212 three-way hybrids and three commercial hybrid checks (H513, WH403, and WH505) were evaluated in an alpha lattice (5 x 43) design (Paterson and Williams, 1976) trial at six environments. This was accomplished by testing for three seasons in Kiboko, two seasons in Kakamega and one season in Embu, in the 2010- 2011 cropping seasons. Table 3.1 below presents site information for the locations used in evaluation of the trials.

Single row plots were used, with plot dimensions varying in the different stations. In Kiboko, 4 meter rows with 2 seeds per hill were planted at a spacing of 20 cm between hills and 75 cm between rows was used, while in Kakamega and Embu, 5 meter rows with 25 cm between hills and 75 cm between rows was used. Thinning was performed at the three to five leaf stage to attain the required plant densities.

Optimum management trials: Two sets of trials in Kiboko, 2 in Kakamega and one in Embu were evaluated under optimum moisture conditions. Five grams of di-ammonium phosphate was applied per hill during planting. Hand weeding was then done four weeks after planting to minimize competition from weeds. Top dressing was then applied using calcium ammonium nitrate fertilizer, at the rate of 60 kg N ha^{-1}.

Trials under managed drought: One set of trial was evaluated under drought stress in Kiboko. It was conducted in Kiboko in 2010, during the rain free period between June and October, 2010.

Planting, fertilization and weeding was done the same way as optimum trials in Kiboko. The trial was irrigated to facilitate germination and throughout the vegetative stage. Irrigation was withdrawn two weeks to flowering so as to induce drought stress during this critical time of flowering, and no further irrigation was applied afterwards. Drought stress during flowering causes delayed silking and ear abortion (Bänziger *et al.*, 2000).

Table 3.1: Test sites environmental characteristics

Country	**Site**	**Longitude**	**Latititude**	**Elevation**	**Rain**	**Temperature °C**		**Area**	**Soil Texture**
				(m asl)	**(mm)**	**Min**	**Max**	(m^2)	
Kenya	Kiboko	37° 75'E	2° 15S'	975	530	14.3	35.1	3.15	Sandy clay
Kenya	Kakamega	34° 45'E	0° 16'N	1585	1916	12.8	28.6	3.94	Sandy loam
Kenya	Embu	37° 42'E	0° 449'S	1510	1200	14.1	25.0	3.90	Clay loam

3.2.4 Data collection

Yield and other secondary traits data for each plot in the different environments were taken. Eighteen variables were measured were as follows:

a) Grain Yield (GYG): Measured as the weight of grains only, after shelling had been done.

b) Field weight (GYF): Measured as the weight of ears, after removal of husks, but before shelling was done.

c) Anthesis date (AD): Measured as number of days from planting until 50% of the tassels had shed pollen.

d) Days to silking (DS): Measured as number of days from planting until 50% of the plants silks had emerged.

e) Anthesis to silking interval (ASI): Determined by calculating the number of days between when 50% of the plants had shed pollen (AD) and when 50% of the plants had their silks emerged.

f) Number of Ears (NE): determined by counting the number of ears which had at least one fully formed grain.

g) Number of plants (NP): Determined by counting the number of plants that survive to complete maturity and were ready for harvesting.

h) Number of ears per plant: (EPP) Determined by computing a ratio of the number of ears to the number of plants.

i) Plant height (PH): Measured as height (in cm) from the base of a plant to the point of the flag leaf or insertion of the first tassel branch of the same plant.

j) Ear height (EH): measured as height (in cm) from the base of a plant to the insertion of the top ear of the same plant.

k) Husk cover (HC): Measured as percentage of plants with bare tips on their ears.

l) Ear rot (ER): Percentage of ears that have at least 50% of them affected by rots.

m) Root lodging (RL): Measured as percentage of plants that were inclined by more than 45 degrees, indicating that they have weak roots.

n) Stem lodging (SL)**:** Measured as percentage of plants whose stems are broken below the ear.

o) Gray leaf spot (*Cercospora zeae-maydis)* (GLS), Nothern leaf blight *(Exserohilum turcicum)* (ET), Maize leaf rust *(Puccinia sorghii)* (PS), Maize streak virus (MSV): Were scored during grain filling stage, on a scale of 1 to 5, where 1 indicated no infection, and 5 being severe infection.

p) Ear aspect (EA): this is a score with a scale of 1-5, where 1 is a score for clean, uniform and large cobs with the preferred texture whereas 5 is a score for small non uniform and diseased cobs with an undesirable texture.

q) Plant aspect (PA): Was scored on a scale of 1 to 5 where 1 was for plants with a uniform height, uniform ear placement, free of diseases and generally looking attractive. Conversely, a score of 5 was for plants that had irregular height, irregular ear placement and were affected by diseases.

r) Leaf senescence (SEN): This was taken during grain filling stage. It was a score on a scale of 1 to 10, indicating the percentage of dead leaf area.

The data collected was then entered into MS Excel software. Data cleaning and preliminary analysis was done using Fieldbook (Bänziger and Vivek, 2007) which is built on Excel software.

3.2.5 Data analysis

Analysis of variance was carried out using the PROC GLM of SAS (SAS Institute, 2003) for each environment and across environments. Adjusted means for individual sites were calculated using the PROC MIXED of SAS (SAS., 2003). Mean separation was carried out using the least significant difference (LSD) method (Snedecor and Cochran, 1980)

Line x tester analysis was carried out according to Kempthorne (1957). The statistical model used for line x tester analysis was:

$$Y_{hijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{hijk}$$

Where;

Y_{hijk} = the observation of the k^{th} full-sib progeny in a plot in h^{th} replication of the i^{th} paternal parent and the j^{th} maternal parent;

μ = the general mean;

α_i = the effect of the i^{th} line;

β_j = the effect of j^{th} tester;

$(\alpha\beta)_{ij}$ = the interaction effect of the cross between i^{th} line and j^{th} tester;

ε_{hijk} = the error term associated with each observation.

In a line x tester analysis, the source of variation due to lines and testers is equivalent to general combining ability (GCA), while the source due to line x tester interaction is equivalent to specific combining ability.

3.3 Results and discussion

3.3.1 Single site analyses of variances

In the Kiboko managed drought trial, the analysis of variance revealed significant differences (*P* < 0.01) among entries and hybrids for GY, AD, ER, SEN and EA (Table 3.2). Entries, hybrids and lines showed significant difference (P < 0.05) for ASI, GY, AD, ASI, EA, EPP and ER (Table 3.2). This showed there was a high genetic variability in the materials used in the experiment, and that there was good potential for making good yielding drought tolerant varieties.

Individual well-watered trials analysis of variance

Significant differences were observed in Kiboko well-watered trial for the season of March to August 2010, where analysis of variance revealed significant differences (P < 0.05) on entries and hybrids for grain yield (GY) and ear aspect. Significant differences (P < 0.001) were also revealed for days to anthesis (AD), days to silking (DS) and ASI and HC (Table 3.3). Lines showed significant difference (p < 0.01) for GY and EA, and (P < 0.001) for AD, DS, ASI, and HC. In Kiboko well-watered second trial, analysis of variance revealed significant differences in entries, hybrids, lines and testers for all traits but ER and EA (Table 3.4).

At Embu, significant differences (P<0.05) between entries were revealed for all traits except ER, ET, MSV, and EA (Table 3.5). Similarly hybrids showed significant differences for all traits except HC and PS. Lines

Table 3.2: Mean squares for all traits in Kiboko drought trial

Source	DF	GY	AD	ASI	RL	SL	EPP	HC	ER	SEN	EA
Rep	1	7.47***	0.15	23.72*	27.08	0.61	0.63***	18.01	40.88*	1.96	1.07**
Entry	214	0.73**	4.65***	7.69***	10.21	58.04	0.03	10.05	16.09**	1.11***	0.20**
Hybrids	211	0.74**	4.44***	7.76***	10.31	58.5	0.03	9.63	16.28**	1.12***	0.20**
Line	105	0.98***	6.85***	9.88***	10.09	62.24	0.03*	8.43	15.85*	1.63	0.24***
Tester	1	1.47	40.47***	0.04	54.70*	119.12	0.09*	0	92.76**	4.16*	0.4
Line*Tester	105	0.5	1.68	5.72*	10.1	54.17	0.02	10.93	15.99*	0.58	0.15
Error	214	0.48	1.35	4.148489	9.8	60.16	0.02	11.51	11.19	0.64	0.13

Grain yield (t/ha) = GY, Anthesis date = AD, Anthesis to Silking Interval (Days) = ASI, Root lodging = RL, Stem Lodging = SL, Husk cover = HC, Ear Rot = ER, and Ear Aspect = EA

Table 3.3: Mean squares for all traits in Kiboko optimum trial, season of March to October, 2010

Source	DF	GY	AD	DS	ASI	RL	SL	HC	ER	EA
Rep	1	194.44***	2.23	2.23	148.86***	29.05	10.75*	386.56**	49.99**	18.42***
Entry	214	2.57*	3.24***	3.24***	3.23***	10.44	1.92	137***	6.49	0.27*
Hybrids	211	2.57*	3.21***	5.11***	3.27***	10.16	1.9	137.68***	5.44	0.27*
Line	105	2.83**	4.42***	13.59***	4.20***	12.07	1.86	128.29***	5.49	0.29**
Tester	1	0.35	5.66*	42.98**	10.91*	0	0.64	8638.55***	1.46	0.002
Line*Tester	105	2.33	1.96**	6.66**	2.27	8.3	1.92	66.16	5.36	0.25
Error	214	1.9	1.26	3	1.78	11.36	2.06	56.58	6.86	0.2

Grain yield = GY, Anthesis date = AD, Days to silking = DS, Anthesis to Silking Interval = ASI, Root lodging = RL, Stem Lodging = SL, Husk cover = HC, Ear Rot = ER, and Ear Aspect = EA,

Table 3.4: Meansquares for Kiboko optimum trial, season of October 2010- February 2011

Source	DF	GY	AD	DS	ASI	PH	EH	HC	ER	SEN	EA
Rep	1	28.33***	61.03***	53.73***	0.23	38.55	89.34	806.1**	19.69	15.45***	0.6
Entry	214	2.81**	2.7***	4.47***	1.44**	240.02**	199.76***	151.68***	16.9	0.62***	0.2
Hybrids	211	2.75**	2.69***	4.4***	1.41**	236.84**	197.91***	152.5***	16.59	0.62***	0.2
Line	105	2.98**	3.62***	6.31***	1.87***	300.76***	3.11***	163.68***	15.83	0.71***	0.23*
Tester	1	14.66**	18.68***	22.19**	0.15	665.63*	134.72***	4266.46***	0.34	1.09	0
Line*Tester	105	2.42	1.61	2.33	0.97	168.85	1.2	102.13	17.51	0.54*	0.17
Error	211	1.94	1.5	2.26	0.97	163.84	71.08	92.66	18.94	0.4	0.18

Grain yield = GY, Anthesis date = AD, Days to silking = DS, Anthesis to Silking Interval = ASI, Plant height= PH, Ear height= EH, Husk cover = HC, Ear Rot= ER, Leaf senescence = SEN and Ear Aspect = EA

Table 3.5: Mean squares for all traits in Embu optimum trial

Source	DF	GY	AD	ASI	EPP	HC	ER	GLS	PS	ET	MSV	EA
Rep	1	64.85***	66.42***	3.18*	147.167**	0.11***	44.99	32.34	0.36	0.0006	1.34	2.77***
Entries	214	2.61***	6.70***	1.74***	23.40*	0.01*	94.59	220.46***	0.58***	0.004	1.63	0.16
Hybrids	211	2.60***	6.61***	1.61***	0.011*	95.16	219.13***	0.58***	0.004	0.04*	0.16*	0.56***
Line	105	3.10***	7.24***	2.32***	0.01	113.53	237.33***	0.75***	0.004	0.05**	0.13	0.64***
Tester	1	70.91***	126.94***	2.27	0.07**	165.63	4446.12***	17.04***	0.03**	0.002	4.57***	20.18***
Line* Tester	105	1.46	4.83*	0.90	0.01	76.12	160.67*	0.26***	0.004	0.03	0.14	0.29
Error	214	1.15	3.51	0.80	17.63	0.01	84.15	111.35	0.16	0.00	1.61	0.13

Grain yield = GY, Anthesis Date = AD, Anthesis to Silking Interval = ASI, Plant height = PH, Ear position = EPO, Root lodging = RL, Stem Lodging = SL, Ears Per Plant = EPP, Husk Cover = HC, Ear Rot= ER, Gray leaf spot = GLS, Maize leaf rust = PS, Turcicum leaf blight = ET, Maize streak virus = MSV, and Ear Aspect = EA.

The analysis of variance revealed significant differences among entries ($P<0.01$) in the Kakamega well-watered trial (Table 3.6). Significant differences ($0.001> P <0.05$) were also revealed among entries and hybrids for all traits except PH, SL, PS and PA (Table 3.9). Significant differences were also observed among entries in the Kakamega optimum trial analysis of variance. Significant differences ($P<0.05$) were revealed between Entries, hybrids and lines (Table 3.7).

Table 3.6: Mean squares for all traits in Kakamega optimum trial (March to September 2010)

Source	DF	GY	AD	ASI	PH	EH	EPO	RL	SL
Rep	1	41.02***	0.002	5.14*	34202.85***	595.43	0.29***	0.29***	1.41**
Entry	214	2.20**	2.58***	1.52**	328.82	424.65**	0.0053**	0.0053**	13.62
Hybrids	211	2.02**	2.52***	1.49*	331.58	428.77**	0.01**	0.01**	12.65
Line	105	2.54***	3.12***	1.97***	435.76**	496.35**	0.1**	0.01**	14.86
Tester	1	13.01**	38.04***	3.06	680.12	6083.10***	0.073***	0.07***	31.98
Line*Tester	105	1.39	1.57	1	224.09	307.34	0.004	0.004	10.25
Error	214	1.44	1.44	1.09	286.57	301.76	0.00	0.00	13.87

Source	DF	EPP	HC	ER	GLS	PS	ET	EA	PA
Rep	1	0.099**	750.50*	4843.24***	3.36***	0.06	0.23	5.93***	0.56*
Entry	214	0.017**	155.92*	122.24***	0.27*	0.10	0.16***	0.38***	0.16
Hybrids	211	0.02**	156.60*	122.59***	0.27*	0.10	0.16***	0.38***	0.15
Line	105	0.02***	223.25***	132.09***	0.32**	0.10	0.20***	0.35***	0.18*
Tester	1	0.01	547.09*	5231.72***	3.23***	0.31	1.72***	24.78***	0.46*
Line*Tester	105	0.01	86.23	64.43	0.20	0.09	0.11	0.18	0.12
Error	214	0.01	117.08	72.06	0.21	0.09	0.10	0.21	0.13

Grain yield = GY, anthesis date = AD, Anthesis to Silking Interval = ASI, Plant height = PH, Ear position = EPO, Root lodging = RL, Stem Lodging = SL Ears Per Plant = EPP, Husk Cover = HC, Ear Rot= ER, Gray leaf spot = GLS, Maize leaf rust = PS, Turcicum leaf blight = ET, Ear Aspect = EA and plant aspect = PA

Table 3.7: Mean squares for Kakamega optimum trial for the season of October 2010- February 2011

Source	**DF**	**GY**	**AD**	**DS**	**ASI**	**HC**	**ER**	**GLS**	**PS**	**ET**	**EA**
Rep	1	489.27***	226.38***	283.26***	3.18	100.67	45.29***	0.05	0.26	0.13	0.00
Entry	214	1.59	5.92***	8.37***	2.17**	87.61*	1.97	0.27***	0.15	0.18***	0.17**
Hybrids	211	1.58	5.98***	8.35***	2.11**	87.23*	1.94	0.27***	0.15	0.18***	0.17**
Line	105	1.63	6.91***	8.84***	2.32**	94.78*	2.18	0.29***	0.13	0.23***	0.19**
Tester	1	0.29	192.92***	285.62***	9.07*	1643.3***	4.24	13.09***	4.46***	2.19***	0.05
Line*tester	105	1.55	3.28	5.22**	1.84	64.86	1.68	0.12*	0.13	0.11	0.15
Error	214	1.72	2.61	3.66	1.46	64.72	2.10	0.09	0.13	0.09	0.12

Grain yield = GY, Anthesis date = AD, Days to silking = DS, Anthesis to Silking Interval = ASI, Husk cover = HC, Gray leaf spot = GLS, Turcicum rust = PS, Turcicum blight = ET and Ear Aspect = EA

3.3.2 Performance of hybrids at individual sites

Managed drought stress

The means for grain yield and other secondary agronomic traits for a selected top and last 19 entries and checks are presented in tables 3.8 and 3.9 respectively. Average grain yield for the whole trial was 2.69 t/ha, ranging from 0.8 t/ha to 4.27 t/ha. The best hybrids mean yield was 29% higher than that of the checks. Mean number of days to anthesis was 69.45 days, with the anthesis to silking interval being 3.66 days, which was slightly more than that of the best 15 hybrids. There was a markable increase in the anthesis to silking interval when the best mid and bottom 15 entries, ranked by yield were compared. This indicated that the best entries were more synchronized and would be part of the factors contributing to the yield observed. This was similar to findings by Banziger et al., (2000); Obeng-Bio et al., (2011). Under drought ASI for the hybrids was markedly longer than under well watered conditions. Mean ASI was highest under managed drought conditions, suggesting that silk production was delayed due to drought stress. This was similar to findings by Bolanos and Edmeades (1996), Obeng-Bio et al., (2011), and Westgate (1997). The mean score for leaf senescence (SEN) in the trial was 5.97, ranging from 3.75 to 7.75. Twenty nine hybrids had a score of 5 and below, and out of these, 8 of them were among the best 25 hybrids. The best 5 entries (19, 25, 74, 90 and 100) had SEN scores of 5.25 and lower.

Table 3.8: Performance of the top 19 entries and checks at Kiboko Drought Trial (June to October 2010)

ENTRY	Line	GY	AD	ASI	PH	EH	EPO	EPP	SEN	EA
74	37	4.3	68.0	2.0	230.5	124.5	0.5	0.9	4.5	2.3
25	13	4.0	69.5	3.0	229.0	125.0	0.6	1.0	5.0	2.5
19	10	4.0	72.5	1.0	225.0	133.5	0.6	0.8	5.0	2.3
90	45	4.0	69.0	3.0	233.0	129.5	0.6	1.0	5.3	2.5
100	50	3.9	70.5	4.5	232.0	127.5	0.6	0.9	3.8	2.3
26	13	3.8	68.5	2.5	229.5	133.0	0.6	1.0	6.0	2.3
72	36	3.8	69.0	2.5	234.0	125.0	0.5	1.0	5.8	2.5
67	34	3.8	68.5	1.5	227.5	113.5	0.5	0.9	5.8	2.5
30	15	3.8	69.0	2.0	228.5	113.5	0.5	0.8	7.0	2.0
23	12	3.7	71.5	1.5	236.5	139.0	0.6	0.9	5.3	2.5
28	14	3.6	73.5	1.0	241.3	149.5	0.6	0.9	6.0	2.5
7	4	3.6	71.0	4.0	226.0	126.5	0.6	0.9	6.8	2.3
89	45	3.6	67.0	2.5	214.5	106.5	0.5	0.8	6.0	2.5
178	89	3.6	69.5	3.5	221.0	119.5	0.5	0.8	5.5	2.5
83	42	3.5	68.5	1.5	212.0	113.5	0.5	0.9	6.5	2.5
12	6	3.5	71.0	3.0	252.5	143.5	0.6	1.0	7.0	2.8
63	32	3.5	67.0	3.5	223.5	114.5	0.5	0.8	5.8	2.5
4	2	3.5	71.0	4.5	227.5	112.3	0.5	0.8	6.5	2.3
110	55	3.5	72.5	2.5	231.5	133.5	0.6	0.8	5.0	2.3
9	5	3.5	68.5	3.5	231.5	120.0	0.5	0.9	6.5	2.3
102	51	3.5	68.0	4.5	215.5	121.0	0.6	0.7	4.8	2.5
35	18	3.5	70.0	1.5	227.5	129.0	0.6	0.8	6.3	2.5
213	Check	2.1	72.0	3.0	215.5	125.5	0.6	0.7	6.5	3.3
214	Check	2.8	73.0	4.5	224.0	125.5	0.6	0.7	6.0	2.5
215	Check	2.7	72.5	2.0	222.5	113.5	0.5	0.8	6.0	2.5
Checks mean		**2.5**	**72.5**	**3.2**	**220.7**	**121.5**	**0.6**	**0.7**	**6.2**	**2.8**
Trial mean		**2.7**	**69.5**	**3.7**	**219.7**	**119.8**	**0.6**	**0.8**	**6.0**	**2.4**
CV		25.9	1.7	55.7	5.3	7.6	6.1	19.1	13.4	13.3
LSD		1.4	2.3	4.0	22.9	17.8	0.1	0.3	1.6	0.7
max		4.3	73.5	16.0	252.5	149.5	0.7	1.0	7.8	3.5
Min		0.8	66.5	0.5	185.5	94.0	0.5	0.4	3.8	2.0

Grain yield (t/ha) = GY, Anthesis date = AD, Silking date = SD, Anthesis to Silking Interval (Days) = ASI, Plant height (cm) = PH, Ear height (cm) = EH, Ear position (Ratio) = EPO, Ears per plant (Ratio) = EPP, Leaf senescence = SEN and Ear Aspect (Score) = EA

Table 3.9: Performance of the last 19 entries and checks at Kiboko Drought Trial (June to October 2010)

ENTRY	LINE	GY	AD	ASI	PH	EH	EPO	EPP	SEN	EA
41	21	1.9	70.0	4.0	236.5	125.0	0.5	0.7	6.3	3.0
45	23	1.9	67.5	6.5	202.5	100.5	0.5	0.6	6.8	3.0
156	78	1.9	68.0	3.5	225.0	122.5	0.5	0.7	7.3	3.3
208	104	1.9	69.5	3.5	225.5	123.5	0.6	0.7	6.3	2.3
195	98	1.8	67.5	5.0	214.0	121.0	0.6	0.6	6.3	3.0
162	81	1.8	70.0	3.5	223.5	127.5	0.6	0.8	6.0	3.0
93	47	1.7	70.5	3.5	216.0	104.5	0.5	0.6	6.0	3.0
203	102	1.7	70.0	3.5	213.5	109.0	0.5	0.6	5.3	3.0
5	3	1.7	73.0	4.0	195.5	98.0	0.5	0.7	6.0	2.8
187	94	1.7	69.0	5.5	217.5	124.5	0.6	0.7	6.0	3.3
141	71	1.6	71.5	3.0	225.5	121.0	0.5	0.6	5.0	3.0
27	14	1.6	72.5	4.0	223.5	139.5	0.6	0.6	6.8	3.0
207	104	1.6	69.5	5.0	229.0	120.5	0.5	0.5	6.0	3.3
189	95	1.5	67.0	6.5	223.0	111.0	0.5	0.6	7.0	3.3
47	24	1.5	68.0	9.5	221.5	115.5	0.5	0.5	7.3	3.3
205	103	1.5	69.5	11.0	218.0	116.0	0.5	0.5	7.0	3.3
159	80	1.5	67.0	4.0	205.5	114.5	0.6	0.7	7.5	3.5
201	101	1.4	69.0	6.0	211.5	111.5	0.5	0.6	6.5	3.3
6	3	1.4	73.0	8.0	228.5	126.0	0.6	0.7	5.8	3.0
129	65	1.3	68.0	16.0	213.5	115.5	0.5	0.4	6.0	3.5
209	105	1.0	69.0	8.5	201.5	107.5	0.5	0.5	6.5	3.5
193	97	0.8	67.5	9.5	215.0	112.0	0.5	0.4	6.8	3.5
213	Check	2.1	72.0	3.0	215.5	125.5	0.6	0.7	6.5	3.3
214	Check	2.8	73.0	4.5	224.0	125.5	0.6	0.7	6.0	2.5
215	Check	2.7	72.5	2.0	222.5	113.5	0.5	0.8	6.0	2.5
Checks mean		**2.5**	**72.5**	**3.2**	**220.7**	**121.5**	**0.6**	**0.7**	**6.2**	**2.8**
Trial mean		**2.7**	**69.5**	**3.7**	**219.7**	**119.8**	**0.6**	**0.8**	**6.0**	**2.4**
CV		25.9	1.7	55.7	5.3	7.6	6.1	19.1	13.4	13.3
LSD		1.4	2.3	4.0	22.9	17.8	0.1	0.3	1.6	0.7
max		4.3	73.5	16.0	252.5	149.5	0.7	1.0	7.8	3.5
Min		0.8	66.5	0.5	185.5	94.0	0.5	0.4	3.8	2.0

Grain yield (t/ha) = GY, Anthesis date = AD, Silking date = SD, Anthesis to Silking Interval (Days) = ASI, Plant height (cm) = PH, Ear height (cm) = EH, Ear position (Ratio) = EPO, Ears per plant (Ratio) = EPP, Leaf senescence = SEN and Ear Aspect = EA

Performance of hybrids under optimum (well-watered) conditions

Means for grain yield and other traits for the top and last 19 entries and checks at Kiboko March to September 2010 optimum trial have been presented on table 3.10 and 3.11. The whole trial had a mean yield of 5.99 t/ha, with the best hybrid (Entry 38) having 9.66 t/ha, and the last having 3.29 t/ha. The best hybrid performed 36% better than the best check. The mean anthesis to silking interval was 2.37 days, with a range of 7 days. The mean anthesis to silking interval for the top 15 hybrids, ranked by yield, was less than that of the checks (1.7 days and 2.5 days respectively).

The average for grain yield and other agronomic traits at Embu are presented in table 3.12 to 3.13. The trial had a mean grain yield of 4.48 t/ha, which was the lowest of the mean yields observed under well-watered environments. The best entry had a mean yield of 7.93 t/ha, which was about 50% better than the best check in the trial. The whole trial mean was 20% higher than that of checks mean. The mean anthesis to silking interval in the trial was 1.02 days, with the highest interval being 5 days and the shortest being -1.5 days. There was a marked increase in the anthesis to silking interval when comparing the top, mid and last 15 hybrids in the trial. A similar trend was observed for Ear aspect (EA) and GLS scores when the best, mid and last 15 hybrids, ranked by yield, were compared.

Table 3.10: Performance of the top 19 Entries and checks at Kiboko well watered trial season of March to August 2010

ENTRY	LINES	GY	AD	ASI	EPP	HC	NP	EA
38	19	9.7	54.0	2.0	1.0	8.2	18.0	1.8
33	17	9.0	55.0	-1.0	1.0	13.8	18.0	2.0
25	13	8.8	55.0	1.0	1.1	10.7	18.5	2.0
35	18	8.8	55.5	0.5	0.9	13.7	18.5	2.0
111	56	8.8	54.0	1.5	1.0	36.8	19.0	2.0
133	67	8.7	54.0	1.5	1.0	18.4	19.0	2.5
66	33	8.7	52.5	2.5	1.0	0.0	19.0	2.5
119	60	8.4	56.0	1.5	1.0	13.2	19.0	2.3
150	75	8.3	56.0	2.0	1.0	2.6	19.5	2.3
100	50	8.1	55.0	2.0	1.0	0.0	18.5	2.3
161	81	7.9	54.5	3.0	1.1	42.9	17.5	3.0
121	61	7.9	55.5	2.5	1.0	5.3	19.0	2.3
105	53	7.9	56.5	1.0	1.0	16.7	18.5	2.3
186	93	7.8	56.0	0.5	1.0	0.0	19.0	2.3
129	65	7.7	52.5	5.0	0.9	29.8	18.5	2.3
108	54	7.7	55.5	1.0	0.9	0.0	18.5	2.3
175	88	7.7	52.0	2.0	1.0	11.1	18.0	2.8
17	9	7.6	54.5	2.0	0.9	15.8	19.0	2.3
193	97	7.6	54.5	1.5	0.9	10.8	18.5	2.8
213	**Check**	6.2	54.5	2.0	1.0	11.8	18.0	2.8
214	**Check**	4.8	57.5	2.5	0.9	5.6	18.5	3.0
215	**Check**	4.4	57.0	2.0	0.8	19.0	18.5	2.8
Checks mean		**5.2**	**56.3**	**2.2**	**0.9**	**12.1**	**18.3**	**2.8**
Trial Mean		**6.0**	**55.3**	**2.4**	**0.9**	**8.5**	**18.5**	**2.8**
Min		**3.3**	**51.5**	**-1.0**	**0.6**	**0.0**	**16.0**	**1.8**
Max		**9.7**	**58.5**	**6.0**	**1.2**	**42.9**	**20.0**	**3.8**
CV		**23.0**	**2.0**	**56.4**	**9.1**	**88.7**	**4.6**	**15.9**
LSD		**2.7**	**2.2**	**2.6**	**0.2**	**14.8**	**1.7**	**0.9**

Grain yield (t/ha) = GY, Anthesis date = AD, Silking date = SD, Anthesis to Silking Interval (Days) = ASI, Ears per plant (Ratio), Number of plants harvested = NP, Ears per plant (Ratio) = EPP, Leaf senescence = SEN and Ear Aspect (score) = EA, Bare tips (%) HC

Table 3.11: Performance of the top 19 Entries and checks at Kiboko well watered Trial Season of March to August 2010

ENTRY	LINES	GY	AD	ASI	EPP	HC	NP	EA
48	24	4.5	55.5	5.0	1.0	0.0	18.0	3.3
71	36	4.5	56.5	2.5	0.9	8.8	16.5	3.0
215	108	4.4	57.0	2.0	0.8	19.0	18.5	2.8
81	41	4.4	56.0	1.5	0.8	5.4	18.5	3.3
132	66	4.3	57.0	3.5	1.0	0.0	19.0	3.5
49	25	4.3	55.5	4.5	0.9	15.8	19.0	3.3
188	94	4.3	56.0	3.5	0.9	2.8	18.5	3.3
58	29	4.3	55.5	4.0	0.9	5.3	19.0	3.5
189	95	4.2	52.5	4.5	0.8	5.6	18.5	3.3
53	27	4.1	57.0	3.0	0.8	13.6	18.5	3.3
6	3	4.1	57.0	5.5	0.8	2.8	19.0	3.3
191	96	4.0	56.5	3.5	0.8	21.5	18.5	3.0
157	79	4.0	54.0	6.0	0.9	8.3	18.5	3.5
115	58	3.9	57.0	5.0	0.8	11.1	18.0	3.3
79	40	3.9	56.0	3.5	0.8	18.4	19.0	2.8
67	34	3.9	54.5	2.5	0.9	10.7	18.5	3.3
181	91	3.7	56.5	5.0	0.8	5.6	18.0	3.3
201	101	3.3	55.0	4.5	0.6	15.8	19.0	3.5
207	104	3.3	55.0	5.0	0.6	0.0	19.0	3.5
213	**Check**	6.2	54.5	2.0	1.0	11.8	18.0	2.8
214	**Check**	4.8	57.5	2.5	0.9	5.6	18.5	3.0
215	**Check**	4.4	57.0	2.0	0.8	19.0	18.5	2.8
Checks mean		**5.2**	**56.3**	**2.2**	**0.9**	**12.1**	**18.3**	**2.8**
Trial Mean		**6.0**	**55.3**	**2.4**	**0.9**	**8.5**	**18.5**	**2.8**
MIN		**3.3**	**51.5**	**-1.0**	**0.6**	**0.0**	**16.0**	**1.8**
MAX		**9.7**	**58.5**	**6.0**	**1.2**	**42.9**	**20.0**	**3.8**
CV		**23.0**	**2.0**	**56.4**	**9.1**	**88.7**	**4.6**	**15.9**
LSD		**2.7**	**2.2**	**2.6**	**0.2**	**14.8**	**1.7**	**0.9**

Grain yield (t/ha) = GY, Anthesis date = AD Silking date = SD, Anthesis to Silking Interval (Days) = ASI, Ears per plant (Ratio) = EPP Number of plants harvested = NP Ear aspect (Score) = EA

Table 3.12: Performance of the top 19 Entries and checks at Embu optimum trial, season of March to September 2010

ENTRY	LINE	GY	AD	ASI	EPP	GLS	MSV	EA
32	16	7.9	75.0	0.0	1.1	1.5	1.3	2.3
106	53	7.7	73.5	1.0	1.1	1.8	1.5	2.8
74	37	7.6	71.5	-0.5	1.1	1.5	1.8	2.5
144	72	7.1	74.5	1.5	1.0	1.5	1.5	3.3
125	63	6.8	73.0	0.5	1.0	1.8	1.3	2.8
119	60	6.8	72.5	1.5	0.9	1.5	1.8	2.5
24	12	6.7	73.5	0.0	1.0	1.5	1.5	3.0
31	16	6.6	70.5	0.5	1.0	2.3	1.8	2.5
140	70	6.5	74.5	1.5	1.0	1.8	1.8	2.8
107	54	6.4	72.0	1.0	0.9	1.8	1.8	3.0
82	41	6.3	72.0	0.5	1.0	2.5	1.3	3.0
50	25	6.3	74.5	1.0	1.0	2.3	1.0	2.8
84	42	6.2	73.0	0.0	1.0	2.8	1.5	3.3
36	18	6.2	75.5	0.5	0.9	2.0	1.5	3.0
78	39	6.1	73.5	0.5	0.9	2.0	1.3	2.8
23	12	6.1	72.5	1.0	1.1	2.3	1.5	3.0
116	58	6.1	74.5	2.0	1.0	1.5	1.3	3.0
37	19	6.0	70.5	1.0	1.0	3.5	1.5	2.8
70	35	6.0	74.0	0.0	0.9	2.0	1.3	3.0
213	**Check**	2.5	73.0	5.0	0.7	2.8	2.0	3.5
214	**Check**	4.2	76.5	1.5	0.9	2.3	2.0	3.5
215	**Check**	4.2	77.0	0.5	1.0	2.3	1.3	3.8
Checks means		**3.6**	**75.5**	**2.3**	**0.9**	**2.4**	**1.8**	**3.6**
Trial mean		**4.5**	**73.7**	**1.0**	**1.0**	**2.1**	**1.5**	**3.6**
MIN		**0.9**	**68.5**	**-1.5**	**0.7**	**1.3**	**1.0**	**2.3**
MAX		**7.9**	**78.0**	**5.0**	**1.2**	**3.5**	**3.0**	**5.0**
CV		**24.0**	**2.5**	**87.8**	**9.6**	**19.0**	**24.2**	**14.2**
LSD		**2.1**	**3.7**	**1.8**	**0.2**	**0.8**	**0.7**	**1.0**

Grain yield (t/ha) = GY, anthesis date = AD, Anthesis to Silking Interval (days) = ASI, Ears Per Plant (Ratio) = EPP, Husk Cover (%) = HC, Ear Rot= ER, Gray leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Turcicum leaf blight (Score) = ET, Maize streak virus (Score) = MSV and Ear Aspect (Score) = EA.

Table 3.13: Performance of the top 19 Entries and checks at Embu optimum trial, season of March to September 2010

ENTRY	LINE	GY	AD	ASI	EPP	GLS	MSV	EA
68	34	3.0	73.5	0.0	0.9	2.5	1.5	3.8
185	93	2.8	75.0	0.0	0.7	1.5	1.8	4.5
6	3	2.8	75.5	1.5	1.0	1.5	1.5	4.5
209	105	2.7	69.5	2.5	0.9	3.3	2.0	4.8
155	78	2.7	72.5	2.0	1.0	2.3	1.8	4.8
123	62	2.7	75.0	1.5	0.9	1.5	1.5	4.5
77	39	2.6	71.5	3.0	0.9	3.3	1.3	3.8
161	81	2.5	70.0	1.0	0.9	3.3	1.8	5.0
213	107	2.5	73.0	5.0	0.7	2.8	2.0	3.5
187	94	2.4	74.0	2.0	1.0	1.8	1.8	4.0
181	91	2.4	73.0	1.5	1.0	2.3	1.5	4.0
5	3	2.4	78.0	1.0	0.8	1.8	1.8	4.5
45	23	2.3	72.0	2.5	0.9	3.0	1.5	4.0
201	101	2.3	74.0	3.0	0.8	2.3	1.3	5.0
133	67	2.3	73.0	0.5	0.9	2.3	2.3	4.8
97	49	2.3	72.5	1.0	0.9	2.3	1.8	4.8
195	98	1.9	71.5	2.5	0.9	2.0	2.0	4.0
179	90	1.7	71.0	2.0	1.1	2.5	1.5	4.8
183	92	0.9	73.0	1.5	0.9	1.5	1.3	5.0
213	**Check**	2.5	73.0	5.0	0.7	2.8	2.0	3.5
214	**Check**	4.2	76.5	1.5	0.9	2.3	2.0	3.5
215	**Check**	4.2	77.0	0.5	1.0	2.3	1.3	3.8
Checks means		**3.6**	**75.5**	**2.3**	**0.9**	**2.4**	**1.8**	**3.6**
Trial mean		**4.5**	**73.7**	**1.0**	**1.0**	**2.1**	**1.5**	**3.6**
MIN		**0.9**	**68.5**	**-1.5**	**0.7**	**1.3**	**1.0**	**2.3**
MAX		**7.9**	**78.0**	**5.0**	**1.2**	**3.5**	**3.0**	**5.0**
CV		**24.0**	**2.5**	**87.8**	**9.6**	**19.0**	**24.2**	**14.2**
LSD		**2.1**	**3.7**	**1.8**	**0.2**	**0.8**	**0.7**	**1.0**

Grain yield (t/ha) = GY, Days to anthesis = AD, Anthesis to Silking Interval (Days) = ASI, Ears Per Plant (Ratio) = EPP, Gray leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Turcicum leaf blight (Score) = ET, Maize streak virus (Score) = MSV and Ear Aspect (Score) = EA.

The mean yield observed in the Kakamega trial was 7.3 t/ha, with the best hybrid yielding 10.36t/ha (Table 3.14 and 3.15). This was 34% better than the best check in the trial. The mean of the best 15 entries was 39% higher than the mean of checks. There was an increasing trend for disease scores, for gray leaf spot (GLS) and northern leaf blight (ET) when the best and last 15 hybrids were compared. A similar trend was observed for EA and PA scores. This suggested that the best yielding entries also had resistance to GLS and ET, alongside other stresses and also had good ear and plant characteristics.

The average grain yield for the Kiboko under well-watered conditions was 9.22 t/ha (Table 3.16 and 3.17), which was the highest mean yield among the optimum trials. The best hybrid (Entry 156) and the best check (WH 505) had yields that were statistically the same. The best 15 hybrids in this trial performed better than the checks by 17%. They also out yielded the last 15 entries by 38 percent. The ASI increased when comparing the interval for the top, mid and the last 15 entries, in that order, with the checks having the longest mean interval above the three groups. A similar trend was also observed for the ear aspect score, indicating that the best hybrids had the best ear characteristics.

Table 3.14: Means For the best 19 entries and checks at Kakamega well watered Trial Season of March to August 2010

ENTRY	LINE	GY	AD	ASI	PH	EPO	GLS	PS	ET	EA	PA
74	37	10.4	68.5	0.0	250.0	0.6	2.0	1.5	2.5	2.5	2.5
27	14	10.2	69.0	0.5	255.0	0.6	1.8	1.5	2.5	2.5	2.5
128	64	10.1	67.5	0.0	235.0	0.6	3.0	1.8	2.5	2.3	2.5
98	49	10.0	68.0	1.0	247.5	0.6	2.5	1.5	3.0	2.5	2.3
118	59	9.7	69.5	-0.5	250.0	0.5	2.0	2.0	2.5	2.0	2.5
176	88	9.6	69.5	1.5	240.0	0.5	2.5	1.8	2.8	2.3	2.5
148	74	9.4	67.5	1.0	240.0	0.5	2.8	2.0	2.8	2.0	2.3
54	27	9.2	68.0	1.0	250.0	0.6	2.8	1.8	3.0	2.3	2.0
96	48	9.2	69.5	0.0	235.0	0.6	2.3	1.5	2.8	3.0	2.5
18	9	9.0	71.5	-0.5	240.0	0.6	2.5	1.8	2.5	2.8	2.3
104	52	9.0	69.5	1.0	235.0	0.5	3.0	1.5	2.8	2.8	2.5
171	86	9.0	68.0	1.0	247.5	0.5	1.8	1.8	2.3	2.8	2.3
92	46	8.9	68.5	1.5	260.0	0.5	2.3	1.5	2.8	2.5	2.3
30	15	8.9	68.5	-0.5	255.0	0.5	2.8	1.5	3.0	2.0	2.8
208	104	8.8	69.0	0.0	255.0	0.3	2.5	1.8	2.3	2.3	2.8
7	4	8.8	69.5	2.5	245.0	0.6	2.5	1.5	2.5	2.3	2.5
114	57	8.7	70.0	2.0	240.0	0.6	2.8	1.8	2.5	2.3	2.5
163	82	8.7	67.5	0.5	260.0	0.5	3.0	1.8	3.0	2.8	2.5
56	28	8.7	68.0	0.0	225.0	0.6	3.0	1.8	3.0	2.3	2.8
213	**Check**	4.3	68.0	2.0	250.0	0.6	2.8	1.5	2.8	3.8	3.0
214	**Check**	6.1	71.0	0.5	240.0	0.5	3.0	2.0	3.0	2.5	3.0
215	**Check**	6.8	71.0	-1.0	245.0	0.5	2.8	1.8	2.8	3.3	3.3
Checks mean		**5.7**	**70.0**	**0.5**	**245.0**	**0.5**	**2.8**	**1.8**	**2.8**	**3.2**	**3.1**
Trial Mean		**7.3**	**68.8**	**0.6**	**237.9**	**0.5**	**2.8**	**1.7**	**2.8**	**3.0**	**2.7**
Min		**4.3**	**66.5**	**-1.5**	**195.0**	**0.3**	**1.5**	**1.3**	**1.8**	**2.0**	**2.0**
Max		**10.4**	**72.5**	**3.0**	**267.5**	**0.7**	**3.5**	**2.5**	**3.5**	**4.0**	**3.3**
CV		**16.5**	**1.7**	**180.3**	**7.1**	**11.3**	**16.4**	**17.6**	**11.3**	**15.4**	**13.6**
LSD		**2.4**	**2.4**	**2.1**	**33.4**	**0.1**	**0.9**	**0.6**	**0.6**	**0.9**	**0.7**

Grain yield (t/ha) = GY, Days to anthesis (Days) = AD, Anthesis to Silking Interval (Days) = ASI, Plant height (cm) = PH, Ear height (cm) = EH, Ear position (Ratio) = EPO, Ears Per Plant (Ratio) = EPP, Ear Rot (Score) = ER, Gray leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Turcicum leaf blight (Score) = ET, Ear Aspect (Score) = EA and plant aspect (Score) = PA

Table 3.15: Means For the last 19 entries and checks at Kakamega well watered Trial Season of March to August 2010

ENTRY	LINE	GY	AD	ASI	PH	EPO	GLS	PS	ET	EA	PA
137	69	6.0	68.5	1.0	235.0	0.5	3.3	1.5	2.3	3.5	2.5
65	33	5.9	68.0	0.5	230.0	0.5	2.8	1.3	3.0	3.3	3.0
189	95	5.9	68.0	0.5	230.0	0.5	3.3	1.5	3.0	3.3	2.8
61	31	5.9	69.0	0.0	240.0	0.5	3.3	2.0	2.8	3.8	2.8
135	68	5.9	69.0	1.5	230.0	0.5	3.0	1.3	3.0	3.8	3.0
139	70	5.8	71.0	1.0	235.0	0.5	2.8	2.0	3.0	3.8	2.8
202	101	5.8	68.5	1.0	237.5	0.6	3.0	1.5	3.0	3.0	3.0
209	105	5.7	67.5	0.5	255.0	0.6	3.0	1.8	2.8	3.3	2.5
201	101	5.7	67.5	2.0	237.5	0.5	2.3	1.5	2.8	3.5	2.8
69	35	5.7	68.5	-0.5	232.5	0.5	3.0	1.8	2.5	3.3	2.8
107	54	5.7	68.5	2.5	235.0	0.5	2.8	1.8	2.8	3.5	2.8
136	68	5.6	68.0	0.0	235.0	0.6	3.0	1.5	3.3	3.3	2.8
140	70	5.6	70.0	0.5	220.0	0.5	2.5	2.3	3.0	2.8	2.5
39	20	5.5	70.5	-1.0	252.5	0.6	3.0	1.5	3.3	3.3	2.5
66	33	5.5	70.5	1.5	210.0	0.5	2.5	2.0	3.0	3.0	3.3
187	94	5.5	68.0	1.5	225.0	0.5	3.3	1.5	3.0	3.8	2.5
134	67	5.3	67.5	0.5	220.0	0.6	3.0	1.5	3.5	3.3	2.5
91	46	4.7	70.5	0.5	230.0	0.5	3.0	1.8	2.8	3.3	2.8
213	**Check**	4.3	68.0	2.0	250.0	0.6	2.8	1.5	2.8	3.8	3.0
214	**Check**	6.1	71.0	0.5	240.0	0.5	3.0	2.0	3.0	2.5	3.0
215	**Check**	6.8	71.0	-1.0	245.0	0.5	2.8	1.8	2.8	3.3	3.3
Checks mean		**5.7**	**70.0**	**0.5**	**245.0**	**0.5**	**2.8**	**1.8**	**2.8**	**3.2**	**3.1**
Trial mean		**7.3**	**68.8**	**0.6**	**237.9**	**0.5**	**2.8**	**1.7**	**2.8**	**3.0**	**2.7**
Min		**4.3**	**66.5**	**-1.5**	**195.0**	**0.3**	**1.5**	**1.3**	**1.8**	**2.0**	**2.0**
Max		**10.4**	**72.5**	**3.0**	**267.5**	**0.7**	**3.5**	**2.5**	**3.5**	**4.0**	**3.3**
CV		**16.5**	**1.7**	**180.3**	**7.1**	**11.3**	**16.4**	**17.6**	**11.3**	**15.4**	**13.6**
LSD		**2.4**	**2.4**	**2.1**	**33.4**	**0.1**	**0.9**	**0.6**	**0.6**	**0.9**	**0.7**

Grain yield (t/ha) = GY, Days to anthesis (days) = AD, Anthesis to Silking Interval (Days) = ASI, Plant height (cm) = PH, Ear position (Ratio) = EPO, Gray leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Turcicum leaf blight (Score) = ET, Ear Aspect (Score) = EA and plant aspect (Score) = PA

Table 3.16: Performance of the best 15 1ntries at Kiboko under well watered conditions, season of October 2010– February 2011

ENTRY	LINE	GY	AD	SD	ASI	EPP	SEN	EA
156	78	11.8	59.0	60.0	1.0	1.4	4.0	2.0
215	108	11.7	62.5	64.0	1.5	1.3	3.5	1.5
25	13	11.5	61.0	63.0	2.0	1.2	3.0	2.3
35	18	11.5	61.0	62.5	1.5	1.2	3.5	2.0
27	14	11.5	61.0	63.5	2.5	0.9	3.5	1.5
31	16	11.2	61.5	61.5	0.0	1.2	3.0	1.8
26	13	11.2	63.0	64.0	1.0	1.2	3.5	2.0
32	16	11.1	60.5	62.5	2.0	1.2	3.5	2.0
95	48	11.1	60.5	62.0	1.5	1.1	4.0	1.5
153	77	11.0	59.0	60.0	1.0	1.2	4.0	2.0
103	52	11.0	61.5	62.5	1.0	1.3	3.5	1.8
79	40	11.0	60.0	60.0	0.0	1.2	3.5	2.3
171	86	11.0	61.5	64.0	2.5	0.9	4.5	2.3
17	9	11.0	62.0	63.5	1.5	1.3	4.0	2.0
210	105	11.0	59.0	61.5	2.5	1.2	3.0	1.5
127	64	11.0	61.5	62.5	1.0	1.2	3.0	2.5
88	44	11.0	61.0	63.5	2.5	1.1	4.0	1.8
13	7	11.0	60.5	62.0	1.5	1.2	4.0	1.5
118	59	10.9	61.0	61.5	0.5	1.2	3.5	1.5
213	**Check**	7.2	61.5	63.0	1.5	1.0	4.5	2.3
214	**Check**	9.1	62.5	66.5	4.0	1.2	3.5	2.3
215	**Check**	11.7	62.5	64.0	1.5	1.3	3.5	1.5
Checks mean		**9.3**	**62.2**	**64.5**	**2.3**	**1.2**	**3.8**	**2.0**
Trial mean		**9.2**	**61.1**	**62.9**	**1.8**	**1.1**	**3.7**	**2.1**
LSD		**2.7**	**2.4**	**3.0**	**3.0**	**0.3**	**1.2**	**0.8**
CV		**15.0**	**2.0**	**2.4**	**53.1**	**12.4**	**17.0**	**19.8**
MAX		**11.8**	**64.5**	**67.5**	**5.0**	**1.4**	**5.0**	**3.0**
MIN		**5.7**	**58.0**	**60.0**	**0.0**	**0.9**	**2.5**	**1.5**

Grain yield (t/ha) = GY, Days to anthesis (Days) = AD, Days to silking (Days) = SD, Anthesis to Silking Interval (Days) = ASI, Ears Per Plant (Ratio) = EPP leaf senescence (Score) = SEN and Ear Aspect (Score) = EA.

Table 3.17: Performance of last 19 entries and checks at Kiboko under well-watered conditions, season of October 2010– February 2011

ENTRY	LINE	GY	AD	SD	ASI	EPP	SEN	EA
61	31	7.5	61.5	65.0	3.5	1.1	4.5	2.3
119	60	7.5	63.0	67.0	4.0	1.1	4.0	2.8
106	53	7.5	61.0	63.0	2.0	1.1	3.5	2.5
6	3	7.5	63.0	65.0	2.0	1.2	4.0	2.8
66	33	7.4	63.0	64.0	1.0	1.0	4.5	2.3
152	76	7.4	59.5	60.5	1.0	1.1	3.0	2.5
41	21	7.3	60.5	62.5	2.0	0.9	4.5	2.5
139	70	7.3	64.5	66.5	2.0	0.9	4.5	2.8
76	38	7.3	60.5	63.0	2.5	1.0	4.5	2.3
144	72	7.2	64.0	67.0	3.0	1.1	4.0	2.5
213	107	7.2	61.5	63.0	1.5	1.0	4.5	2.3
198	99	7.2	61.0	63.0	2.0	1.1	3.5	2.5
22	11	7.1	64.5	67.5	3.0	1.2	4.0	2.5
196	98	7.0	61.5	65.0	3.5	0.9	3.5	2.3
197	99	6.6	61.0	62.5	1.5	1.0	3.5	2.3
188	94	6.6	60.0	63.5	3.5	1.2	3.5	2.3
195	98	6.5	61.5	64.5	3.0	1.1	3.0	2.5
42	21	6.3	62.0	64.0	2.0	0.9	4.5	2.8
104	52	5.7	61.5	63.5	2.0	1.1	4.0	2.3
213	**Check**	7.2	61.5	63.0	1.5	1.0	4.5	2.3
214	**Check**	9.1	62.5	66.5	4.0	1.2	3.5	2.3
215	**Check**	11.7	62.5	64.0	1.5	1.3	3.5	1.5
CHECKS MEAN		**9.3**	**62.2**	**64.5**	**2.3**	**1.2**	**3.8**	**2.0**
TRIAL MEAN		**9.2**	**61.1**	**62.9**	**1.8**	**1.1**	**3.7**	**2.1**
LSD		**2.7**	**2.4**	**3.0**	**3.0**	**0.3**	**1.2**	**0.8**
CV		**15.0**	**2.0**	**2.4**	**53.1**	**12.4**	**16.9**	**19.8**
MAX		**11.8**	**64.5**	**67.5**	**5.0**	**1.4**	**5.0**	**3.0**
MIN		**5.7**	**58.0**	**60.0**	**0.0**	**0.9**	**2.5**	**1.5**

Grain yield (t/ha) = GY, Days to anthesis (Days) = AD, Days to silking (Days) = SD, Anthesis to Silking Interval (Days) = ASI, Per Plant (Ratio) = EPP, Leaf senescence (Score)= SEN and Ear Aspect = EA.

3.3.3 Across sites analysis of variance

Mean squares for GY and other secondary traits are presented in Table 3.18. Analysis of variance across all sites revealed highly significant differences among environments for all traits except PA. This indicated that the environments used in the study were highly variable. Entries and hybrids and their interaction with the environment revealed significant difference ($P< 0.01$) for GY, AD, ASI, HC, ER and EA. This suggested that the entries performed differently across the different test environments. Mean squares due to lines showed significant differences ($P<0.01$) for all traits except SL, GLS and MSV. Similarly mean squares due to testers showed high levels of significance ($P<0.5$ to 0.01) for all traits but ASI. Mean squares due to the interaction between the lines and testers revealed significant differences for AD, ASI, HC, EA and ET. The preponderance of line and tester mean squares over line by tester interaction mean squares suggested that additive effects were of more importance than in the inheritance of traits. This was in agreement with other studies which have shown similar results (Bayisa *et al.*, 2008).

Table 3.18: Mean squares for across all environments analysis of variance

Source	DF	GY	AD	ASI	RL	SL	HC	ER	EA
Rep	1	106.08***	172.44***	22.89***	917.7***	3.51	1549.83***	386.41**	0.16
Env	5	2206.2***	34384.16***	589.96***	13302.69***	9589***	3757.46***	63767.66***	115.51***
Rep(env)	5	143.88***	36.76***	32.29***	618.5***	59.28**	111.37	929***	5.44***
Entry	214	3.41***	13.86***	6.33***	55.41	15.47	238.33***	80.7**	0.53***
Env*entry	1070	1.80***	2.38***	2.29***	52.65***	16.32	79.70*	60.69***	0.25***
Env*hybrids	1055	1.79***	2.38***	2.28***	52.97***	16.12	79.74*	60.29***	0.25***
Hybrids	211	3.31***	13.57***	6.26***	55.83**	15.42	240.15***	80.51***	0.53***
Line	105	4.80***	20.09***	9.25***	71.1***	14.84	288.45***	93.21***	0.65***
Tester	1	14.95**	328.38***	1.46	280.82*	118.79**	9207.49***	2906.44***	16.12***
Env*line	525	1.85	2.42*	2.66***	65.25***	17.8*	88.70**	63.11***	0.26***
Env*tester	5	17.14***	18.87***	4.8*	144.92**	22.96	1210.77***	1374.04***	5.86***
Line*tester	105	1.71	4.05***	3.32***	38.42	15.01	106.44**	40.89	0.26*
Env*line*tester	525	1.59	2.18	1.88	39.82	14.37	60	44.95	0.19
Error	1284	1.44	1.95	1.71	41.29	15.63	71.45	37.11	0.18

Grain Yield = GY Days to anthesis = AD, Anthesis to silking interval = ASI, Root Lodging = RL, Ear rot = ER, Ear aspect = EA.

Table 3.18: Mean squares for across all environments analysis of variance (continuation).

Source	DF	PH	DF	GLS	PS	ET	DF	MSV	PA
Rep	1	22892.44***	1	0.70*	0.03	0.1	1	1.64**	0.03
Site	3	154748.28***	2	140.33***	16.88***	177.73***	1	365.30***	0.02
Rep(site)	3	13796.00***	2	1.54***	0.14	0.36**	1	1.15*	0.79*
Entry	214	522.83***	214	0.71***	0.07	0.21***	214	0.2	0.19*
Site*entry	642	216.75	428	0.21***	0.09*	0.09*	214	0.17	0.14
Site*hybrids	633	217.3	422	0.21***	0.09*	0.09*	211	0.17	0.14
Hybrids	211	523.63***	211	0.72***	0.21***	0.21***	211	0.2	0.18**
Line	105	777.99***	105	0.91***	0.07	0.30***	105	0.18	0.21***
Tester	1	2718.56**	1	30.36***	0.99***	2.51***	1	3.83***	1.17**
Site*line	315	200.98	210	0.23***	0.08	0.09*	105	0.16	0.15
Site*tester	3	283.37	2	1.50***	1.91***	0.70***	1	1.13*	0.01
Line*tester	105	248.36	105	0.24***	0.07	0.10*	105	0.18	0.13
Site*line*tester	315	233	210	0.17	0.08	0.08	105	0.17	0.14
Error	856	212.14	642	0.15	0.07	0.07	428	0.19	0.13

PH = Plant height GLS = Gray leaf spot, PS = Puccinia sorghi, ET = Exserohilum turcicum), MSV=Maize streak virus, PA = Plant aspect

3.3.4 Performance across locations

The overall mean for the experiment across all (6) sites was 5.83 t/ha. The best hybrid, entry 74, had a mean yield of 7.59 t/ha, while the least yielding one had a mean of 4.03 t/ha across all sites. Means for GY and other traits across all environments, for the top and last 19 hybrids and checks are presented on table 3.19 and 3.20. The best 15 entries had a mean yielded 15% greater than the overall mean, and 25% more than the checks. The anthesis to silking interval means for the top and mid 15 entries was closely similar. However, there was an overall trend where the yield increased with a decrease in ASI (Figure 3.1). ASI was significantly longer for the top and mid 15 entries, suggesting that the mean yield across all the locations was affected by ASI.

The new experimental hybrids yielded better than all the commercial checks. This suggested that the materials in the experiment have the potential of being released as new hybrids for these environments upon further testing.

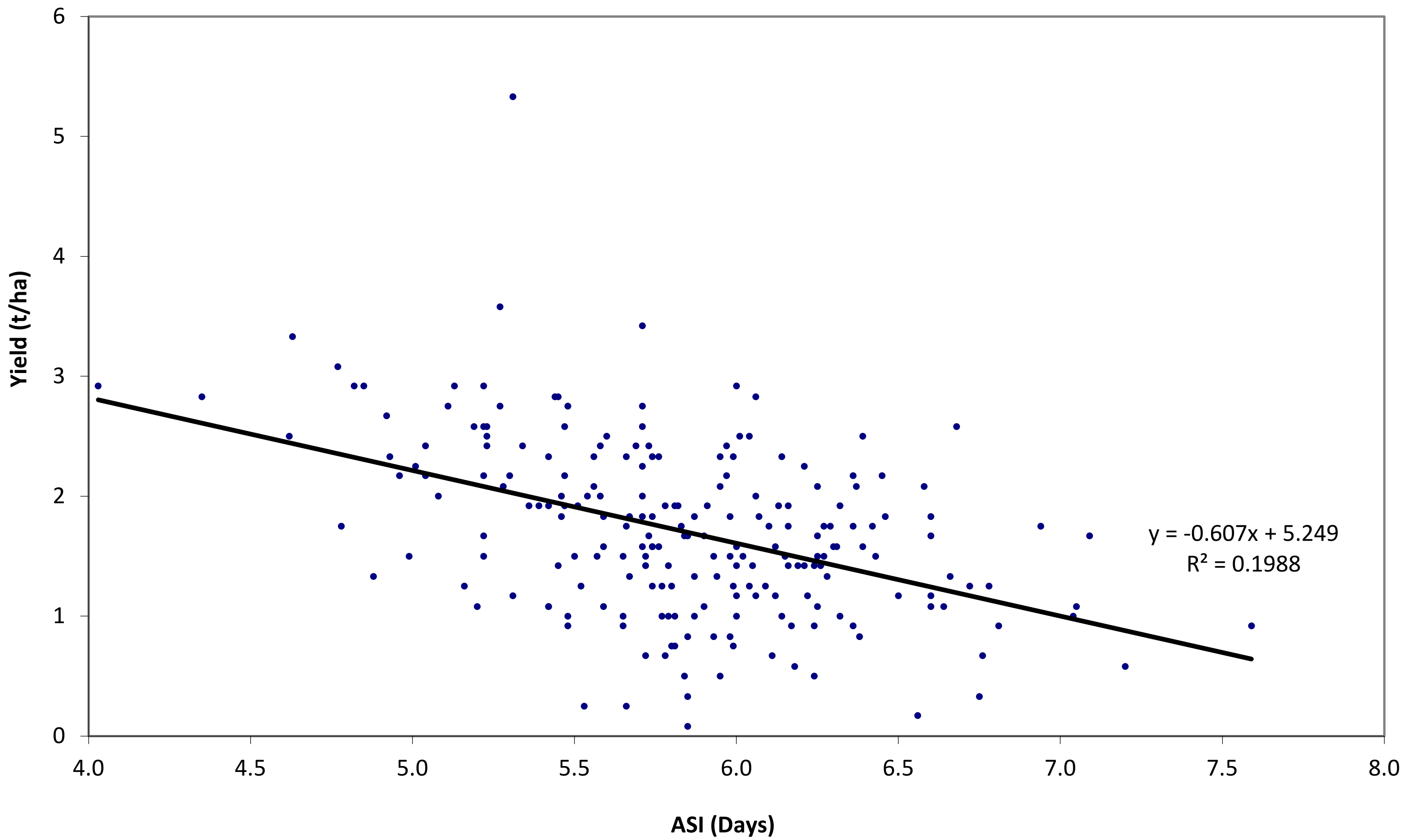

Figure 3.1: Relationship between ASI and grain yield across environments

Table 3.19: Performance of best 19 entries and checks across all (6) environments

ENTRY	LINE	GY	AD	ASI	EPP	EA	PH	EPO	GLS	PS	ET	SEN	PA
74	37	7.6	66.9	0.9	1.0	2.3	227.3	0.6	1.5	1.5	2.3	3.8	2.6
35	18	7.2	67.9	0.6	1.0	2.5	237.1	0.6	2.2	1.3	2.7	4.9	2.4
1	1	7.1	68.3	1.7	1.1	2.5	225.1	0.6	2.2	1.4	2.2	5.3	2.4
25	13	7.1	68.0	1.1	1.1	2.7	224.8	0.6	2.3	1.4	2.3	4.0	2.5
26	13	7.0	68.8	1.0	1.1	2.4	217.6	0.6	1.8	1.5	2.5	4.8	2.6
32	16	6.9	69.5	1.8	1.0	2.4	206.0	0.6	1.8	1.3	2.3	4.8	2.4
23	12	6.8	67.9	0.9	1.0	2.5	229.9	0.6	2.3	1.5	2.5	4.4	2.8
17	9	6.8	69.2	1.3	1.0	2.5	232.0	0.5	1.9	1.6	2.1	5.1	2.3
118	59	6.8	68.2	0.7	1.0	2.4	222.5	0.6	1.6	1.6	2.0	4.9	2.6
31	16	6.8	67.7	0.3	1.0	2.3	222.6	0.6	2.3	1.5	2.3	4.8	2.6
27	14	6.7	69.8	1.3	1.0	2.6	224.1	0.6	1.5	1.4	2.2	5.1	2.6
7	4	6.7	69.6	2.6	1.1	2.3	229.3	0.6	1.8	1.4	2.1	5.1	2.5
128	64	6.7	67.8	1.3	1.0	2.5	217.9	0.6	2.0	1.4	2.0	3.5	2.8
24	12	6.6	69.3	1.1	1.0	2.6	226.5	0.6	1.8	1.3	2.5	4.5	2.8
28	14	6.6	70.5	1.1	1.0	2.3	242.6	0.6	1.7	1.6	2.4	4.5	2.9
38	19	6.6	68.2	1.7	1.0	2.5	229.9	0.6	1.8	1.5	2.7	4.3	2.6
113	57	6.6	66.8	1.2	1.1	2.4	213.4	0.6	2.3	1.4	2.1	5.1	2.3
145	73	6.6	67.8	1.8	1.0	2.6	211.0	0.5	2.3	1.6	2.0	5.0	2.4
100	50	6.6	68.9	2.1	1.0	2.6	227.1	0.5	2.0	1.5	2.2	3.9	2.6
213	**Check**	4.4	68.4	2.8	0.9	3.0	223.9	0.6	2.7	1.5	2.3	5.5	3.3
214	**Check**	5.2	70.1	2.5	0.9	2.7	224.3	0.5	2.3	1.6	2.3	4.8	3.1
215	**Check**	5.9	70.3	0.8	1.0	2.7	230.5	0.6	2.3	1.5	2.2	4.8	3.0
Check mean		**5.1**	**69.6**	**2.1**	**0.9**	**2.8**	**226.2**	**0.6**	**2.4**	**1.5**	**2.2**	**5.0**	**3.1**
Trial mean		**5.8**	**68.1**	**1.7**	**1.0**	**2.7**	**219.3**	**0.5**	**2.2**	**1.5**	**2.3**	**4.8**	**2.7**
LSD		**1.0**	**1.1**	**1.0**	**0.1**	**0.3**	**14.3**	**0.1**	**0.4**	**0.3**	**0.3**	**1.0**	**0.5**
CV		**20.5**	**2.0**	**76.5**	**11.7**	**15.6**	**6.6**	**8.8**	**17.9**	**18.4**	**11.9**	**14.9**	**13.7**
Max		**7.6**	**71.1**	**5.3**	**1.1**	**3.3**	**245.1**	**0.6**	**3.1**	**2.3**	**2.8**	**6.0**	**3.3**
Min		**4.0**	**65.7**	**0.1**	**0.8**	**2.3**	**200.1**	**0.5**	**1.5**	**1.3**	**1.8**	**3.5**	**2.1**

Grain yield (t/ha) = GY, Days to anthesis (Days) = AD, Anthesis to silking interval (Days) = ASI, Ears per plant (Ratio) = EPP, Ear aspects (Score) = EA, Plant height (cm) = PH, Ear position (Ratio) = EPO, Grey Leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Northern leaf blight (Score) = ET, Leaf senescence = SEN, Plant aspect (Score) = PA

Table 3.20: Performance of last 19 entries and checks across all (6) environments

ENTRY	LINE	GY	AD	ASI	EPP	EA	PH	EPO	GLS	PS	ET	SEN	PA
61	31	5.1	67.4	2.9	1.0	3.0	210.8	0.5	2.3	1.6	2.2	5.1	2.6
188	94	5.1	68.4	2.8	1.0	2.7	218.4	0.5	1.8	1.4	2.5	4.5	2.3
134	67	5.1	67.4	2.0	1.0	2.9	208.0	0.6	2.1	1.3	2.8	4.6	2.6
41	21	5.0	67.3	2.2	0.9	3.0	220.1	0.6	2.5	1.6	2.6	5.4	2.6
135	68	5.0	67.4	2.4	1.0	3.2	206.8	0.5	2.7	1.3	2.4	4.8	2.9
191	96	5.0	68.1	2.3	0.9	3.0	215.9	0.5	2.3	1.5	2.1	3.9	2.5
42	21	5.0	68.8	1.5	0.9	2.9	225.9	0.6	2.1	1.3	2.5	5.3	2.9
132	66	5.0	68.4	2.2	1.0	3.1	207.3	0.6	1.8	1.6	2.5	4.5	3.0
181	91	4.9	67.6	2.3	0.9	3.0	211.0	0.5	2.3	1.5	2.1	5.3	2.5
211	106	4.9	68.8	2.7	0.9	3.2	213.6	0.5	2.0	1.5	1.9	4.4	3.0
5	3	4.9	70.7	1.3	0.9	3.1	210.8	0.5	2.3	1.6	2.2	4.8	2.5
187	94	4.9	67.8	2.9	0.9	3.0	209.1	0.5	2.2	1.4	2.3	5.0	2.4
195	98	4.8	66.8	2.9	1.0	3.0	210.3	0.5	2.2	1.5	2.3	4.6	2.9
183	92	4.8	66.8	1.8	1.0	3.3	200.1	0.5	1.8	1.3	2.3	5.3	2.6
209	105	4.8	66.5	3.1	0.8	3.2	218.8	0.5	2.9	1.6	2.2	5.0	2.6
6	3	4.6	70.8	3.3	1.0	3.2	218.1	0.5	1.7	1.4	2.3	4.9	3.0
189	95	4.6	66.3	2.5	0.9	3.0	215.4	0.5	2.6	1.5	2.3	4.8	2.8
213	107	4.4	68.4	2.8	0.9	3.0	223.9	0.6	2.7	1.5	2.3	5.5	3.3
201	101	4.0	68.2	2.9	0.8	3.3	210.8	0.5	2.1	2.3	2.1	4.5	3.0
213	**Check**	4.4	68.4	2.8	0.9	3.0	223.9	0.6	2.7	1.5	2.3	5.5	3.3
214	**Check**	5.2	70.1	2.5	0.9	2.7	224.3	0.5	2.3	1.6	2.3	4.8	3.1
215	**Check**	5.9	70.3	0.8	1.0	2.7	230.5	0.6	2.3	1.5	2.2	4.8	3.0
Check mean		**5.1**	**69.6**	**2.1**	**0.9**	**2.8**	**226.2**	**0.6**	**2.4**	**1.5**	**2.2**	**5.0**	**3.1**
Trial mean		**5.8**	**68.1**	**1.7**	**1.0**	**2.7**	**219.3**	**0.5**	**2.2**	**1.5**	**2.3**	**4.8**	**2.7**
LSD		**1.0**	**1.1**	**1.0**	**0.1**	**0.3**	**14.3**	**0.1**	**0.4**	**0.3**	**0.3**	**1.0**	**0.5**
CV		**20.5**	**2.0**	**76.5**	**11.7**	**15.6**	**6.6**	**8.8**	**17.9**	**18.4**	**11.9**	**14.9**	**13.7**
Max		**7.6**	**71.1**	**5.3**	**1.1**	**3.3**	**245.1**	**0.6**	**3.1**	**2.3**	**2.8**	**6.0**	**3.3**
Min		**4.0**	**65.7**	**0.1**	**0.8**	**2.3**	**200.1**	**0.5**	**1.5**	**1.3**	**1.8**	**3.5**	**2.1**

Grain yield (t/ha) = GY, Days to anthesis (Days) = AD, Anthesis to silking interval (Days) = ASI, Ears per plant (Ratio) = EPP, Ear aspects (Score) = EA, Plant height (cm) = PH, Ear position (Ratio) = EPO, Grey Leaf spot (Score) = GLS, Maize leaf rust (Score) = PS, Northern leaf blight (Score) = ET, Leaf senescence = SEN, Plant aspect (Score) = PA

3.3.5 General combining ability analysis for individual sites

Significant GCA effects ($P<0.01$) were revealed in the analysis of variance for GY in both managed drought and well watered conditions, except Kakamega well-watered trial (Tables 3.2 to 3.7). This trend was consistent with previous work by Derera *et al.*, (2008), when they found that GCA effects were of more importance for expression of traits under optimum conditions. Specific combining ability (SCA) effects were non-significant under managed drought. This was also consistent with findings reported by Derera *et al.*,(2008) who found out that non additive gene effects are not important in expression of grain yield under managed drought. A similar observation was made under well watered conditions, suggesting that additive gene action was of more importance across these sites. Other agronomic traits in Kiboko managed drought trial displayed significant GCA effects ($P<0.05$), except RL, SL, HC and SEN. Additive gene effects were important in expression of these traits. For ASI and ER, both GCA and SCA mean squares were significant, indicating that both additive and non-additive gene effects were of importance in their expression. Other agronomic traits in Kiboko well watered trial for the season of March to October 2010 showed significant GCA effects except for RL, SL, and ER. Only ER did not show significant GCA effects in the October 2010 to February 2011 trial.

Kakamega well watered trials showed similar results. In the March to August 2010 season all other agronomic traits showed significant GCA effects, except SL and PS. In the Second season trial, all other agronomic traits also showed significant GCA effects, except ER and PS. Similarly, in the Embu optimum trial, significant GCA effects were revealed for other agronomic traits, with the exception of EPP, HC, PS, and MSV.

3.3.6 General combining ability at Kiboko drought trial

Lines with the best GCA effects in Kiboko managed drought are presented in Table 3.21. Of the 106 lines, 46 had positive GCA, and only 13 had positive and significant GCA for grain yield. These lines could be used as potential parents in development of hybrids that have good yield. Lines 13, 50, 10 15, 34, 4, 12, 85 and 35 showed favourable and significant GCA for ear aspect. Among these, line 50 showed a favourable and highly significant GCA for senescence. This indicated that it retained green leaf area under drought conditions. Line 4 had a favourable and significant GCA score for SL, suggesting that it had good stalk strength under drought. Lines 13 and 35 had a favourable and significant GCA score for EPP, an indication that they were prolific lines. Lines 10, 34 and 15 had a favourable and significant GCA for anthesis to silking interval (ASI), suggesting that they maintained a short ASI under drought conditions.

Table 3.21: GCA effects for agronomic traits of the best 15 lines in Kiboko drought trial

LINE	GY	AD	SD	ASI	RL	SL	EPP	HC	ER	SEN	EA
13	1.25***	-0.41	-1.32	-0.92	-1.24	-0.83	0.19**	1.25	1.75	-0.47	-0.31*
37	1.11***	-0.66	-2.07*	-1.42	-1.24	-4.3	0.05	0.94	0.31	-0.97***	-0.19
45	1.08***	-1.41**	-2.32**	-0.92	-1.24	3.43	0.14*	-0.22	-1.16	-0.35	-0.19
50	0.89***	0.59	0.43	-0.17	1.53	0.31	0.05	-1.69	-1.16	-0.97***	-0.31*
10	0.89***	2.59***	0.93	-1.67*	0.15	4.11	-0.04	1.09	-1.16	-0.47	-0.44**
34	0.87**	-0.91*	-2.82**	-1.92*	1.39	-4.99	0.11	-0.3	0.4	-0.1	-0.31*
15	0.82**	-0.16	-1.82*	-1.67*	1.62	8.68**	0.06	0.94	-1.16	0.53	-0.56***
4	0.72**	2.59***	1.93*	-0.67	-1.24	-9.49**	0.11	-0.3	0.5	0.03	-0.31*
89	0.67**	0.34	0.43	0.08	0.07	-0.13	0.07	1.01	-1.16	-0.1	-0.19
12	0.66*	1.34**	0.68	-0.67	-1.24	4.18	0.04	1.08	-1.16	-0.35	-0.31*
79	0.61*	-1.91***	-3.32***	-1.42	-1.24	6.43	0.18**	-1.69	-1.16	-0.22	-0.06
32	0.6*	-0.91*	-1.57	-0.67	-1.24	1.72	-0.01	-1.69	-1.16	0.03	-0.06
85	0.46	0.59	0.18	-0.42	-1.24	0.31	0.04	-1.69	-1.16	0.53	-0.31*
35	0.43	-0.41	-1.32	-0.92	-1.24	-2.62	0.14*	1.08	0.31	0.28	-0.31*
51	0.43	-1.16*	-0.82	0.33	-1.24	4.18	-0.01	-0.3	-1.16	-0.6*	0.06

Grain yield = GY, Anthesis date = AD, Silking date = SD, Anthesis to Silking Interval = ASI, Root lodging = RL Stem Lodging = SL Husk cover = HC, Ear Rot= ER, and Ear Aspect = EA

General combining ability at Kiboko optimum trials

Out of the 106 lines in Kiboko well watered trial for the season of March to October 2010, 53 of them had a favourable GCA for GY (Table 3.22). Fifteen lines, out of the 53 had significant GCA for GY. Only lines 13, 60, 17, 19, 50, 75, 56 and 55 had favourable and significant GCA for EA. Lines 19, 88 and 67 had a favourable and significant GCA for AD, and showed that they are early maturing lines. However, they didn't have the best GCA scores for ASI. Lines 13, 60, 17, 53, 55, and 18 had favourable and significant GCA for ASI. Only line 50 had favourable and significant GCA for HC. This indicated that most of the lines had a problem with bare tips in this trial. General combining ability scores at Kiboko optimum trial, season of October 2010-February 2011 are displayed on table 3.23 below. Fifty five lines out of the total 106 showed positive GCA for grain yield, but only 5 showed positive and significant GCA for yield. These were potentially good yielding lines. Line 78 also showed favourable and significant GCA for maturity, suggesting that it was an early maturing line. In addition it has favourable and significant GCA for EPP and EA, suggesting that it was a prolific line with good ear characteristics.

Table 3.22: GCA effects for agronomic traits of the best 15 lines in Kiboko optimum trial (March to October 2010).

LINE	GY	AD	ASI	RL	SL	EPP	HC	ER	EA
13	2.088***	-0.271	-1.118*	-1.442	-0.298	0.106*	-1.684	-0.793	-0.538***
60	1.813***	0.479	-1.118*	-1.442	-0.298	0.106*	-1.859	-0.793	-0.538***
17	1.705***	-0.771	-1.618**	3.908*	-0.298	0.006	2.566	0.607	-0.538***
19	1.683**	-1.271**	0.132	1.358	-0.298	0.031	8.616*	-0.793	-0.538***
50	1.533**	-0.021	-0.868	-0.042	-0.298	0.056	-7.109*	-0.793	-0.538***
33	1.508**	-1.521	0.132	-1.442	-0.298	0.056	-0.534	3.382**	0.087
75	1.465**	0.729	-0.618	-1.442	-0.298	0.106*	-4.334	-0.793	-0.413**
70	1.355**	0.479	-0.368	-1.442	-0.298	0.031	-4.409	0.607	-0.288
53	1.323**	1.479**	-1.618**	-1.442	-0.298	0.031	-0.109	-0.793	-0.288
56	1.285*	-0.771	-0.118	-0.117	1.102	-0.044	11.316***	0.607	-0.538***
55	1.228*	1.229**	-1.118*	-1.442	-0.298	0.031	2.241	-0.793	-0.538***
18	1.12*	0.229	-1.118**	2.508	1.027	-0.044	7.641*	0.682	-0.288
88	1.028*	-1.021*	-0.868	-0.117	-0.298	0.006	2.366	-0.793	-0.038
54	0.993*	0.229	-0.868	1.283	2.477***	0.006	-5.659	-0.793	-0.288
67	0.99*	-1.271**	-0.118	-1.442	-0.298	0.031	2.116	1.982	0.087

Grain yield = GY, Anthesis to Silking Interval = ASI, Stem Lodging = SL Ears Per Plant = EPP, Husk Cover = HC, Ear Rot= ER, and Ear Aspect = EA

Table 3.23: 15 entries with the highest GCA scores at Kiboko optimum trial (October 2010- February 2011)

LINE	GYG	AD	SD	ASI	PH	EH	EPO	RL	EPP	HC	SEN	EA
13	2.11**	0.95*	0.62	-0.33	-13.04**	3.06	0.05**	-0.45	0.08	-3.48	-0.45	0.00
16	1.95**	-0.05	-0.88	-0.83	-4.79	-0.19	0.01	2.68*	0.11	0.93	-0.45	-0.25
78	1.59*	-2.55***	-2.88***	-0.33	-0.79	-3.44	-0.01	-0.45	0.13*	5.57	0.55*	0.00
1	1.58*	-0.05	-0.13	-0.08	1.46	10.56**	0.04**	3.72**	0.14*	-4.79	0.55*	-0.38*
18	1.36*	-0.55	-1.13	-0.58	28.21***	22.56***	0.03	-0.45	-0.04	0.93	-0.20	-0.13
27	1.27	-0.30	-0.88	-0.58	4.71	-0.94	-0.02	-0.45	-0.09	8.52	-0.7**	-0.13
104	1.23	-0.05	0.12	0.17	14.46***	7.56*	0.00	-0.45	0.09	7.36	-0.20	-0.38
55	1.16	1.70***	1.62**	-0.08	1.46	-7.19*	-0.03*	-0.45	0.06	-4.93	-0.45	-0.25
49	1.15	0.20	0.87	0.67	-4.79	-4.19	-0.01	-0.45	0.05	6.48	-0.45	-0.38*
64	1.14	0.45	-0.13	-0.58	0.21	1.31	0.01	-0.45	0.08	-4.43	-0.95***	0.25
14	1.13	1.20*	1.62**	0.42	13.71**	17.06***	0.04**	-0.45	-0.03	3.59	-0.45	-0.5**
12	1.09	0.20	0.62	0.42	1.96	10.56**	0.04**	-0.45	0.01	12.94**	-0.45	-0.25
44	1.01	0.20	0.87	0.67	7.96	0.31	-0.02	-0.45	-0.04	8.44	-0.45	0.00
105	0.99	-1.05*	-0.38	0.67	5.46	1.31	-0.01	-0.45	0.04	-6.18	-0.45	-0.38
40	0.85	-0.55	-2.38***	-1.83***	3.46	5.56	0.02	-0.45	0.00	-7.73	0.30	0.38*

Grain yield = GY, anthesis date = AD, Days to silking = DS, Anthesis to Silking Interval = ASI, Plant height = PH, Ear height = EH, Ear position = EPO, Root lodging = RL, Ears Per Plant = EPP, Husk Cover = HC, Leaf senescence = SEN and Ear Aspect = EA.

General combining ability analysis in Kakamega well watered trials

Table 3.24 presents lines that had the best GCA effects for Kakamega optimum. General combining ability effects for grain yield in the whole trial ranged from -1.62 to 2.07. Out of the 106 lines in the experiment, 47 had positive GCA for grain yield, and only 10 lines had positive and significant GCA for GY. Out of the 10 lines with favourable and significant GCA for yield, only 3 lines (14, 74 and 59) had favourable and significant GCA for good ear characteristics (EA). Line 14 showed favourable and significant GCA for GLS, while Line 59 showed favourable and significant GCA for northern leaf blight (ET). Line 74 showed favourable and significant GCA for days to anthesis, indicating that it is an early line. It also showed good and significant GCA for plant aspect, and ear aspect indicating that it has good plant and ear characteristics, as presented in table 3.15 above. Line 37 had favourable and significant GCA for yield (GY), northern leaf blight (ET), gray leaf spot (GLS) and Root lodging (RL) suggesting that this line had some resistance to northern leaf blight, gray leaf spot and had good stalk strength. Line 86 had favourable and significant GCA for GLS and ET, and could therefore be used as a possible source of resistance to these diseases. Kakamega optimum trial, season of October 2010- February 2011GCA scores are presented in **t**able 3.3.25. Out of the 106 lines, 50 lines showed positive GCA scores for grain yield, and 4 were significant. Lines 88, 73 and 61 showed favourable and significant GCA for GLS. In addition, Line 73 showed favourable and significant GCA for northern leaf blight. This suggested that they could be used as a source of resistance to GLS. Line 73, showed favourable and significant GCA for both diseases and a favorable and significant GCA Score for ear aspect, indicating that it had desirable ears. Lines 58, 50, 34 and 88 also showed favourable and significant GCA for EA.

Table 3.24: GCA effects for agronomic traits of the 10 best lines at Kakamega season of March to September2010

LINE	GY	AD	ASI	ET	RL	EA	EH	EPO
14	2.069*	1.21*	-0.08	0.064	0.025	-0.723**	19.868*	0.025
49	1.672**	-0.54	0.42	-0.061	-0.04	-0.098	-11.382	-0.04
37	1.579**	-0.54	-0.58	-0.436**	-0.108***	-0.098	-22.632**	-0.108***
74	1.577**	-1.79**	0.92	-0.061	-0.003	-0.598**	-2.632	-0.003
59	1.457*	-0.04	-0.33	-0.436**	-0.033	-0.473*	-7.632	-0.033
9	1.394*	1.21*	-0.58	-0.186	-0.005	-0.098	1.118	-0.005
27	1.352*	-0.04	-0.58	0.064	0.057	-0.348	19.868*	0.057*
88	1.304*	-0.29	0.92	-0.186	-0.045	-0.223	-12.632	-0.045
60	1.257*	0.71	0.67	0.064	-0.003	-0.348	6.118	-0.003
86	1.224*	0.96	0.92	-0.436**	-0.003	-0.098	1.118	-0.003

	EPP	ER	GLS	HC	PA	PH	PS	SL
14	0.057	-6.804	-0.632**	-8.502	0.229	23.408**	-0.039	-0.318
49	0.049	4.724	-0.132	-5.562	-0.521**	-5.342	-0.039	-1.788
37	-0.028	1.719	-0.507*	-8.502	-0.021	4.658	-0.164	-1.788
74	0.014	1.074	0.243	-1.115	-0.521**	-4.092	0.086	-1.788
59	-0.043	-0.954	-0.257	11.811*	-0.146	-0.342	0.086	0.99
9	0.172***	-3.252	-0.132	-2.775	-0.521	5.908	0.211	2.757
27	-0.061	-2.887	0.243	5.023	-0.271	10.908	-0.039	-1.788
88	-0.001	3.964	-0.007	9.901	-0.146	-2.842	0.211	-0.225
60	0.032	-3.897	0.243	1.671	-0.021	13.408	-0.039	-1.788
86	-0.006	2.854	-0.632**	-0.512	-0.021	3.408	0.086	-1.788

Grain yield = GY, anthesis date = AD, Anthesis to Silking Interval = ASI, Plant height = PH, Ear position = EPO, Root lodging = RL, Stem Lodging = SL Ears Per Plant = EPP, Husk Cover = HC, Ear Rot= ER, Gray leaf spot = GLS, Maize leaf rust = PS, Turcicum leaf blight = ET, Ear Aspect = EA and plant aspect = PA

Table 3.25: GCA scores for the best 15 lines at Kakamega trial season of October 2010- February 2011

LINE	GYF	AD	DS	ASI	HC	GLS	ET	EA	PA
1	1.46*	1.56*	1.79*	0.23	-3.19	-0.12	-0.08	-0.16	0.11
88	1.36*	-0.44	-0.21	0.23	-5.77	-0.37**	-0.2	-0.28*	-0.39*
73	1.28*	0.06	0.29	0.23	-6.95	-0.37**	-0.33*	-0.28*	-0.39*
34	1.18*	-1.19	-2.46***	-1.27*	-5.83	0.38**	-0.2	-0.28*	-0.14
50	1.05	-0.19	0.54	0.73	-3.17	0.13	-0.2	-0.41**	-0.01
37	1.03	-1.44*	-2.46***	-1.02	-8.33*	-0.49***	0.05	-0.28*	-0.01
41	1.02	0.31	-0.21	-0.52	2.39	0.26	-0.08	-0.16	0.36*
58	0.99	0.81	1.04	0.23	-4.76	-0.24	-0.33*	-0.41**	-0.14
22	0.95	-1.44*	-1.71*	-0.27	1.2	0.51***	0.3*	-0.16	-0.01
61	0.88	-0.19	1.54*	1.73**	1.45	-0.37**	-0.2	-0.03	-0.26
32	0.8	-0.19	-0.96	-0.77	0.01	0.01	-0.08	0.34*	-0.01
18	0.78	0.06	-1.21	-1.27*	8.7*	-0.12	0.67***	-0.16	-0.26
81	0.77	-2.69***	-2.96***	-0.27	-0.89	0.26	-0.08	0.22	-0.01
13	0.77	-0.19	-0.71	-0.52	-2.38	0.01	0.3*	-0.16	-0.01
25	0.76	-0.44	-0.71	-0.27	4.76	0.13	0.3	0.09	-0.14

Grain yield = GY, anthesis date = AD, Days to silking = DS, Anthesis to Silking Interval = ASI, Husk Cover = HC, Gray leaf spot = GLS, Turcicum leaf blight = ET, and Ear Aspect = EA.

General combining ability analysis in Embu optimum trial

Table 3.26 presents lines that had the best GCA effects for Kiboko drought trial. General combining ability effects ranged from -1.9 to 2.8. Out of the 106 lines in the trial, 50 had positive GCA for yield, and 10 of the 15 lines, with highest GCA effects, had good ear aspect, as shown by their favourable and significant GCA for ear aspect (EA). Only two lines; 37 and 19 had favourable and significant GCA for days to anthesis. This showed that these lines were early maturing and had good yield and good ear characteristics. This would be attributed to their earliness, suggesting that they synchronized and were adequately pollinated. In addition, line 63, 37, 72, 60, 70 and 54 showed significant and favourable GCA for gray leaf spot (GLS). These lines could be used as sources of resistance to GLS. Only line 69, among the best 15 lines showed favourable and significant GCA for northern leaf blight (ET). Line 70 had favourable and significant GCA for yield, ear rot and gray leaf spot. However, its ear aspect did not show significant GCA.

Table 3.26: GCA effects for agronomic traits of the 15 best lines at Embu

LINE	GY	AD	ASI	RL	SL	EPP	HC	ER	GLS	PS	ET	MSV	EA
16	2.788***	-0.915	-0.748	-0.061	0.54	0.08	-4.79	-11.285*	-0.205	0.00	0.06	0.02	-1.199***
63	1.898***	1.335*	-0.498	1.129***	-1.963	0.121**	-4.626	-9.375	-0.455**	0.00	-0.06	-0.229	-0.699***
12	1.886***	-0.665	-0.498	-0.061	-1.963	0.106*	1.91	-13.892**	-0.205	0.00	-0.06	0.02	-0.574**
37	1.786***	-1.915**	-1.998***	-0.061	-1.963	0.088*	-3.601	-1.857	-0.455**	0.00	-0.06	0.15	-0.449*
72	1.611***	1.09	0.25	-0.061	-1.963	0.03	-0.209	-5.97	-0.58***	0.00	-0.06	0.02	-0.199
60	1.588***	0.59	0.50	-0.061	-0.713	0.05	0.98	-10.85*	-0.58***	0.00	-0.06	0.02	-0.699***
70	1.341**	1.09	0.75	-0.061	-0.573	0.01	-5.896	-12.74**	-0.455**	0.00	-0.06	0.15	-0.699
53	1.293**	0.34	0.25	-0.061	-0.713	-0.052	-1.036	-4.142	-0.205	0.00	-0.06	0.771***	-0.199
54	1.201**	0.09	0.50	-0.061	1.67	-0.034	-3.661	-6.35	-0.455**	0.00	-0.06	0.15	-0.574**
18	1.156**	1.09	-0.248	1.189***	1.93	-0.009	6.95	-7.067	-0.08	0.00	0.06	0.02	-0.199
57	1.071*	-0.165	-0.998*	-0.061	11.787***	0.07	2.79	-4.25	-0.205	0.00	-0.06	-0.104	-0.449*
15	1.058*	-0.165	-1.248**	-0.061	-1.963	0.093*	-3.47	-1.622	0.05	0.00	0.06	-0.104	-0.449*
1	1.003*	-0.92	-0.248	-0.061	5.614**	0.05	-4.654	-5.542	-0.205	0.00	-0.06	0.02	-0.699***
19	0.951*	-1.415*	0.00	-0.061	4.112*	0.02	-7.411	-6.517	0.545***	0.00	0.44	-0.229	-0.574**
69	0.928*	0.09	-0.748	-0.061	0.42	-0.079	1.10	-9.415	0.30	-0.129***	-0.06	-0.104	-0.199

Grain yield = GY, anthesis date = AD, Anthesis to Silking Interval = ASI, Plant height = PH, Ear position = EPO, Root lodging = RL, Stem Lodging = SL Ears Per Plant = EPP, Husk Cover = HC, Ear Rot= ER, Gray leaf spot = GLS, Maize leaf rust = PS, Turcicum leaf blight = ET, Maize streak virus = MSV and Ear Aspect = EA.

3.3.6 General combining abilities across all sites

General combining ability effects varied considerably across all environments among the lines in the experiment (Table 3.27). Of the 106 lines, only 48 displayed favorable GCA for grain yield, and only 12 displayed favorable and significant GCA scores for grain yield. Out of the 12, lines 16, 37, 14, 1 and 4 displayed favourable and significant GCA effects for EA, suggesting that they are potentially good lines for use as parents in hybrid combinations. Lines 37 and 19 displayed favourable and significant GCA for days to anthesis, indicating that they were early maturing across all environments. Lines 13, 16, 37, 18, 12 and 17 showed favourable and significant GCA scores for anthesis to silking interval indicating that they had a short and ideal period between anthesis and pollen shed. Lines 37, 14 and 4 showed highly significant and favourable GCA for GLS. This suggested that these lines were tolerant to gray leaf spot. In addition, they showed favourable and significant GCA for EA, showing that they had good ear characteristics. Lines 54, 56, 59 and 73 showed favourable and significant GCA for GLS and ET. They could be used as sources of genes for improvement of other lines which show weakness on these traits.

Table 3.27: GCA scores for the best 15 lines across locations

LINE	GY	AD	ASI	PH	HC	ER	GLS	PS	ET	MSV	EA
13	1.201***	0.27	-0.661*	2.036	2.369	2.369	-0.11	-0.021	0.14	-0.08	-0.176
16	0.999***	0.479	-0.661*	-4.839	-1.261	-1.261	-0.151	-0.063	0.057	-0.08	-0.364***
37	0.926***	-1.021**	-0.994**	1.661	-4.981**	-4.981**	-0.485***	-0.063	-0.151	-0.018	-0.218*
18	0.914***	0.062	-0.911**	21.973***	8.162***	8.162***	-0.151	0.021	0.349***	0.045	-0.176
12	0.878**	0.479	-0.702*	9.036**	5.912**	5.912**	-0.11	-0.063	0.224**	0.045	-0.176
14	0.815**	2.062***	-0.536	14.198***	-1.23	-1.23	-0.568***	0.021	0.015	-0.143	-0.26*
1	0.613*	0.312	0.006	5.598	-3.619	-3.619	-0.193	-0.104	-0.068	0.17	-0.218*
9	0.598*	1.604***	-0.202	9.223**	0.217	0.217	-0.318	0.063	-0.193*	-0.018	-0.093
60	0.577*	0.937**	0.631	2.586	-1.409	-1.409	-0.151	0.021	-0.026	0.045	-0.135
4	0.562*	1.395***	0.548	9.286**	-3.001	-3.001	-0.485***	-0.063	-0.151	-0.268	-0.301**
50	0.554*	0.354	-0.077	1.536	-3.728	-3.728*	-0.026	0.021	-0.193*	-0.08	-0.176
19	0.547*	-0.605*	-0.161	9.348**	4.61*	4.61*	0.224	0.021	0.39***	-0.08	-0.197
17	0.528	0.062	-1.327***	15.473***	5.86**	5.86**	0.265*	-0.021	0.39***	0.107	0.053
73	0.524	-0.063	0.381	-4.277	-0.014	-0.014	-0.235	0.063	-0.276**	-0.143	-0.135
28	0.504	0.104	-0.327	1.911	4.831**	4.831**	0.099	-0.063	0.057	-0.143	-0.093

Grain yield= GY, Days to anthesis = AD, Anthesis to silking interval = ASI, Plant height = PH, Husk cover = HC, Ear rot = ER, Grey Leaf spot = GLS, Maize leaf rust = PS, Nothern leaf blight = ET, Maize streak virus = MSV, Ear aspects = EA

3.3.7 Specific combining abilities (SCA) and heterotic grouping of lines

Specific combining ability can be calculated and information from this used to assign lines to various heterotic groups based on the patterns displayed. Two single cross testers, CML 312/CML444 (HG A) and CML395/CML442 (HG B) were used in this experiment. Positive SCA effects meant that the line was in the opposite heterotic group, while negative SCA effects meant the line was in the same heterotic group (Vasal *et al.*, 1992c). SCA scores for across environments for grain yield and heterotic patterns and groups are presented in Table 3.35. Based on SCA scores on lines, 51 lines were shown to belong to heterotic group A, while 55 lines were shown to belong to Group B (Table 3.29). Lines 37, 95, 101 and 104 revealed favourable and significant SCA for GY with the Tester B (CML395/CML444). On the other hand, lines 1, 18 and 66 showed favourable and significant SCA with tester A (CML312/CML442) (Table 3.29). This suggested that these lines can be used in the development of hybrids with a high yield potential. Entries 1, 35, 74 and 208, made from lines 1, 18, 37 and 104, respectively, with tester A and B appeared among the top 30 best hybrids across all locations (Table 3.28). They also revealed superior GCA effects across all locations. This suggests that they are potential materials in hybrid development. Further experiments using more testers should be done to confirm these findings.

Table 3.28: Hybrids that have a good yield potential, based on their SCA scores

LINE	TESTER	Entry	Pedigree
1	1	1	(1368/CML445)-B-3-1//CML312/CML442
18	1	35	(5012/CML445)-B-3-3//CML312/CML442
66	1	131	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-1//CML312/CML442
37	2	74	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-5-1//CML395/CML444
95	2	190	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-1//CML395/CML444
101	2	202	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-7-1//CML395/CML444
104	2	208	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-2//CML395/CML444

Table 3.29: SCA scores for Lines and their heterotic Groups

LINE	Pedigree	CML395/CML444	CML312/CML442	HG
1	(1368/CML445)-B-3-1	-0.71**	0.71**	B
2	(1368/CML445)-B-3-2	-0.15	0.15	B
3	(DT-SR-W-3-3-2-1-1-B-B-B-B-B-B-B-B/CML445)-B-4-1	-0.2	0.2	B
4	(1368/CML445)-B-3-4	-0.35	0.35	B
5	(1368/CML445)-B-3-5	-0.31	0.31	B
6	(1368/CML445)-B-3-6	0.21	-0.21	A
7	(1368/CML445)-B-3-7	-0.29	0.29	B
8	(1368/CML445)-B-3-8	0.29	-0.29	A
9	(1368/CML445)-B-3-9	-0.41	0.41	B
10	(1368/CML445)-B-6-3	0.07	-0.07	A
11	(1368/CML445)-B-6-5	-0.24	0.24	B
12	(1368/CML445)-B-6-6	-0.16	0.16	B
13	(1368/CML445)-B-6-7	-0.08	0.08	B
14	(1368/CML445)-B-6-8	-0.14	0.14	B
15	(POP 10/CML445)-B-3-1	-0.2	0.2	B
16	(POP 10/CML445)-B-3-2	0.02	-0.02	A
17	(5012/CML445)-B-3-2	-0.27	0.27	B
18	(5012/CML445)-B-3-3	-0.52*	0.52*	B
19	(5012/CML445)-B-3-5	0.13	-0.13	A
20	(5012/CML445)-B-3-6	0.04	-0.04	A
21	(5012/CML445)-B-6-1	-0.1	0.1	B
22	(5012/CML445)-B-6-2	0.14	-0.14	A
23	(5012/CML445)-B-6-3	-0.14	0.14	B
24	(5012/CML445)-B-8-1	0.13	-0.13	A
25	(5012/CML445)-B-12-1	0.35	-0.35	A
26	(5012/CML445)-B-12-2	0.07	-0.07	A
27	(5012/CML445)-B-12-3	0.06	-0.06	A
28	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-1	-0.05	0.05	B
29	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-2	-0.19	0.19	B
30	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-3	-0.07	0.07	B
31	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-5	0.23	-0.23	A
32	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-6	-0.01	0.01	B
33	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-1	0.14	-0.14	A
34	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-3	-0.04	0.04	B
35	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-4	0.13	-0.13	A
36	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-6	-0.24	0.24	B
37	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-5-1	0.75**	-0.75**	A
38	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-7-1	-0.24	0.24	B
39	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-1	0.04	-0.04	A
40	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-2	0.22	-0.22	A
41	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-3	0.26	-0.26	A
42	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-4	-0.01	0.01	B
43	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-1	-0.26	0.26	B
44	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-2	0.29	-0.29	A
45	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-3	-0.14	0.14	B
46	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-4	0.16	-0.16	A
47	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-5	-0.06	0.06	B
48	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-3-1	-0.13	0.13	B
49	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-1	0.06	-0.06	A
50	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-2	0.1	-0.1	A
51	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-3	0.15	-0.15	A
52	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-4	-0.35	0.35	B
53	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-5	-0.23	0.23	B

Table 3.29: SCA scores for Lines and their heterotic Groups (Continuation)

LINE	Pedigree	CML395/CML444	CML312/CML442	HG
54	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-1	0.15	-0.15	A
55	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-2	0.04	-0.04	A
56	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-3	-0.32	0.32	B
57	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-4	-0.44	0.44	B
58	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-5	0.12	-0.12	A
59	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-6	0.43	-0.43	A
60	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-1	-0.04	0.04	B
61	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-2	-0.24	0.24	B
62	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-3	0.1	-0.1	A
63	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-4	0.1	-0.1	A
64	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-4-1	0.33	-0.33	A
65	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-7-1	-0.1	0.1	B
66	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-1	-0.68**	0.68**	B
67	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-2	-0.33	0.33	B
68	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-3	0.16	-0.16	A
69	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-1	-0.31	0.31	B
70	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-2	0.43	-0.43	A
71	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-3	0.02	-0.02	A
72	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-5	-0.13	0.13	B
73	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-1	-0.31	0.31	B
74	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-2	0.16	-0.16	A
75	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-3	-0.002	0.002	B
76	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-1	-0.33	0.33	B
77	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-2	-0.18	0.18	B
78	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-3	0.31	-0.31	A
79	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-4	0.06	-0.06	A
80	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-5	0.01	-0.01	A
81	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-6	-0.26	0.26	B
82	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-7	-0.14	0.14	B
83	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-8	-0.05	0.05	B
84	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-1	-0.1	0.1	B
85	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-2	-0.02	0.02	B
86	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-4	-0.11	0.11	B
87	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-5	-0.33	0.33	B
88	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-6-1	-0.05	0.05	B
89	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-6-2	-0.1	0.1	B
90	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-7-1	-0.07	0.07	B
91	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-7-2	0.17	-0.17	A
92	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-1	0.32	-0.32	A
93	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-2	0.31	-0.31	A
94	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-3	0.06	-0.06	A
95	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-1	0.61*	-0.61*	A
96	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-3	0.21	-0.21	A
97	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-5	0.18	-0.18	A
98	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-3-1	0.26	-0.26	A
99	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-3-2	-0.04	0.04	B
100	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-5-1	0.26	-0.26	A
101	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-7-1	0.78**	-0.78**	A
102	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-10-1	-0.04	0.04	B
103	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-1	0.06	-0.06	A
104	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-2	0.52*	-0.52*	A
105	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-3	0.39	-0.39	A
106	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-4	0.44	-0.44	A

3.3.8 Conclusion and recommendation.

Good performing hybrids in specific sites and across all sites were identified. Entries 74 (Line 37 x tester 2) for Kakamega optimum and Kiboko drought trials, entry 25 (Line 13 x tester1) and entry 35 (Line 18 x tester 1) for Kiboko optimum trials, entry 32 (Line 16 x tester 2) for Embu optimum trial, were identified as good hybrids. In addition, three hybrids (Entries 1, 35 and 74) were identified with consistently good performance across all environments. Entry 74 (Line 37 x tester 2) had the highest mean yield (7.59 t/ha) across all environments and yielded considerably well at all sites except Kiboko optimum. It consistently appeared among the top 15 entries in the other trials. The parental line for this hybrid had a favourable and highly significant GCA across all environments. This line can be used as a parent in formation of hybrids for further testing and recommendation in these environments. Line 18 x tester 1 (Entry 35) had the second highest mean yield (7.2 t/ha) across all environments, and showed favourable and highly significant GCA effects for GY. This entry appeared among the best 15 hybrids only in Kiboko optimum trials, and ranked 22 in Kiboko drought trial, and even lower in Embu and Kakamega trials. This suggested that it was more adapted to optimum conditions in Kiboko, but still had a good overall performance. Entry 1 (Line 1 x tester 1) had the third highest mean yield across all locations, and displayed favourable and significant GCA effects across all environments. All these entries out yielded the checks both at specific sites and across locations. These entries should therefore be tested further to generate more information because they are candidate hybrids for release in these environments.

Based on SCA scores on the experimental lines, 51 lines were shown belong to heterotic group A, while the remaining 55 lines were in Group B.

CHAPTER 4: STABILITY ANALYSIS OF DROUGHT TOLERANT MAIZE HYBRIDS

4.0 SUMMARY

Multi environmental trials (MET) are routinely conducted every year in many breeding programs in the world to generate information that is used for variety selection and recommendation. METs are an important activity in plant breeding and other agricultural research programs. Traditional multi environmental trial data analysis strategies were limited to analysis of variance and mean comparisons among genotypes. This approach did not exploit the total genotype-environment interaction encountered by plants in the field. Several scientists have proposed different methods to try and reconcile the diversity in ideas by relating them with the grouping of genotypes by their environmental response patterns. The objective of this study was to utilize six approaches of stability analysis to assess stability of grain yield performance of new drought tolerant maize hybrids, identify methods of stability analysis that give similar results and to identify the best testing sites. The different methods of stability analysis did not result in exact same ranking of genotypes but showed general similarities and common trends, for both the line x tester and regional trial data sets.

Hybrids 1, 23, 27, 28, 32, 35, 74, 100 and 116 were among the best yielders and the most stable entries in the line x tester trial, as seen from different stability analysis parameters. Wrickes' ecovalence and Shuklas' stability variance methods did not show consistency in ranking with the other parameters. In the regional trial data set, genotype 29 was yielded above average and also showed minimum variation in performance across environments based on results obtained using

the different stability parameters. Genotypes 7, 16, 23, 31, 33 and 42 also displayed above average yield and good stability.

Of all the methods reviewed, the GGE biplot method provided the best visualizations and clarity in exploration of genotypes GEI and analysis of data.

4.1 INTRODUCTION

Hybrids or open-pollinated varieties (OPVs) formed in breeding programs are tested in many environments, which include different locations, different years and across seasons. Selection for superior genotypes is done using results obtained across environments. However, genotype by environment interaction (GEI) reduces the correlation between genotypic and phenotypic values, thus complicating the process of selection of superior genotypes for a particular target environment. Genotype by environment is disadvantageous since it reduces progress from selection and also makes cultivar recommendation difficult (Kang and Magari, 1996). Genotype by environment interaction has been cited as one of the main reasons for the failure of formal breeding to serve small scale resource poor farmers (Ceccarelli *et al.*, 2006). Knowledge of GEI can also help plant breeders reduce the cost of evaluations by eliminating unnecessary testing sites (Basford and Cooper, 1998). Research on GEI has in many ways contributed to the understanding of this issue. Nonetheless, disparity on measurement and understanding still exists between breeders versus biometricians and quantitative geneticists. Some authors have applied the yield stability concept with respect to consistency in time of genotype performance, and using adaptation concept with respect to space.

In maize, important and economic traits such as yield are commonly affected by GEI (Fan *et al.*, 2007). It has been noted that yield stability in maize is quantitatively controlled and may be selected (Scott, 1967). Evaluation of new maize hybrids across dissimilar environments enables breeders to get useful information for them to ascertain their adaptability and stability. Use of heterogeneous rather than homogenous or pureline varieties has been suggested as a means of reducing GEI. Heterozygous and heterogeneous populations offered the best opportunities of producing hybrids that showed consistency in performance across environments (Allard and Bradshaw, 1964). Three-way hybrid performance has been shown to be better than that of single cross hybrids, across different locations (Patanothai and Atkins, 1974). Similar results were found when single cross and double cross hybrids were compared when in trials evaluated across ten environments in Central Brazil (Oliveira *et al.*, 2003). The single crosses showed a greater mean yield, but the double crosses showed greater yield stability over single crosses (Oliveira *et al.*, 2003).

There have been many attempts to analyze GEI for both new and old varieties in production. Different authors therefore have used different methods of evaluating genotypes and their interactions with the environments (Crossa and Cornelius, 1997). These methods differed in analysis parameters used, and in the biometrical procedures employed. Analysis of variance was, for a long time, applied on test genotypes to partition variation into the different sources, which were genotypes, environments, years and their interactions. However, this is not sufficient since it does not bring out important genotypic patterns, environmental patterns and genotype environment interactions (Gomez and Gomez, 1984).

Environmental and socioeconomic changes experienced in maize production environments have resulted in reduced yields, frequent crop failures and frequent food shortages. Breeding work in maize has therefore focused on developing new maize varieties that have better yields and agronomic traits, under varying environments. Stress tolerant hybrids have been developed to give improved yield under these stress environments. The International Maize and Wheat

Improvement Center (CIMMYT) tests elite stress tolerant maize hybrids in regional trials that are conducted in eastern and central Africa by its partners. Information on the GEI interaction of new hybrids in regional trials would be useful for determining which hybrids are more stable in the target environments. The objective of this study was to assess stability of grain yields of new drought tolerant hybrids, and identify the best testing sites and varieties.

4.2 Materials and methods

(i) Forty six new three-way cross hybrids and five commercial checks were evaluated in different locations in 2008. A total of 17 different environments were used to evaluate the hybrids in the 6 countries (Table 4.1). The experimental design used was an alpha-lattice (0,1) design (Paterson and Williams, 1976) with two replications at all locations. The trials were planted and managed according to the recommended agronomic practices of the different sites by CIMMYT collaborators.

(ii) The testcross hybrid trial presented in chapter 3 was subjected to stability analysis.

Table 4.1: Test sites used for regional trials evaluations

Location	Country	Management	Environment classification
Afsf-Arusha	Tanzania	Managed Low Nitrogen	Dry Mid-altitude
Bako	Ethiopia	Optimal	Wet Upper mid-altitude
Bumula	Kenya	Optimal	Wet Upper mid-altitude
Busia	Kenya	Random Drought	Wet Upper Mid-altitude
Elgon Downs	Kenya	Optimal	Wet Upper mid-altitude
Embu	Kenya	Optimal	Wet Lower Mid-altitude
Kagio	Kenya	Optimal	Wet Lower mid-altitude
Kakamega	Kenya	Optimal	Wet Upper Mid-altitude
Kiboko	Kenya	Managed Drought	Dry Mid-altitude
Kibos	Kenya	Optimal	Wet Upper Mid-altitude
Kimaeti	Kenya	Optimal	Wet Upper Mid-altitude
Kutus	Kenya	Optimal	Wet Lower Mid-altitude
Maseno	Kenya	Random Drought	Wet Upper Mid-altitude
Mosso	Burundi	Optimal	Wet Mid-Altitude
Mparambo	Burundi	Optimal	Wet Mid-Altitude
Patancheru	India	Optimal	Unclassified
Selian	Tanzania	Optimal	Dry mid-altitude
Siaya	Kenya	Optimal	Wet Upper mid-altitude
Wad Medani	Sudan	Optimal	Unclassified

4.2.2 Data collection

Data were recorded for grain yield at all locations, and analysed as discussed below.

Analysis of variance was carried out using the GLM procedure of SAS (SAS Institute, 2003), and means calculated for each site and mean separation done using the least significant difference method (Snedecor and Cochran, 1980). Entries were considered as fixed effects and locations as random effects. The means for grain yield of each hybrid at each of the 17 locations were used for stability analysis.

Different stability analysis statistics were calculated using SAS code (Hussein *et al.*, 2000). The following stability statistics were calculated Wricke's Ecovalence (Wricke, 1962), Shukla's stability variance (Shukla, 1972), Coefficient of Variation (Francis and Kannenberg, 1978), and joint regression analysis (Eberhart and Rusell, 1966; Finlay and Wilkinson, 1963). GGE biplot analysis (Yan *et al.*, 2001) was carried out using GenStat software (Payne *et al.*, 2009). Pearson's correlation coefficient (Steel and Torrie, 1980) was used to correlate the different stability statistics from the different analyses. The correlations were calculated using PROC CORR of SAS (SAS., 2003). Stability analysis was carried out separately for the regional trial and the testcross hybrids (presented in Chapter 3).

4.3 RESULTS AND DISCUSSION

4.3.1 STABILITY ANALYSIS OF EARLY GENERATION TESTCROSS HYBRIDS

4.3.1.1 Wricke's Ecovalence and Shukla's stability variance

Yield data from the testcross trials were analyzed using Wricke's ecovalence *Wi* (Wricke, 1962) and stability variance (Shukla, 1972) showed similarities in ranking of genotypes. Similar positive associations were revealed in wheat and maize in previous studies by Purchase and Kandus respectively (Kandus *et al.*, 2010; Purchase *et al.*, 2000). Table 4.2 presents the best 25 entries on grain yield basis. Check entry 214 (WH403) showed the highest stability in yield across environments, contributing only 0.12% variation. Entry 110 was the second most stable genotype, and ranked 26th by grain yield. They were followed by entries 28, 145, 23 and 118 which ranked 16th, 19th, 10th and 13th respectively. Entry 147 showed the highest contribution to instability (1.37%), and ranked 120th on yield basis, across environments. It was interesting to note that entry 74 was the best entry on yield ranking but ranked 182nd in contribution to instability by both these methods. Checks Entries 213 and 215 ranked 153rd and 158th in their contribution to instability and on the other hand, they ranked 214th and 104th on yield basis. This suggests that materials used in the experiment may be more stable compared to the check varieties. The similarity and consistency in ranking revealed using the two approaches suggested that either of the two methods could be used to assess stability in this set of hybrids. This is in agreement with previous findings in studies on temperate maize (Yue *et al.*, 1997), soybean (Mekbib, 2003) and chickpea (Segherloo *et al.*, 2008).

Table 4.2: Wricke (1962) Ecovalence and Shukla (1972) Stability variance methods for the best 25 entries ranked on yield basis for testcross hybrids

Genotype	*Wi*	*Wi (%)*	Shukla	Ranking by *Wi and Shukla*	Ranking by yield	Mean yield
74	30.68	0.67	6.17	182	1	7.59
35	17.90	0.39	3.59	95	2	7.20
1	34.31	0.75	6.91	191	3	7.09
25	28.77	0.63	5.79	174	4	7.05
26	19.20	0.42	3.86	111	5	7.04
32	44.35	0.97	8.93	207	6	6.94
23	9.33	0.20	1.86	14	7	6.81
17	16.57	0.36	3.33	77	8	6.78
118	11.74	0.26	2.35	31	9	6.76
31	34.47	0.75	6.94	194	10	6.75
27	50.49	1.10	10.17	211	11	6.72
7	17.69	0.39	3.55	91	12	6.68
128	15.79	0.34	3.17	69	13	6.66
24	18.09	0.39	3.63	98	14	6.64
28	7.10	0.15	1.41	5	15	6.60
38	37.91	0.82	7.63	199	16	6.60
113	32.86	0.71	6.61	188	17	6.60
145	7.23	0.16	1.44	7	18	6.60
100	38.03	0.83	7.66	200	19	6.58
33	19.33	0.42	3.88	113	20	6.56
126	13.20	0.29	2.64	41	21	6.50
116	16.87	0.37	3.39	81	22	6.46
120	22.66	0.49	4.55	142	23	6.45
88	22.12	0.48	4.45	138	24	6.43
208	29.17	0.63	5.87	175	25	6.42

4.3.1.2 Coefficient of variation (Francis and Kannenberg, 1978)

Figure 4.1 present a scatter plot of mean yield against coefficient of variation (CV) values for genotypes across all environments. These genotypes were grouped into four based on their mean yields and coefficients of variation. Genotype 74 had the highest mean yield and a small coefficient of variation, and appeared on the top left quadrant. Other entries 1, 26, 35, 23, 28, 121, 126, 145, 116, 100, 24 and 33 also had above average mean yields, and at the same time had a small coefficient of variation. Entries 27, 31, 32 and others in the top right quadrant showed above average mean yields, but were considered not preferable due to the above average coefficient of variation they displayed in across location yields. Similar findings were presented by other authors working on rice (Das *et al.*, 2010).

Checks 213 and 215 had a below average mean yield and also showed a high coefficient of variation. This suggested that some materials in the experiment displayed comparatively better adaptation than these checks. On the other hand, check 214 showed a low coefficient of variation value and below average yield. This would suggest that it was adapted to unfavourable environments. The entries that fell in the bottom left and bottom right quadrants appearing below the average yield line were considered to be poor performers (Francis and Kannenberg, 1978).

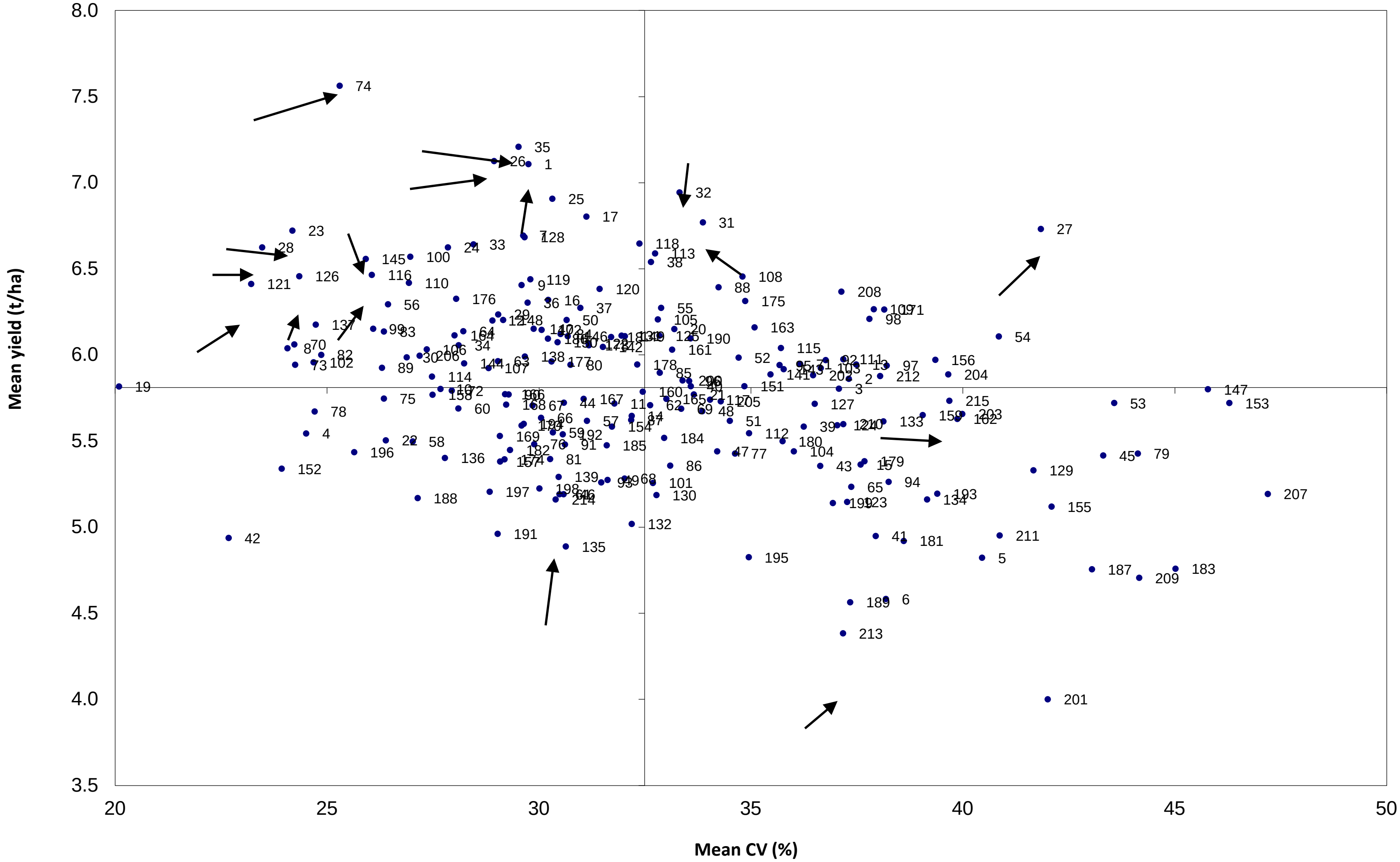

Figure 4.1: Scatter plot of mean CV (%) against mean yield on Francis and Kannenberg (1978) method

4.3.1.3 Joint regression (Eberhart and Rusell 1966)

A scatter diagram of mean yield against ***b*** values from Eberhart and Rusell (1966) method of stability analysis is presented (Figure 4.2). Entry 74 had the highest mean yield, above average and a *b* value of less than 1. However it showed a large deviation from regression of 1.6. On the other hand, entries 1, 35 and 27 had an above average yield and a slope greater than 1 and similarly had deviation from regression values of 2.04, 1.14 and 1.11. These results suggested that the genotypes are adapted to optimum environments with high inputs, and could yield best under these conditions. Other entries that showed good potential were entries17, 23, 24, 33, 26, 32 and 118. They all had above average mean yields and regression coefficients close to 1. Checks 213 and 214 had a below average mean yield, and also had a regression coefficient (*b*) value of less than 1. Check 215, similarly had a regression coefficient greater than 1 and a deviation from regression of 1.6.this showed that it had a good response to optimum environments but yielded less significantly less that the best genotypes. Entries 201, 6, and 183 had b values very close to 1 and deviation from regression values of 0.6, 1.2 and 1.6. This indicated that they were more adapted but were among the least yielders.

4.3.1.4 Regression of coefficients (Finlay and Wilkinson, 1963)

Figure 4.3 is a scatter plot of regression coefficients against mean yield. Entry 74 showed the highest mean yield and above average slope. This observation was similar to that in Eberhart and Rusell (1966) method. Entries 100, 126, 116, 105, 23 and 176 also showed high mean yields and above average stability. They performed predictably well across the test environments, and showed relatively stable yields. The best check was entry 215 (H505) displayed the highest mean yield of all the checks, but showed below average slope. The remaining two checks (H513 and WH403) had above average slope, but below average mean yield across environments.

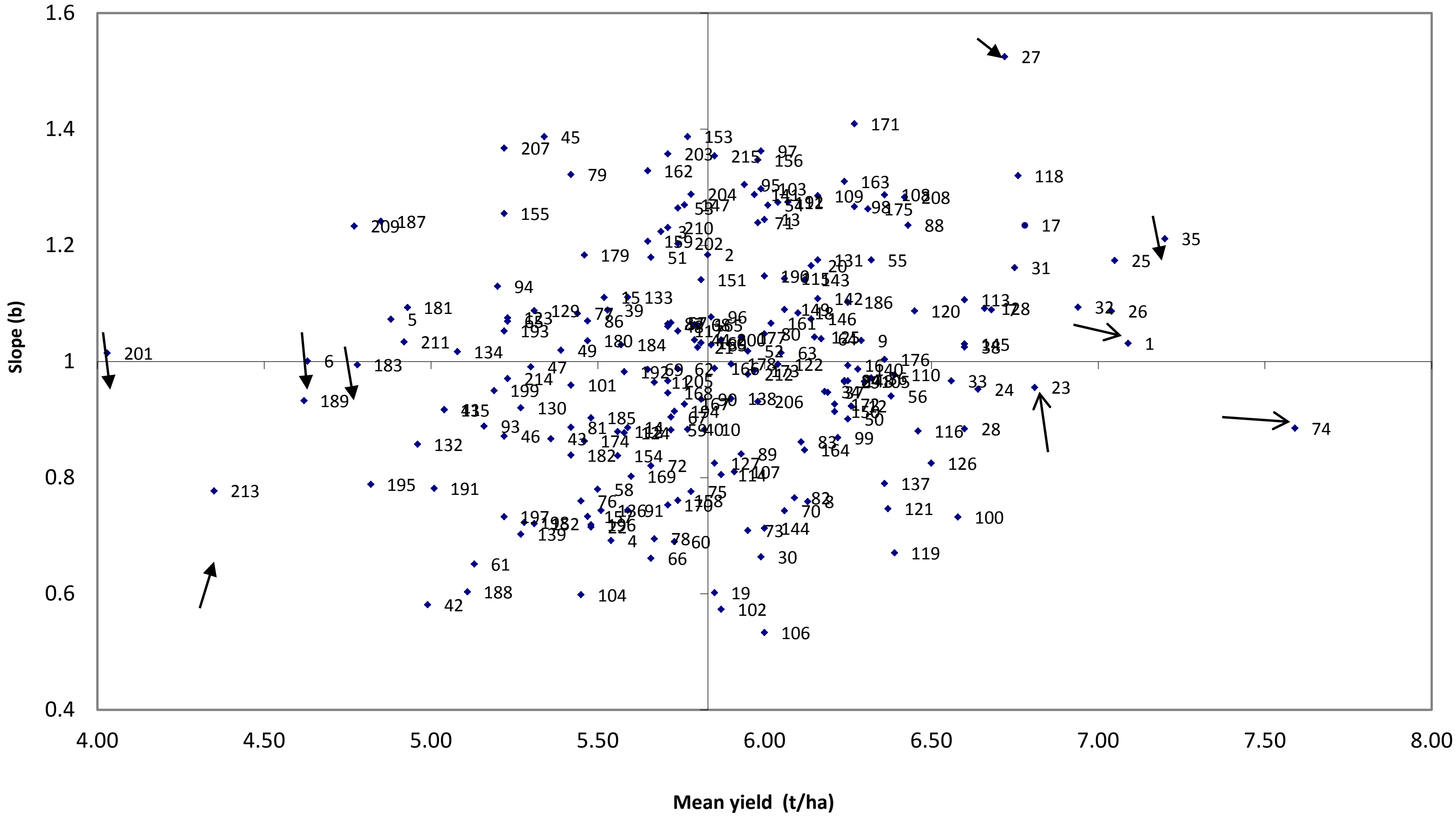

Figure 4.2: Scatter plot of mean yield against regression coefficients of entries on Eberhart and Rusell (1966) method

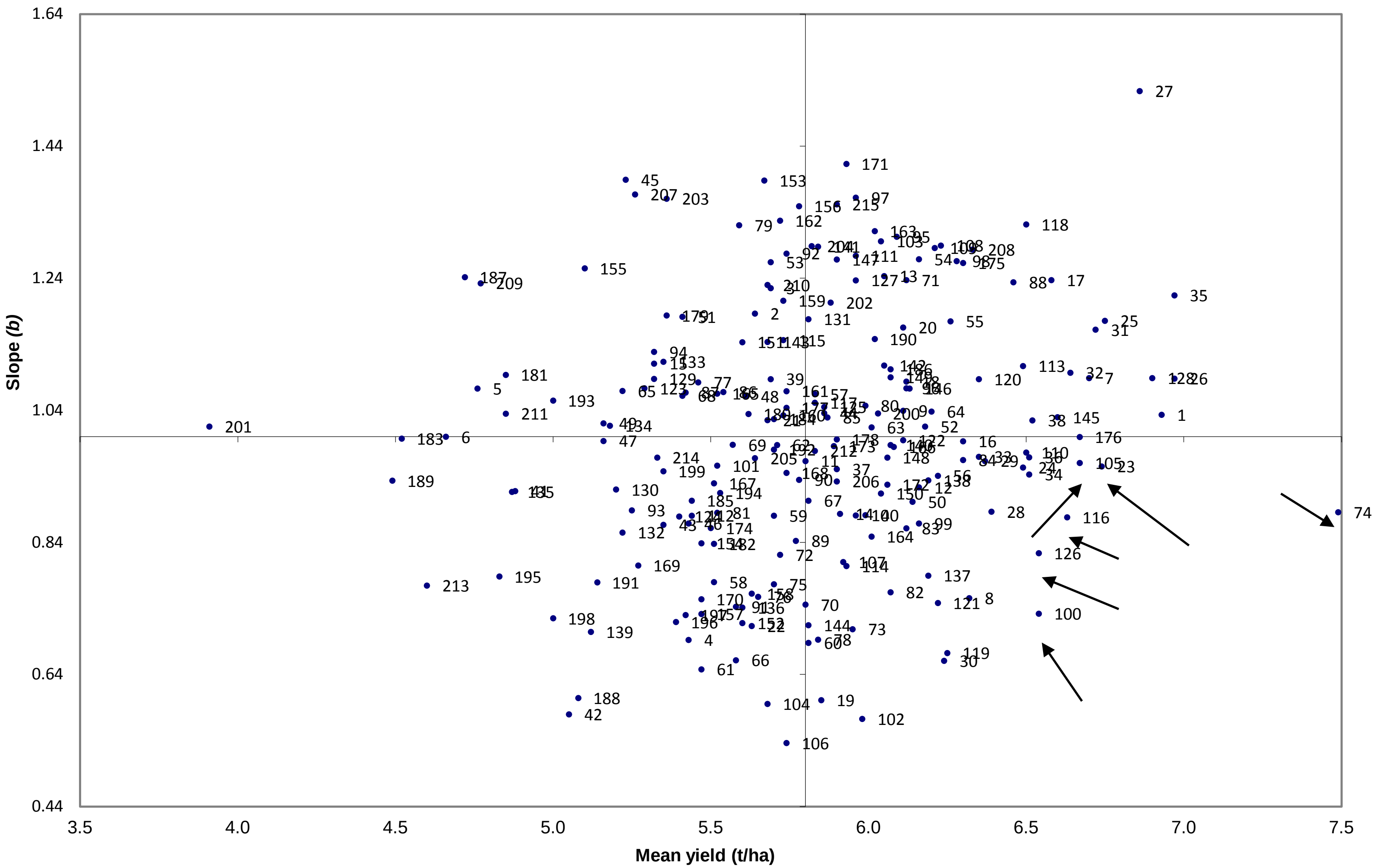

Figure 4.3: Scatter plot of mean yield against regression coefficients of entries (Finlay and Wilkinson, 1963)

4.3.1.5 GGE Biplot analysis (Yan and Tinker, 2006)

Figure 4.4 presents a GGE biplot of trials conducted in seven environments. Principal component 1 and 2 explained 46.2% of the genotype main effects and GEI. The angles formed between the environments vectors at the origin suggested that the test environments could be grouped into 2 mega environments. The first would comprise of environments 3, 4, 5, 7 and 8. The second group would comprise of environments 2 and 9. The most discriminating (most informative) environments were 9, 4 and 5, while environments 7 and 8 were the least discriminating (least informative), as shown by the lengths of their environments vectors to the origin. There were close associations between some environments, for instance, 2 vs 9 and 7 vs 3. This showed that there was a possibility of generating the same cultivar information from fewer sites, and therefore cutting down on the evaluation costs (Yan and Tinker, 2006).

Figure 4.5 is a GGE biplot where the tests environments are compared relative to the ideal test environment. Environments 3 (Kakamega well-watered) and 4 (Embu well-watered) were the closest to the ideal environments, which is represented by the middle of the concentric rings (Yan and Tinker, 2006). This meant that environments 3 and 4 were the most representative environments. From this, it was revealed that as much as environment 9 (Kiboko well-watered) and 5 (Kitale well watered) were highly informative, they were not representative of all the test environments.

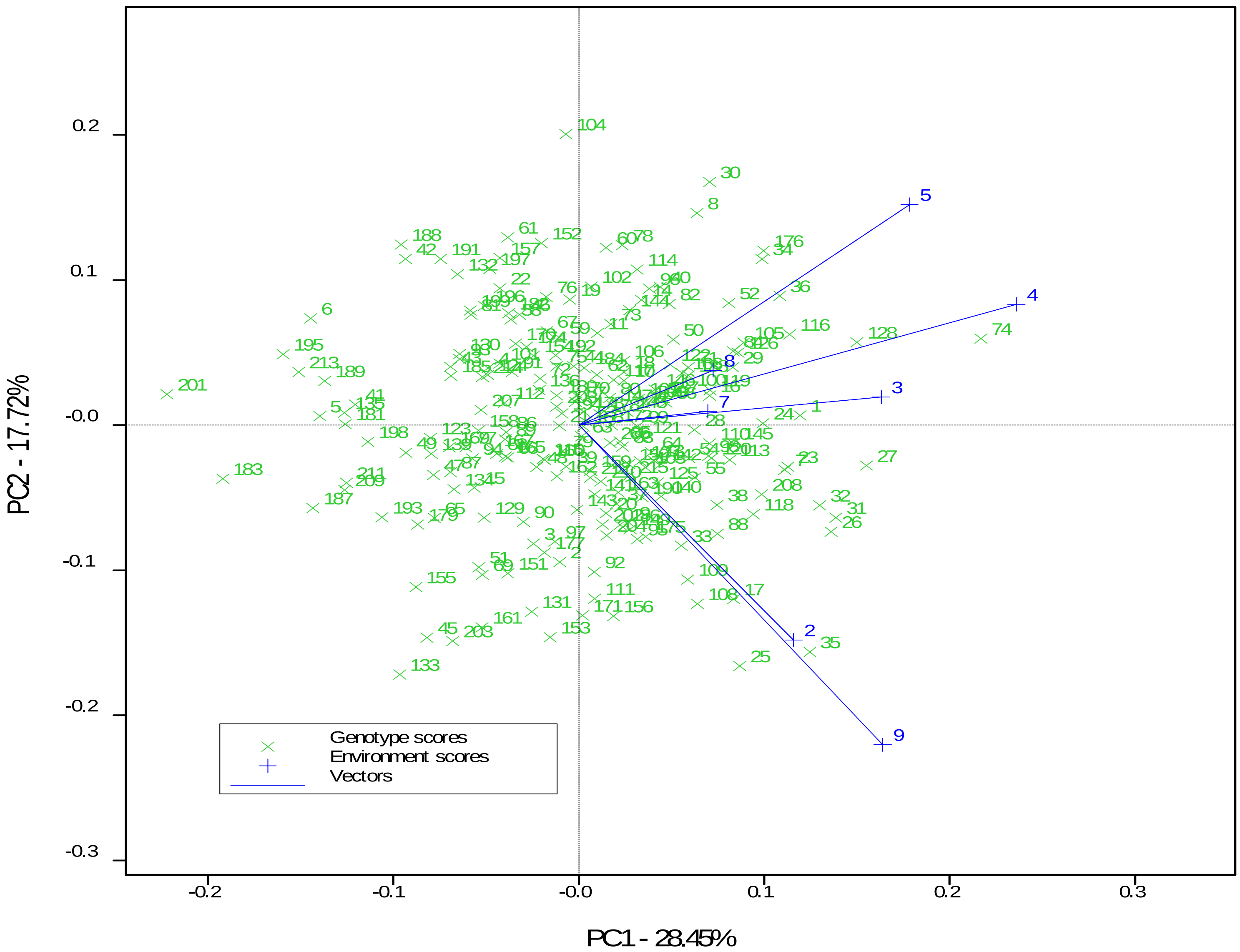

Figure 4.4: Relationship among test environments

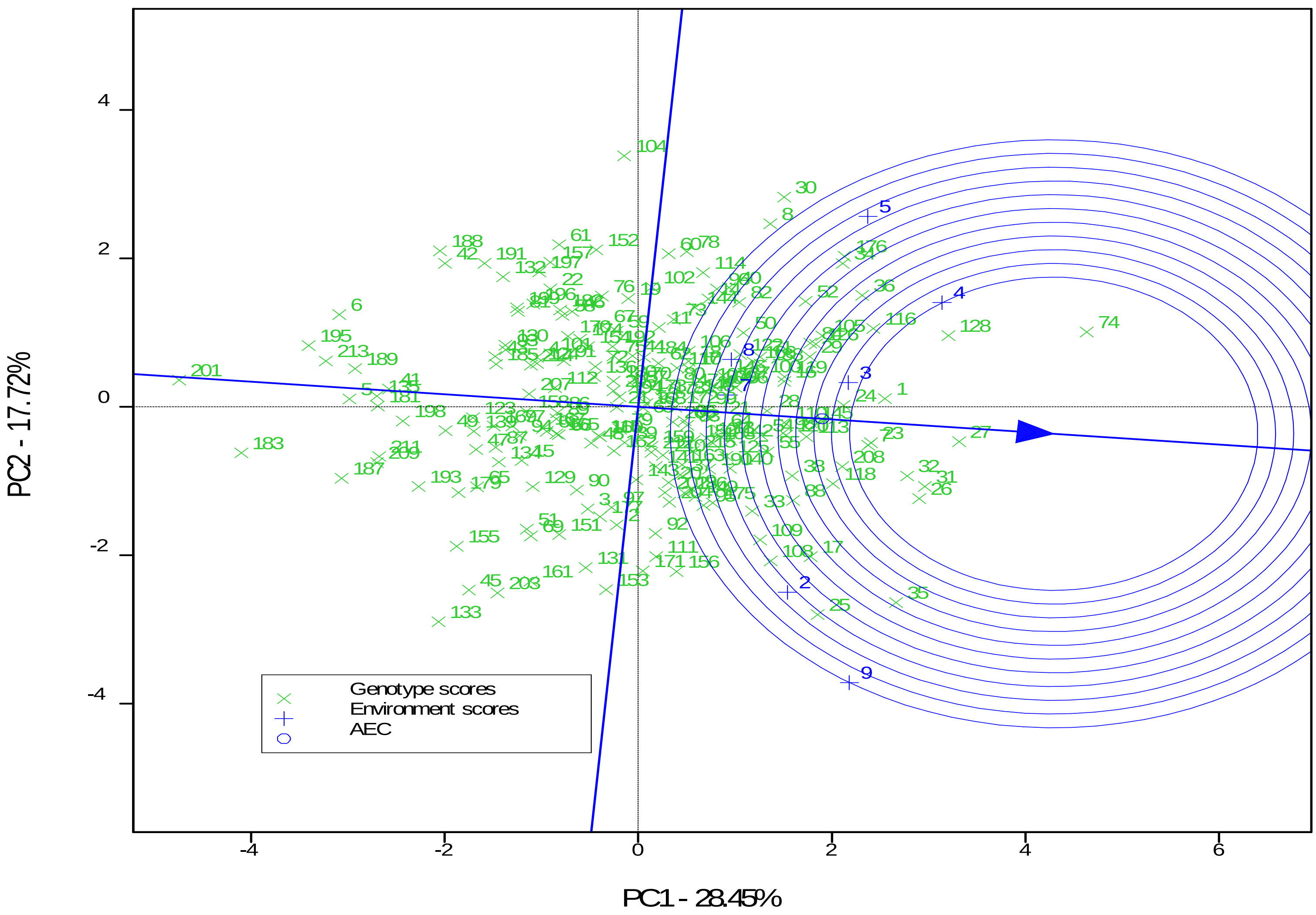

Figure 4.5: Environment ranking relative to the mean environment

Relationships between genotypes.

The GGE biplot in Figure 4.6 presents a ranking of genotypes relative to the average environment. The average environment coordination line passes through the biplot origin and the average environment, represented by the small circle on the AEC abscisa arrowhead (Yan and Tinker, 2006). Genotypes were ranked on the line, with those having above average performance on the right hand side of the origin. Genotype 74 had the highest mean yield, followed by 27, 128, 32, 31, 26 and others respectively. Genotypes 201, 183 and 195 had the least mean yields in the experiment. The most ideal genotype was expected to have a high yield and be stable across different environments.

Figure 4.7 presents a biplot of genotypes compared relative to the most ideal and stable genotype, represented by the centre of the concentric rings. Genotypes 27 and 74 were the closest to the centre of the concentric rings in the biplot diagram. This showed that they were the most ideal genotypes in the experiment. They were closely followed by genotypes 26, 31, 32, 128, 23 and 1. Their performance across environments was above average and without much variation. Genotype 27 was the second best in mean yield, but had a higher stability over genotype 74. It was therefore the most ideal genotype in the experiment.

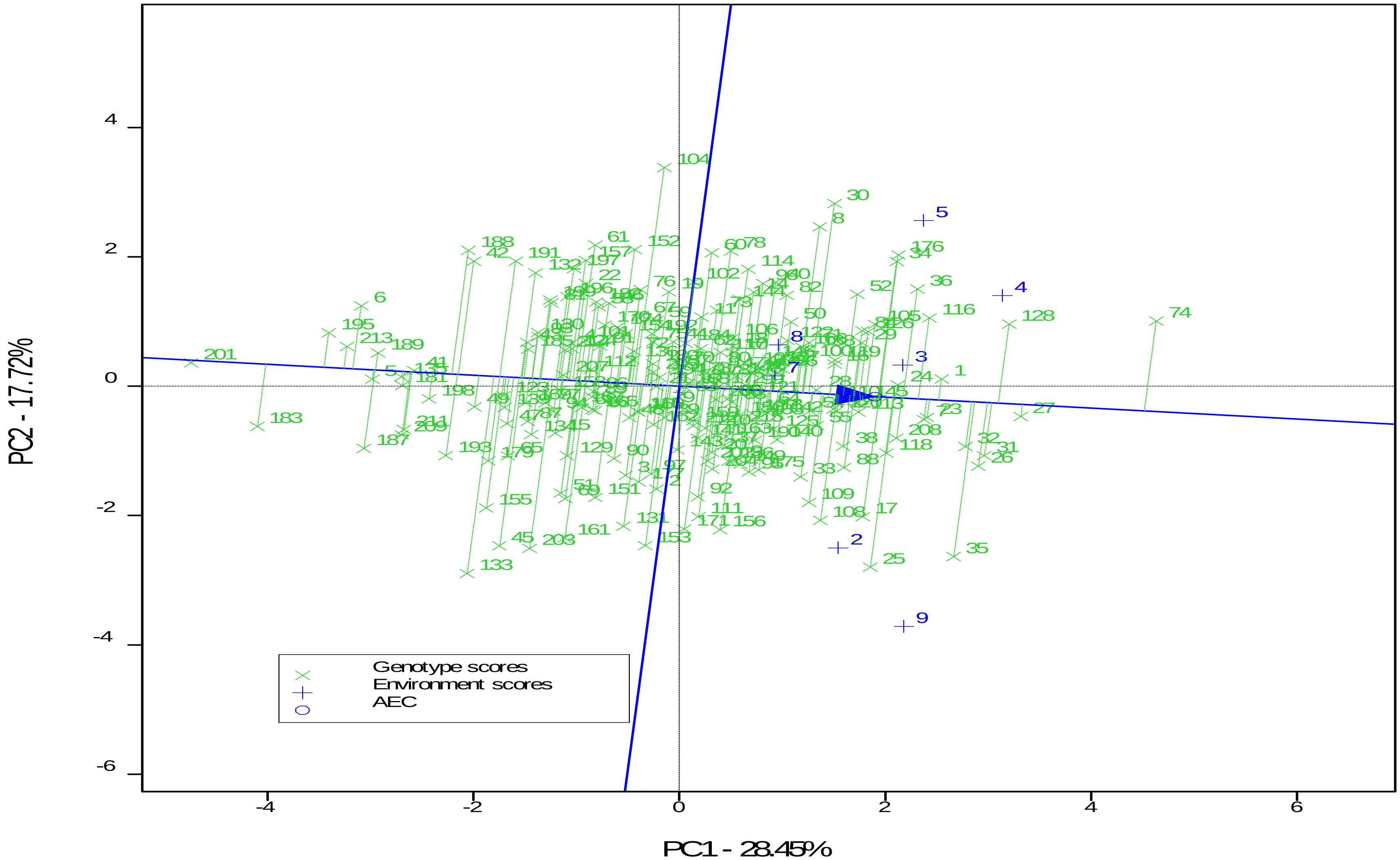

Figure 4.6: Ranking of genotypes based on average environment

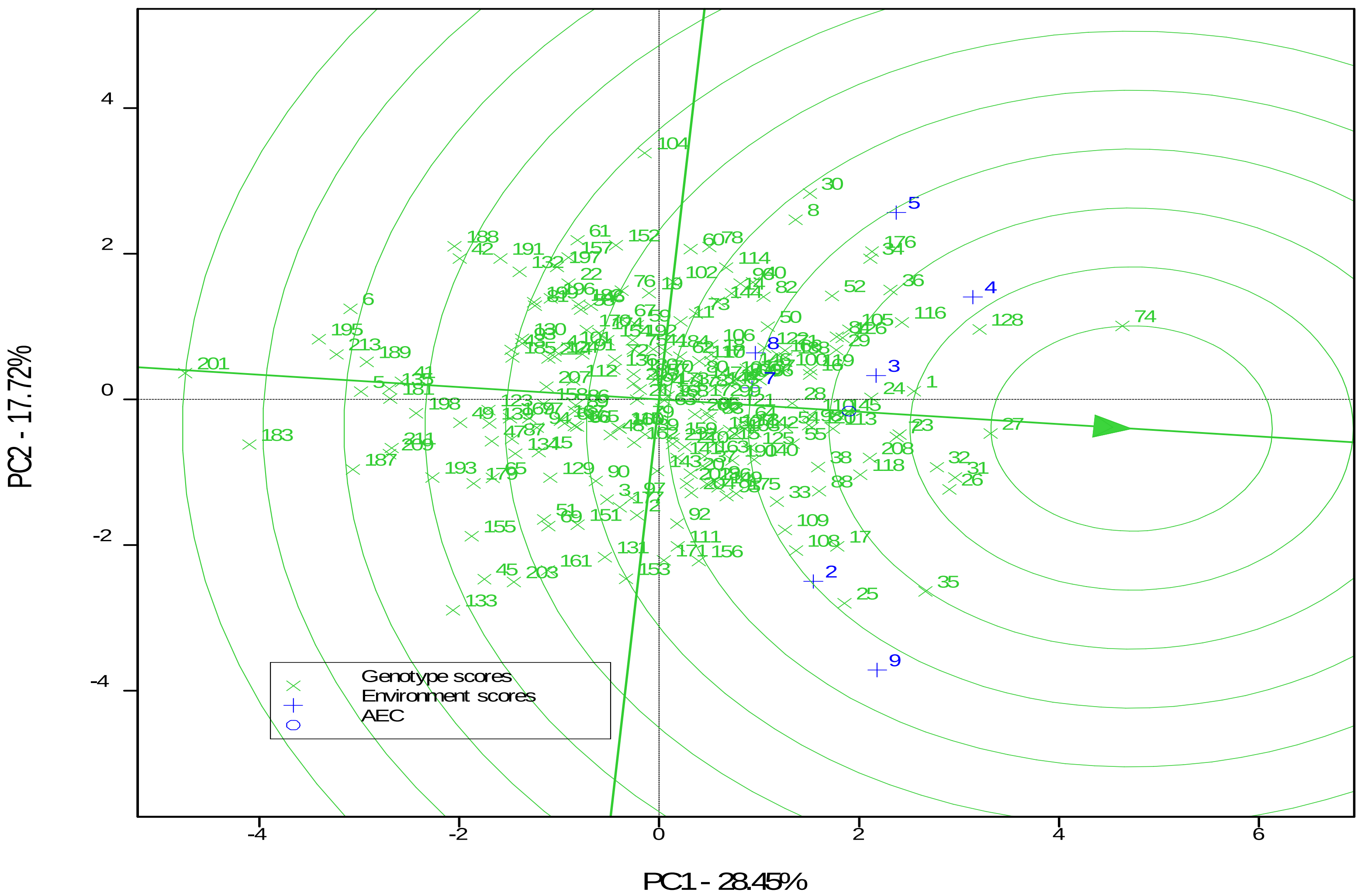

Figure 4.7: The average environment coordination to rank genotypes by both mean and stability

Which won where

The GGE bilpot Figure 4.8 presents results to show the best entries. The polygon was formed by genotype markers, 201, 104, 30, 74, 35, 25, 133 and 183. Eight sectors were formed by drawing lines from the biplot origin and perpendicular to the edges of the polygon (Yan and Tinker, 2006). The polygon enclosed all the genotypes, and contained all the environments in two sectors. This suggested that the environments could be grouped into 2 mega environments. In the first group of environments (environment 2 and 9), genotypes 35 was the best performer followed by 25, in that order. Genotype 74 emerged the best in all the other environments (3, 4, 5, 7 and 8). These two genotypes showed potential adaptability in their respective environments, as shown in the polygon.

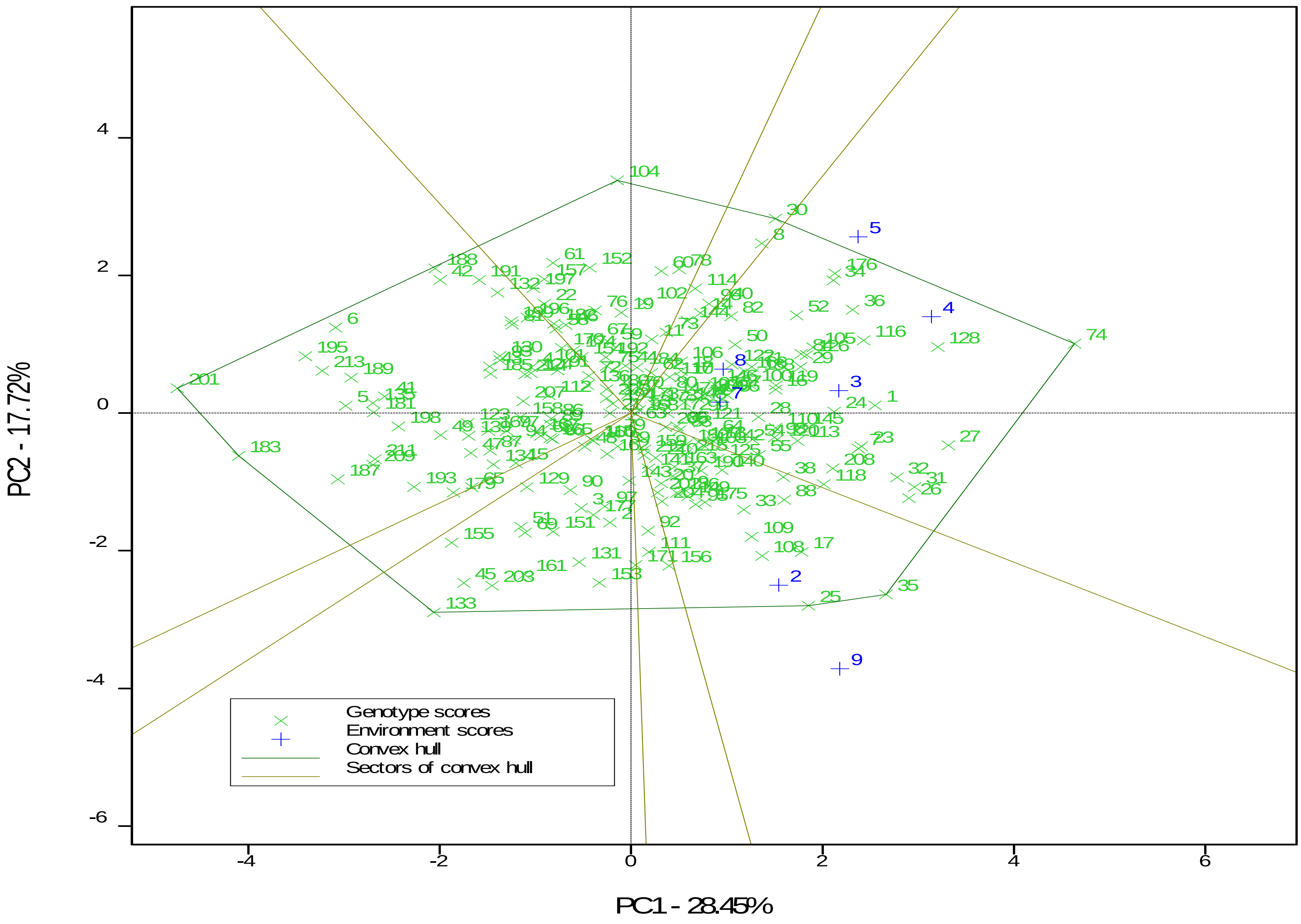

Figure 4.8: Which won where view showing which genotypes win in which environments

4.3.2 Performance of Regional Trial Hybrids

4.3.2.1 Analysis of variance across environments

The across sites analysis of variance revealed highly significant differences among enviornments for all traits (Table 4.3) indicating that the environments used in the experiment were varied and are important for conducting multi-environmental trials. Genotypes and interaction terms were all different ($P<0.001$) for all traits (Table 4.3), suggesting that the genotypes were genetically variable and performed variably in the different environments. Therefore stability analysis was carried out.

4.3.2.2 Performance of the regional trials hybrids across environments

The average grain yield across all the 17 environments was 3.8 tons/ha , and ranged from 2.3 to 4.6 tons/ha (Table 4.4). The mean of the best 15 hybrids across all the environments was 11% better than the overall mean. Checks WH 403 appeared among the best 15 hybrids across all test environments. However, the mean of WH403 was statistically similar to that of the best six hybrids, individually compared. Among the last 15 entries, were checks H513, H516 and H520, which also showed no statistical difference among themselves.

Table 4.3: Analysis of variance for grain yield and other agronomic traits across 17 environments

	DF	GY	EA	DF	PH	EH	DF	ET
ENV	16	485.4***	17.0***	13	122955.7***	47080.1***	14	41.0***
REP(ENV)	17	13.5***	1.3***	14	3745.7***	2572.1***	15	0.2
ENTRY	50	9.6***	1.4***	51	1402.5***	1029.4***	51	1.2***
ENV*ENTRY	800	1.4***	0.4***	663	289.9***	173.1***	714	0.3***
Error	850	1.0	0.3	714	210.1	129.2	765	0.2

DF = degrees of freedom, GY = Grain yield, EA = Ear aspect, PH = Plant height, EH = Ear height, ET = Northern leaf blight.

Table 4.4: Means of entries across all (17) locations

ENTRY	GY	AD	PH	EH	EPP	EA	PA
1	2.7	82.4	203.3	103.3	0.8	2.8	2.9
2	2.3	80.7	194.5	98.3	0.8	3.1	3.1
3	3.6	74.9	205.7	104.8	0.9	2.4	2.7
4	3.7	76.1	212.4	106.9	0.9	2.4	2.7
5	3.0	77.6	205.9	97.4	0.9	2.7	2.5
6	3.7	79.2	215.2	107.3	0.9	2.5	2.8
7	4.3	76.4	218.2	113.3	0.9	2.2	2.7
8	3.6	79.0	214.5	107.1	0.9	2.6	2.7
9	3.9	75.3	210.1	104.9	0.9	2.6	2.8
10	4.0	73.4	208.1	100.1	0.9	2.4	2.8
11	3.9	75.3	212.1	107.2	0.8	2.5	2.8
12	3.1	74.8	205.0	100.9	0.8	2.7	2.8
13	4.1	76.7	215.7	109.6	0.9	2.4	2.7
14	3.6	75.9	207.7	103.0	0.9	2.5	2.7
15	3.7	74.8	213.4	109.0	0.9	2.4	2.8
16	4.2	75.8	209.7	109.8	0.9	2.6	2.7
17	3.4	75.6	211.0	111.8	0.9	2.7	3.0
18	3.7	76.7	213.6	113.4	0.9	2.6	2.9
19	4.1	77.9	223.0	112.6	1.0	2.3	3.0
20	3.4	73.9	200.9	99.1	0.9	2.7	2.9
21	3.6	79.1	213.4	116.8	1.0	2.6	3.0
22	4.4	79.1	218.7	113.2	0.9	2.3	2.9
23	4.1	79.6	215.5	114.4	1.0	2.4	2.8
24	3.8	75.9	205.6	105.4	0.9	2.6	2.7
25	3.9	75.9	207.1	100.8	0.9	2.4	2.8
26	3.4	80.0	208.3	108.8	0.8	2.7	2.8
27	3.8	77.5	210.4	110.5	0.9	2.5	2.8
28	4.0	77.3	217.3	112.0	0.9	2.4	2.8
29	4.6	77.0	213.5	107.4	0.9	2.2	2.8
30	4.1	78.0	215.8	114.0	0.9	2.3	2.7
31	4.5	78.9	218.7	115.6	0.9	2.1	2.7
32	3.8	76.1	213.5	109.5	1.0	2.5	2.8
33	4.4	76.7	223.4	115.9	0.9	2.7	3.1
34	3.9	73.1	199.9	97.2	0.9	2.5	2.6
35	3.8	78.1	220.6	114.8	0.9	2.5	3.1
36	3.8	76.9	221.0	114.3	0.9	2.6	3.0
37	3.2	74.8	210.2	103.4	0.9	2.7	2.8
38	3.7	77.9	216.1	111.5	1.0	2.5	3.1
39	3.6	76.5	209.5	106.3	0.9	2.6	2.9
40	3.6	75.6	210.8	102.0	0.9	2.7	2.8
41	3.6	77.1	205.3	100.2	0.8	2.8	2.8
42	4.5	74.8	214.7	107.7	1.0	2.4	2.7
43	3.7	76.7	217.4	113.5	0.9	2.7	2.8
44	3.8	75.5	193.1	99.0	0.9	2.6	2.6
45	3.6	79.9	222.2	111.8	1.0	2.7	2.8
46	3.4	74.8	202.8	100.4	0.9	2.7	2.7
47	4.3	75.2	221.7	113.0	0.9	2.3	2.5
48	4.0	77.9	220.1	110.8	0.9	2.5	2.8
49	3.3	74.9	210.6	105.3	0.9	2.7	2.9
50	3.5	75.6	218.3	119.8	0.9	2.6	3.1
51	3.5	78.6	224.8	122.2	0.9	2.6	3.0
Checks mean	**3.7**	**76.4**	**218.1**	**112.4**	**0.9**	**2.5**	**2.8**
Trial MEAN	**3.7**	**76.8**	**212.2**	**108.1**	**0.9**	**2.5**	**2.8**
MAX	**4.6**	**82.4**	**224.8**	**122.2**	**1.0**	**3.1**	**3.1**
MIN	**2.3**	**73.1**	**193.1**	**97.2**	**0.8**	**2.1**	**2.5**
CV	**27.3**	**2.3**	**6.8**	**10.5**	**18.0**	**20.2**	**14.9**
LSD	**0.4**	**2.0**	**7.6**	**6.0**	**0.1**	**2.0**	**0.2**

GY = Grain yield, AD = Days to anthesis, PH = Plant height, EH = Ear height, EPO = Ear position, ET = Northern leaf blight, , EA = Ear aspect, PA = Plant aspect

4.3.3 Stability analysis of regional trial hybrids

4.3.3.1 Wricke ecovalence measure *Wi* (Wricke 1962) and Stability variance measure (Shukla 1972a)

Results for two different stability methods (ecovalence and stability variance) for the 51 entries, ranked by yield are presented in Table 4.5. Stability analysis using these two measures revealed same ranking of genotypes by these criteria. This was in agreement with a previous study by wricke and Weber (1980) where they found similar ranking of genotypes from these two measures of stability. Genotypes that had low values are considered stable in this method of stability analysis. Ecovalence measure values were expressed in percentage.

Entries 31, 33, 45, 29 and check entry 51 displayed high levels of stability across environments by both of these methods. Entries 31, 33 and 29 ranked 1st, 2nd and 3rd respectively on yield basis. This indicated that they were promising genotypes for production across these environments. Two out of the six checks used appeared among the top 10 most stable entries, across all test locations. Hybrid H520 was the most stable check in the trial, followed by WH505. Hybrid 520 was releases in the year 2010 in Kenya while WH505 was released in 2005. Both hybrids are popular with farmers in western Kenya.

Table 4.5: Wricke's ecovalence and Shukla's Stability variance measure for the 25 best entries, ranked by grain yield

Entry	Yield	Yield rank	*Wi*	*Wi (%)*	Shukla	Stability rank
29	4.5	1	61.6	2.9	4.0	49
42	4.4	2	58.6	2.7	3.8	48
16	4.4	3	46.5	2.2	3.0	34
31	4.3	4	93.8	4.4	6.0	51
22	4.3	5	55.1	2.6	3.5	44
33	4.3	6	68.4	3.2	4.4	50
47	4.2	7	32.2	1.5	2.0	13
23	4.2	8	48.8	2.3	3.1	40
7	4.1	9	30.9	1.4	2.0	10
19	4.1	10	47.3	2.2	3.0	37
9	4.1	11	33.9	1.6	2.2	14
30	4.1	12	46.1	2.2	2.9	33
11	4.0	13	57.8	2.7	3.7	47
28	4.0	14	51.0	2.4	3.3	42
48	4.0	15	43.8	2.1	2.8	30
10	4.0	16	31.6	1.5	2.0	12
34	3.9	17	37.4	1.8	2.4	21
24	3.9	18	41.0	1.9	2.6	25
25	3.9	19	35.2	1.6	2.2	18
36	3.8	20	56.8	2.7	3.6	46
13	3.8	21	43.0	2.0	2.7	28
14	3.8	22	23.0	1.1	1.4	3
38	3.8	23	41.7	2.0	2.7	26
27	3.8	24	30.2	1.4	1.9	9
21	3.7	25	42.3	2.0	2.7	27
35	3.7	26	43.9	2.1	2.8	31
4	3.7	27	47.8	2.2	3.1	38
44	3.7	28	22.6	1.1	1.4	2
41	3.7	29	43.5	2.0	2.8	29
32	3.7	30	51.6	2.4	3.3	43
6	3.7	31	29.4	1.4	1.9	8
8	3.7	32	39.1	1.8	2.5	22
15	3.7	33	35.5	1.7	2.3	19
43	3.7	34	44.2	2.1	2.8	32
40	3.6	35	48.7	2.3	3.1	39
18	3.6	36	24.1	1.1	1.5	4
39	3.6	37	49.2	2.3	3.1	41
46	3.6	38	46.9	2.2	3.0	35
17	3.6	39	25.8	1.2	1.6	7
3	3.6	40	47.3	2.2	3.0	36
45	3.5	41	55.1	2.6	3.5	45
51	3.5	42	37.0	1.7	2.4	20
20	3.5	43	24.7	1.2	1.6	5
50	3.4	44	31.1	1.5	2.0	11
49	3.4	45	25.6	1.2	1.6	6
26	3.3	46	34.4	1.6	2.2	15
37	3.3	47	35.1	1.6	2.2	17
12	3.2	48	39.1	1.8	2.5	23
5	3.1	49	39.8	1.9	2.5	24
1	2.9	50	20.1	0.9	1.3	1
2	2.5	51	34.9	1.6	2.2	16

4.3.3.2 Eberhart and Russell (1966) method

Eberhart and Russell (1966) proposed regression of genotype means against the environmental index. They described a stable variety as one with a regression coefficient, b = 1 and minimum deviation from the regression, $s^2d = 0$. The scatter plot presented in Figure 4.9 shows the regression ***b*** plotted against mean yield for the 51 entries across all the test environments. Out of the 51 entries included in the trial, 24 had above average performance. Entries 16, 22, 23, 29, 31 and 42 showed the best above average performance across all environments, with entry 29 being the best yielder. Only WH403 among the checks yielded above average across all locations. Entries 29 and 23 had a slope close to 1. The deviation from regression showed that entry 42 had the highest variation across environments. Entry 22 had the least deviation from regression among the best 10 entries. Entries 23 and 16 also showed low deviation from regression (Table 4.6).

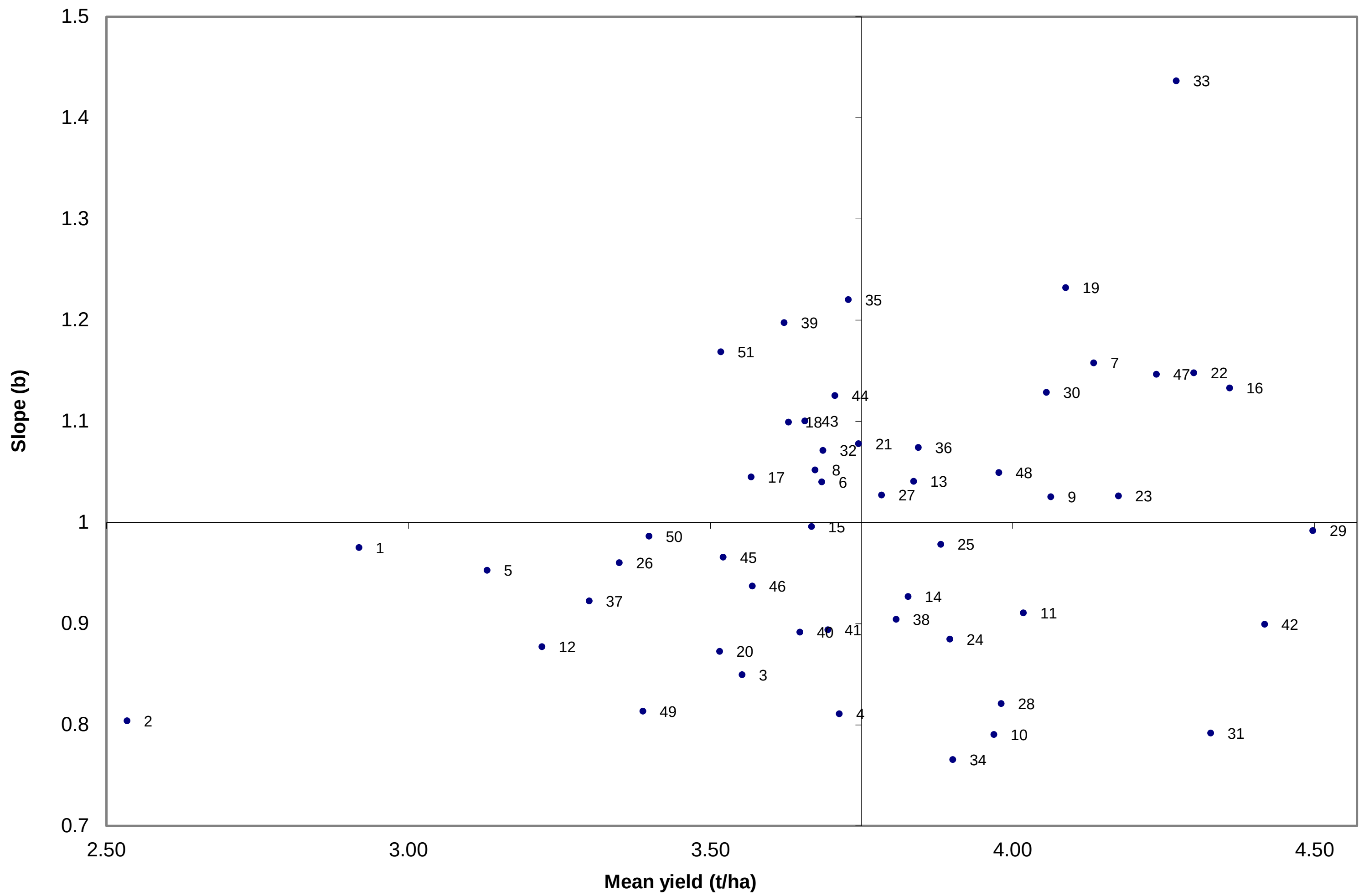

Figure 4.9: Relationship of regression and mean grain yield (Eberhart and Rusell, 1966) for 51 maize varieties across 17 locations

4.3.3.3 Finlay and Wilkinson (1963) Model

Figure 4.10 presents a scatter of mean yield plotted against regression coefficients. Entry 29 was the best yielder and showed above average stability. Other entries that showed above average yield and stability were entries 42, 31, 7 and 10 among others. Hybrid WH505 was the only check that had above average performance across environments, and also had above average stability and ranked 15th in yield across environments. Checks H513, H516 showed above average stability but yielded below average, across environments. Check WH403 yielded well above average but had a below average stability. On the contrary, check variety H520 showed below average performance for both yield and stability. This showed that the new hybrids in this trial constituted materials that had better performance than the commercial hybrids.

Table 4.6: The best 25 entries; Eberhart and Russel (1966); Finlay and Wilkinson (1963) stability parameters for regional hybrid trials data

		Eberhart and Russel		Finlay and Wilkinson	
Entry	Yield	Slope	DEV REG	Slope	Yield rank
29	4.50	0.99	0.57	0.87	1
42	4.42	0.90	0.66	0.97	2
16	4.36	1.13	0.49	1.26	3
31	4.33	0.79	0.54	0.72	4
22	4.30	1.15	0.39	1.2	5
33	4.27	1.44	0.43	1.15	6
47	4.24	1.15	0.44	1.19	7
23	4.18	1.03	0.44	1.15	8
7	4.13	1.16	0.37	0.98	9
19	4.09	1.23	0.50	1.15	10
9	4.06	1.03	0.40	1.07	11
30	4.06	1.13	0.37	1.06	12
11	4.02	0.91	0.59	1.04	13
28	3.98	0.82	0.42	0.9	14
48	3.98	1.05	0.45	0.98	15
10	3.97	0.79	0.41	0.85	16
34	3.90	0.77	0.32	0.91	17
24	3.90	0.88	0.29	0.99	18
25	3.88	0.98	0.41	1	19
36	3.84	1.07	0.39	1.12	20
13	3.84	1.04	0.37	0.97	21
14	3.83	0.93	0.30	0.96	22
38	3.81	0.90	0.46	0.99	23
27	3.78	1.03	0.39	0.99	24
21	3.75	1.08	0.32	1.09	25
35	3.73	1.22	0.46	1.09	26
4	3.71	0.81	0.45	0.82	27
44	3.71	1.13	0.34	0.96	28
41	3.69	0.89	0.55	0.9	29
32	3.69	1.07	0.39	0.95	30
6	3.68	1.04	0.35	1.05	31
8	3.67	1.05	0.40	1.05	32
15	3.67	1.00	0.36	0.96	33
43	3.66	1.10	0.43	1	34
40	3.65	0.89	0.43	0.98	35
18	3.63	1.10	0.32	1.06	36
39	3.62	1.20	0.44	1.09	37
46	3.57	0.94	0.46	1.09	38
17	3.57	1.04	0.35	1.02	39
3	3.55	0.85	0.41	0.91	40
45	3.52	0.97	0.55	0.94	41
51	3.52	1.17	0.45	1.05	42
20	3.52	0.87	0.33	0.91	43
50	3.40	0.99	0.42	0.92	44
49	3.39	0.81	0.33	0.89	45
26	3.35	0.96	0.43	0.98	46
37	3.30	0.92	0.47	1	47
12	3.22	0.88	0.43	0.9	48
5	3.13	0.95	0.31	1.05	49
1	2.92	0.98	0.29	1.06	50
2	2.53	0.80	0.39	0.89	51

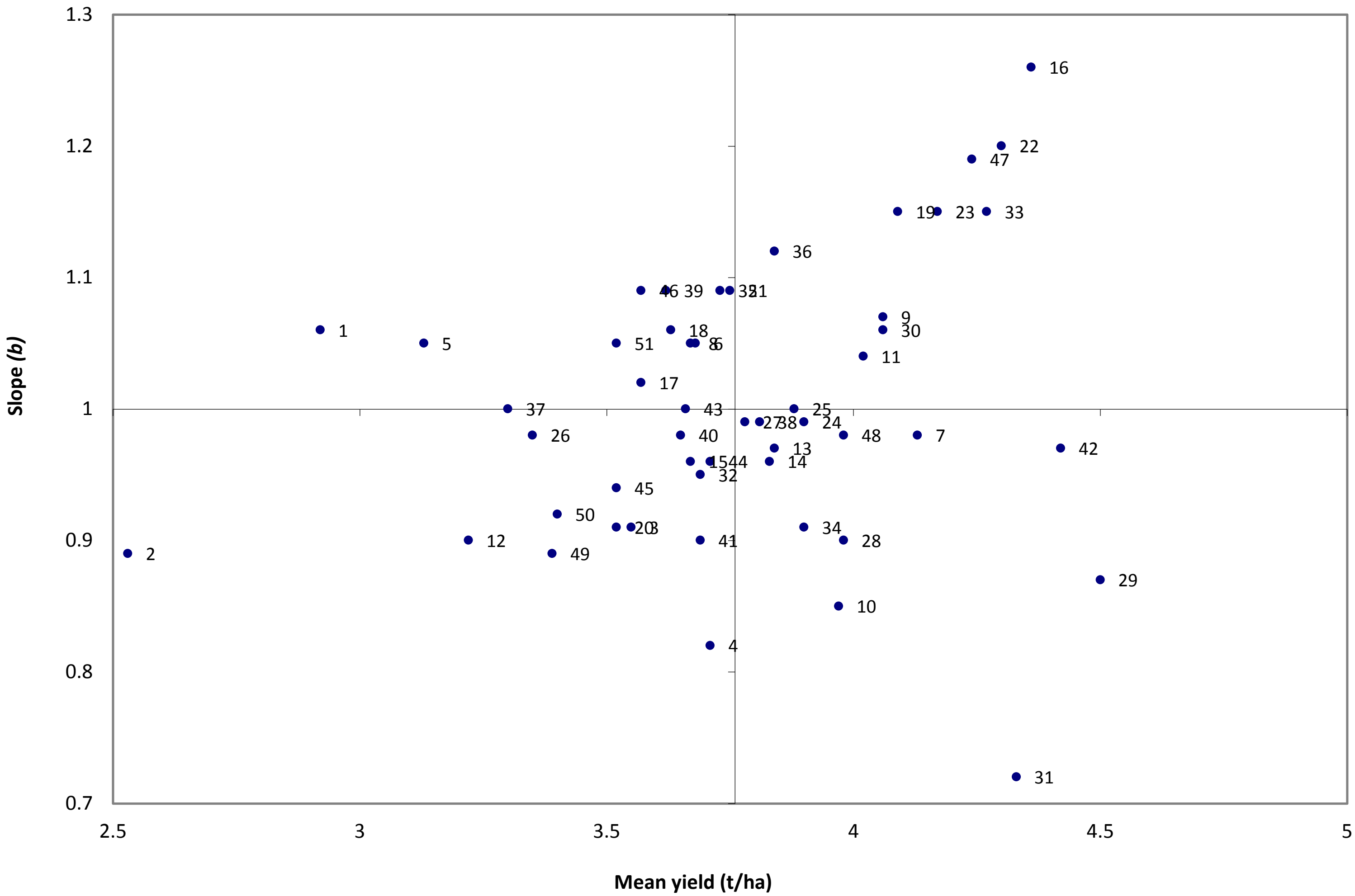

Figure 4.10: Relationship between mean grain yield and regression coefficient of 51 maize hybrids in 17 locations

4.3.3.4 Coefficient of variation (Francis and Kannenberg, 1978)

Francis and Kannenberg (1978) proposed a method of testing stability whereby genotypes were grouped on the basis of their mean yields and coefficient of variation across environments. Figure 4.11 is a scatter plot of mean grain yield plotted against CV for across environment means. This scatter plot grouped genotypes into four, based on their mean grain yield and coefficient of variation.

Entries 31, 29 and 42 showed the best yields and also had lowest coefficients of variation values. These three hybrids showed the most stability compared to the other entries. Entries 10, 34, 28 25 and 24 also appeared in the same quadrant – they had above average mean grain yield and low coefficient of variation across sites indicating stability of performance. Checks 47 and 48 (WH403 and WH505 respectively) had above average mean yields and below average CV. This showed that they were the most stable among the checks. Entries 1 and 2 showed the highest coefficients of variation and the lowest mean yields at the same time. This suggested that they were the most unstable entries across environments.

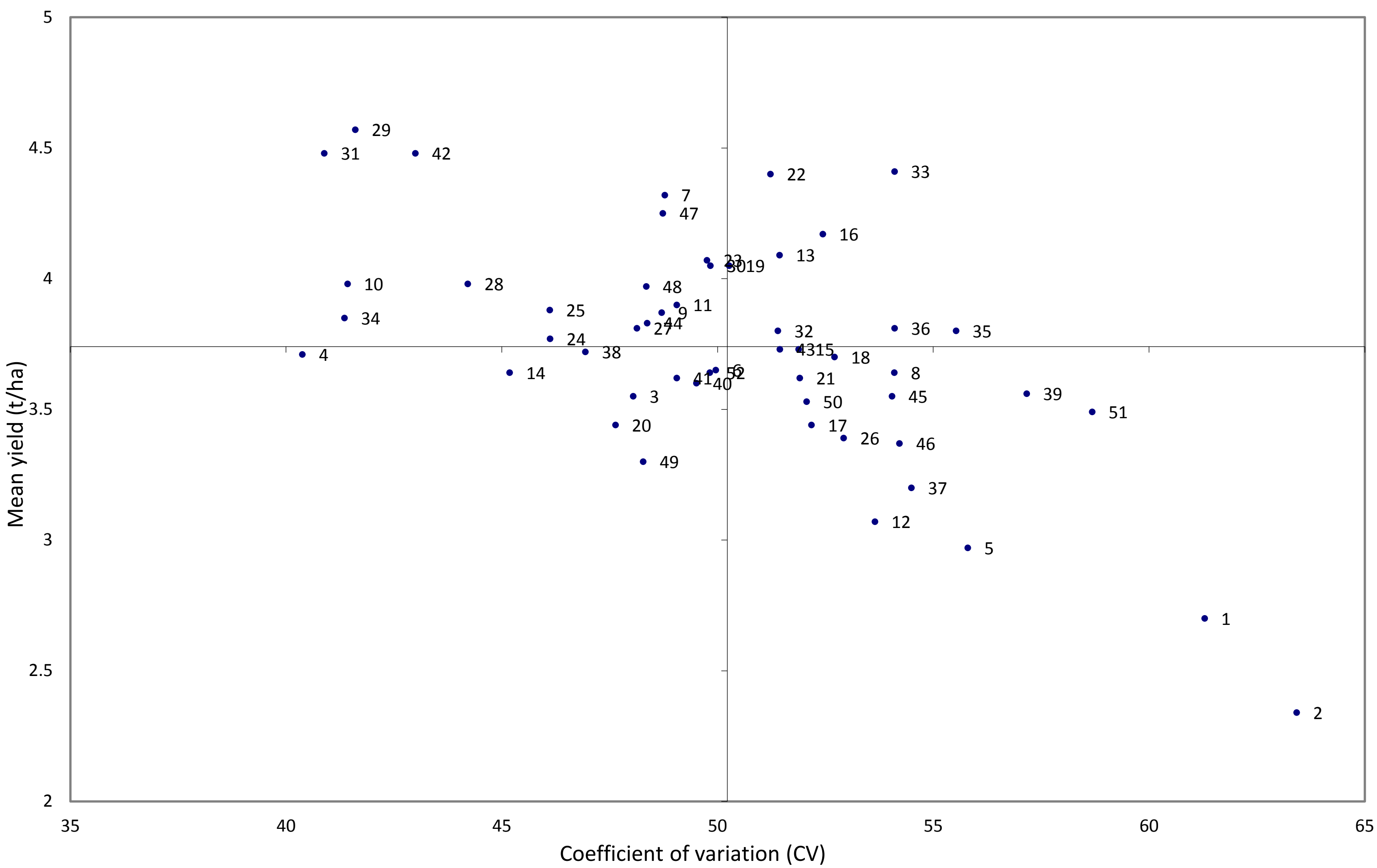

Figure 4.11: Scatter plot of mean grain yield against coefficient of variation from data of 51 hybrids grown in 17 locations

4.3.3.5 GGE Biplot analysis

Relationships among environments

Results of GGE biplot analysis showed that the first two principal components (PC1 and PC2) explained 49.5% of the genotype main effects and genotype by environment interaction (Figure 4.12). All environments had positive PC1 score sign, with environment 4 being the most discriminating, followed by 38 and 34. This was shown by the length of their environmental vectors, which were the longest relative to other environments. In contrast, environments 2, 9, 20 and 31 were the least discriminating (least informative), as shown by their short environment vectors. Acute angles between most environments indicated that they were closely related environments. These close associations among the test environments suggested that similar information could be generated from testing the genotypes in fewer environments.

Biplot analysis was used to show the ranking of the environments. Results showed that environment 38 was closest to the ideal and most representative environment (Figure 4.13). The next best environments were environments 21, 34, 24, 3, 25 and 11. These environments were the most ideal environments in this study because they were able to discriminate the test genotypes and at the same time, best represented all the other environments. Environment 4 was highly discriminative, but was least representative of the other environments. Selection under ideal environments would result in cultivars that would perform well above average across environments stand a better chance of being selected. However, it is recommended that selection be done under both low and high potential areas (Bänziger *et al.*, 2006). This way, a breeder would select for traits that would increase yields under both conditions.

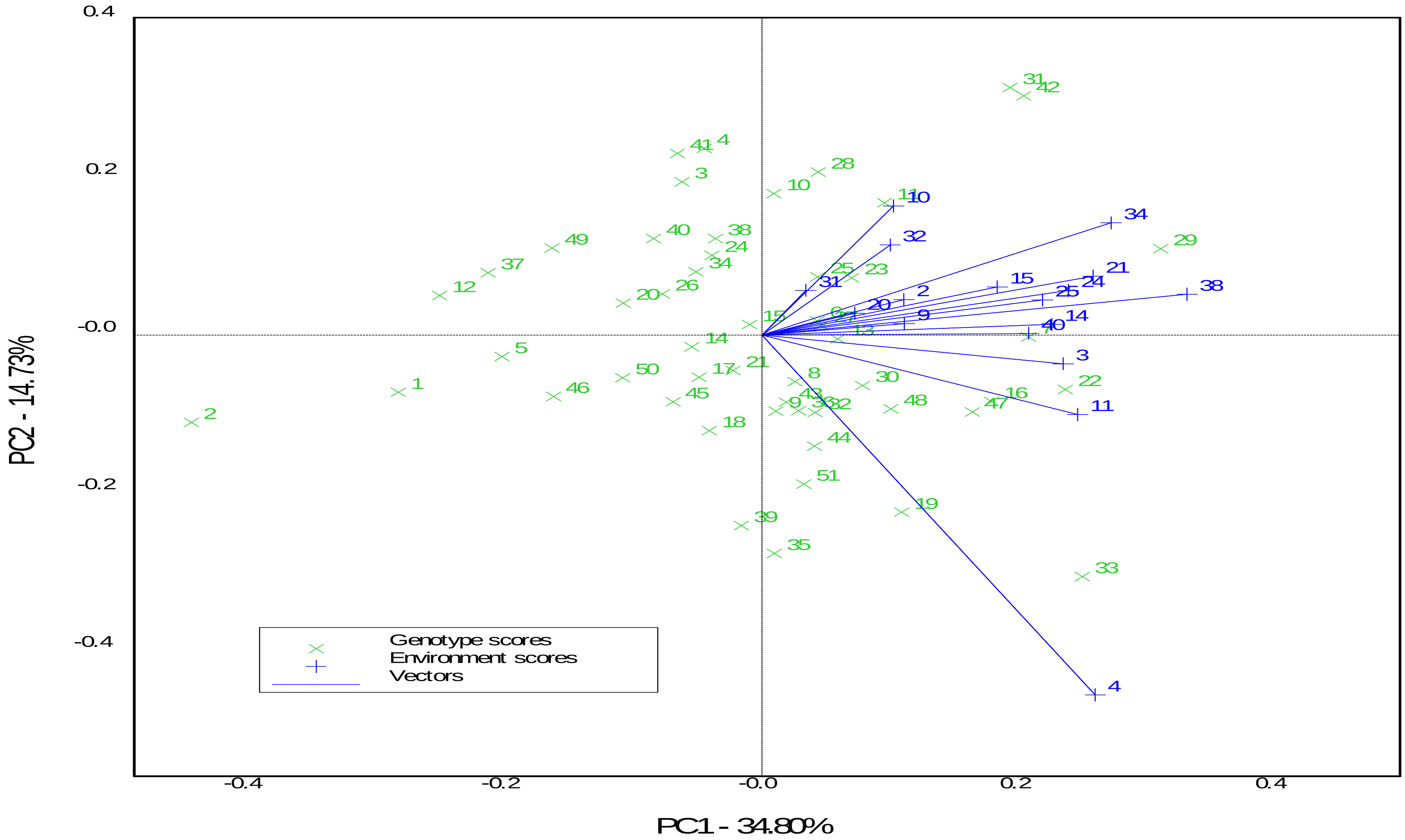

Figure 4.12: GGE biplot showing relationships among 17 locations used to evaluate 51 hybrids

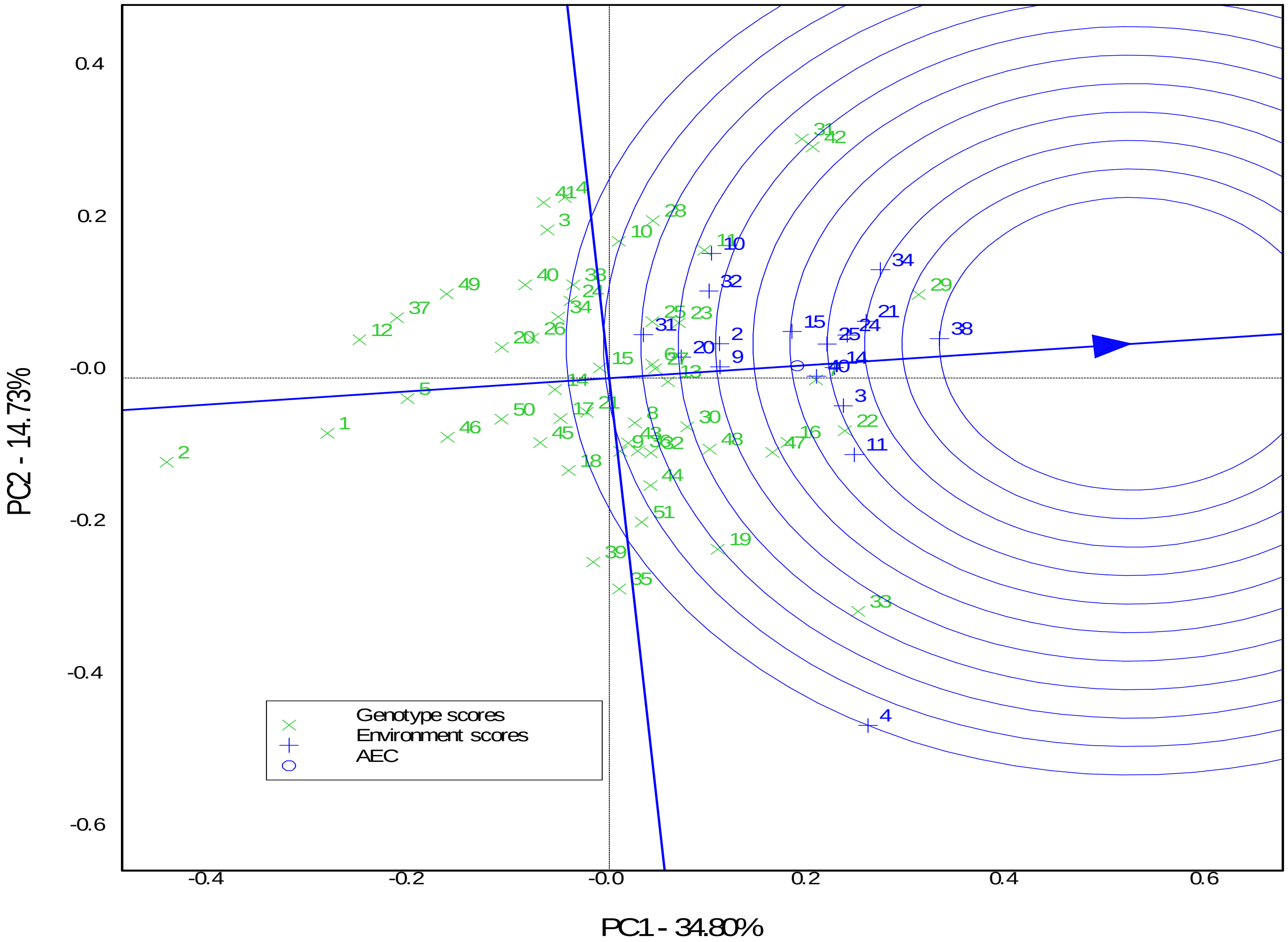

Figure 4.13: Biplot showing ranking of environments relative to the mean environment

Relationship among genotypes

The GGE biplot presented in Figure 4.14 shows the relative mean performance of the 51 genotypes. The average environment coordination line (AEC) passes through the biplot origin and the average environment, which is the small circle at the tip of the arrow on the AEC abscissa. Genotypes are ranked on the AEC axis expressing the genotypes main effects. Ideal genotypes were defined as those that have projections towards the AEC axis (Yan *et al.*, 2001). Those furthest away in the direction of the AEC line have the highest average yield, while those closest to the ideal environment (the small circle at the tip of the arrow on the AEC line) are the most stable genotypes. Genotypes 29, 22, 42, 33 and 31 were the highest yielders across the different environments. However entries 31, 42 and 33 showed relatively high variations in yield across different environments, and could be considered less stable (Figure 4.14). On the other hand, genotypes 2, 1, 12, 37 and 5 were the least yielding across all environments. These showed better stability than the best yielding genotypes but were not good options due to their poor yields. The GGE biplot presented in Figure 4.15 shows a comparison of genotypes, relative to the point of the ideal genotype. The center of the concentric rings represents an ideal genotype which would be absolutely stable. Genotypes that appear closer to the ideal genotype would be more desirable than those that are far off. Genotypes 29, 22, 7 and 16 are the closest to the center of the concentric rings, and are therefore the most ideal genotypes among those tested. Check WH403 and WH505 were the most stable checks and closest to the ideal genotype.

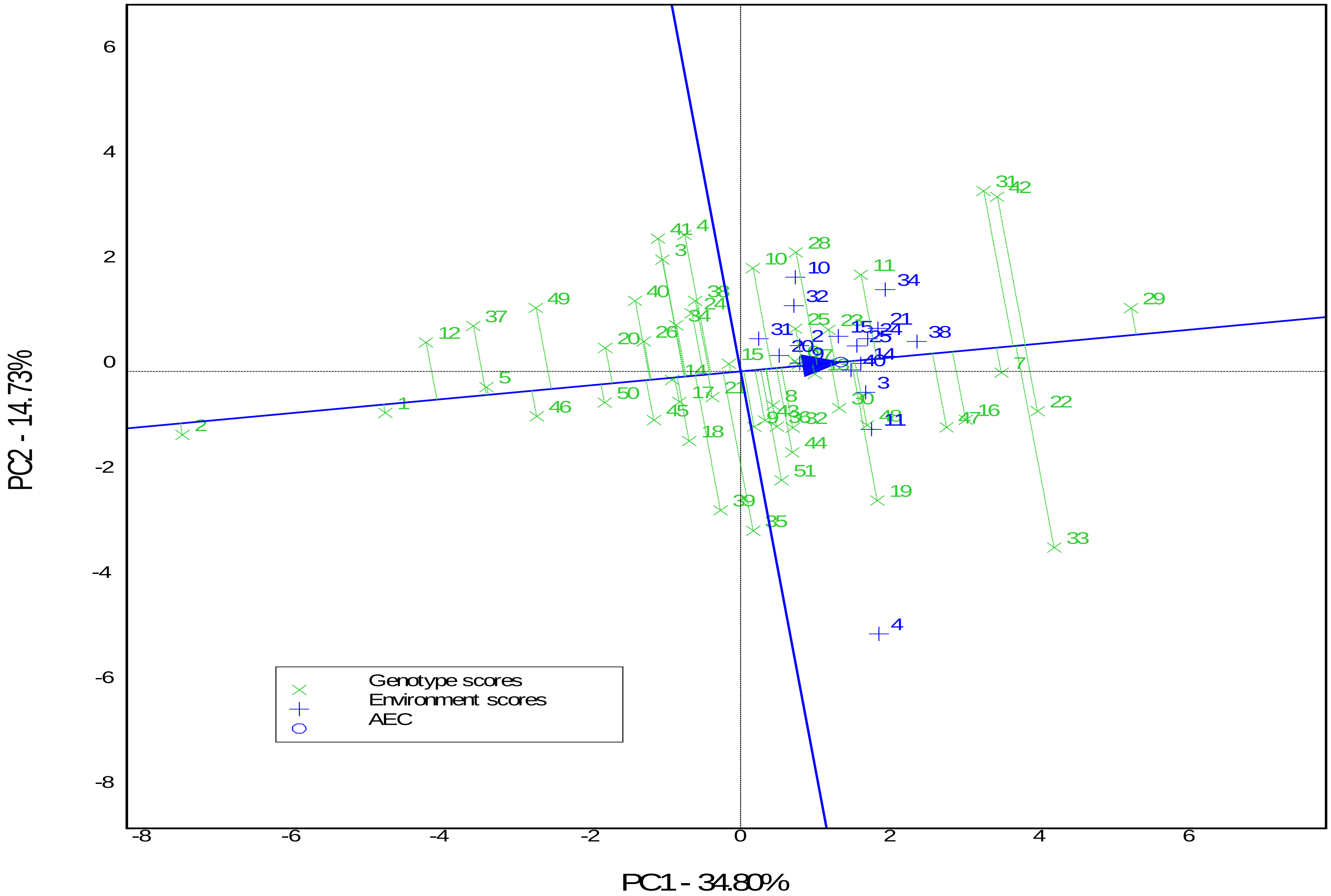

Figure 4.14: Biplot of genotypes by environmental mean (ideal environment)

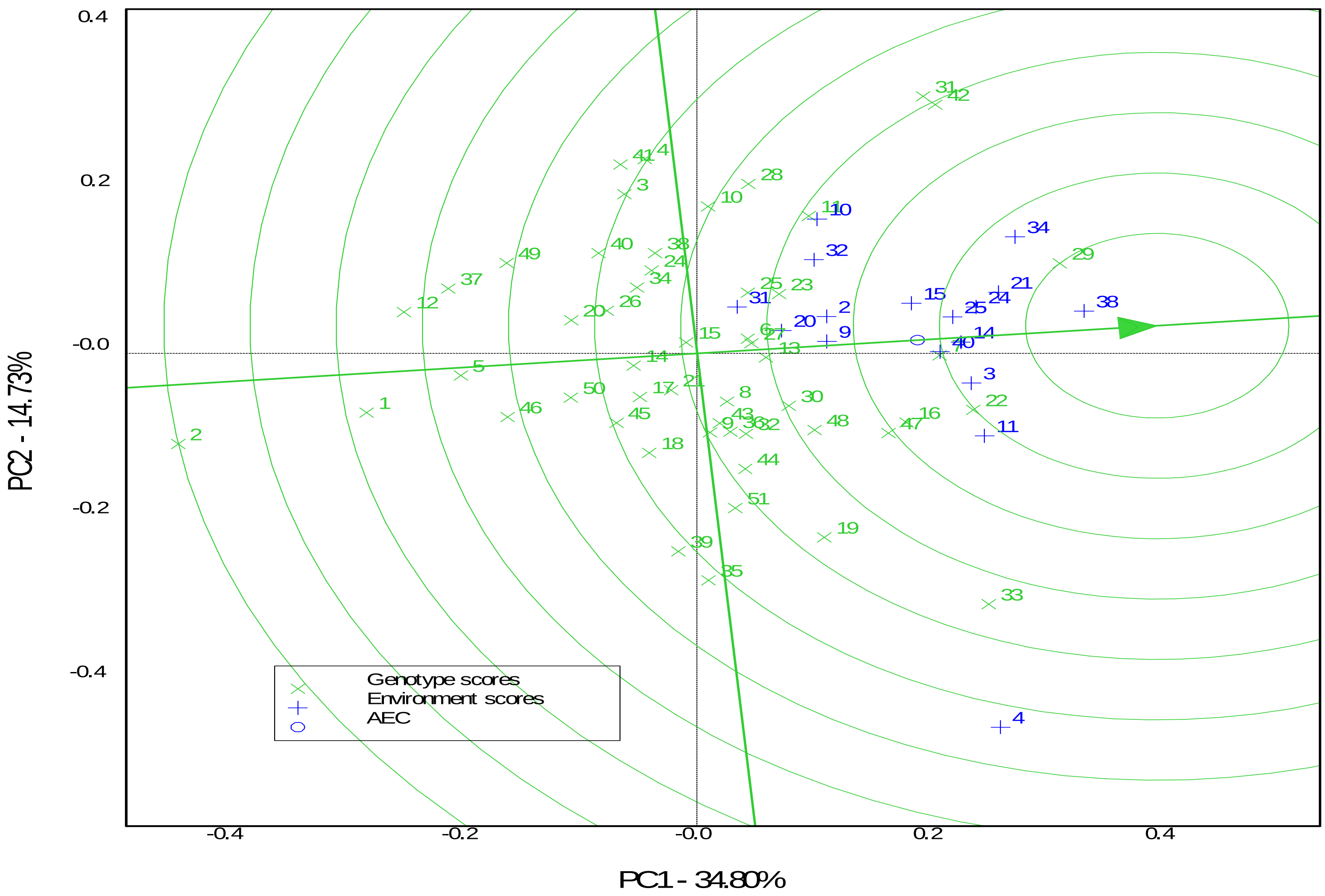

Figure 4.15: Ranking of genotypes relative to the ideal genotype.

Which-won-where

The GGE biplot figure 4.16 presents a seven sided polygon formed from genotype markers 41, 31, 42, 29, 33, 35, and 2. These genotypes are furthest away from the origin and a line joining them all encloses all the other genotypes. Six lines drawn from the biplot origin and perpendicular to the sides of the polygon divide the polygon into seven sectors, of which all environments are contained in 3 sectors. This suggested that three different mega environments can be formed from these environments, given that these patterns are repeatable over years. Genotypes 29, 42 and 33 were the first, second and third winners, respectively for most environments. Entry 42 was the best in environments 31, 32 and 10. Similarly, Entry 29 was the best for environments 20, 9, 2, 15, 25, 40, 14, 24, 21, 34 and 38. Entry 33 performed best in environments 3 11 and 4. These genotypes can be recommended for these specific locations where they performed best.

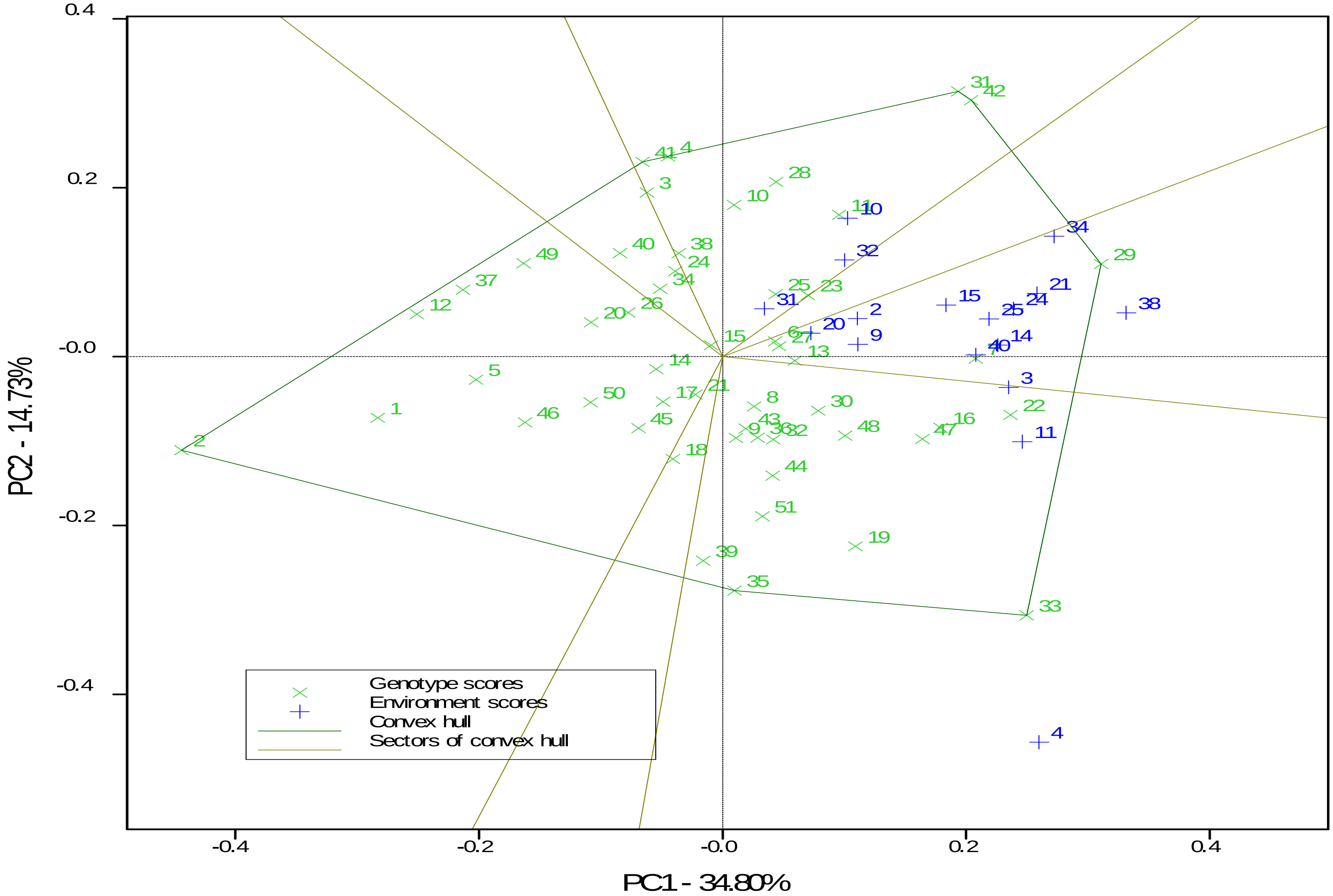

Figure 4.16: A 'which-won-where' view of 51 genotypes evaluated in 17 locations

4.3 Discussion and conclusion

Testcross hybrids

Good performing hybrids were identified among the new three way crosses and among the regional hybrid trial test genotypes. The different approaches brought out the most stable genotypes by their individual methods of calculating stability. Entry 74 appeared among the most stable hybrids when calculation was done using all criteria but ecovalence measure (Wricke, 1964) and stability variance measure (Shukla, 1972). Estimation of stability using Finlay and Wilkinson, (1963) and Eberhart and Rusell, (1966) regression of genotypes methods revealed some similarities on classification of genotypes. Entries 100, 126, 116 and 23 were found to be yielding above average and consistently across different environments.

Regional trial hybrids

Similar trends were also seen on the regional hybrid trial data. Entries 29 and 31, which were the best yielders showed good performance across environments, indicating that they were the most stable entries. Entry 42 was shown to be stable by when using the methods of Finlay and Wilkinson (1963), Francis and Kannenberg (1978) and using the GGE biplot procedure (Yan, 2001).

These observations suggested that the different models do not all result in the same genotype rankings, but show common trends in genotype groupings. For instance Wricke's ecovalence and Shukla's stability variance measures revealed a positive and significant correlation score of 1.00 (Table 4.7). Similarly, Eberhart and Russell (1966) joint regression and Finlay and Wilkinson (1963) regression parameters revealed a strong positive and significant correlation (r=0.73, p<0.01). This indicates that these methods show closely similar ranking of genotypes in this set of hybrids. On the other hand, Wricke's ecovalence and Shukla's stability variance measures revealed very strong significant (r=1, p<0.01) between themselves and contrastingly negative correlation with both Finlay and Wilkinson (1963) joint regression and Francis and Kannenberg (1978) CV measure.

Using GGE biplots however provides a better tool to allow for different types of analyses, and recommendation of genotypes to specific environments, and also to recommend informative environments for use in testing of new genotypes.

Table 4.7: Correlation scores between different stability parameters

	Wricke	Shukla	CV	Eberhart and Rusell *(b)*	Eberhart and Rusell (sdev)
Shukla	1.00***				
CV	-0.18	-0.18			
Eberhart and Rusell *(b)*	0.05	0.05	0.37**		
Eberhart and Rusell (d2S)	0.63***	0.63***	-0.196	-0.02	
Finlay and Wilkinson *(b)*	-0.07	-0.07	0.36**	0.73***	-0.08

CV- coefficient of variation.

CHAPTER 5:GENERAL DISCUSIONS AND CONCLUSIONS

The present study revealed good performing hybrids in specific locations and across all locations for both the early generation hybrids and the regional trial hybrids. Specific combining abilities for the 106 early generation lines were determined from the line by tester analysis, and this information used to assign lines to their respective heterotic groups, based on the combining ability patterns. It was revealed that 55 lines belonged to heterotic group B and the remaining 51 lines were in heterotic group A. Previous workers have obtained combining ability information and lines assigned to their respective heterotic groups, on CIMMYT maize germplasm (Vasal *et al.*, 1992b; Vasal *et al.*, 1992c).

General combining abilities were calculated and good combiners identified. Line 37, used to form entry 74, was among the best yielders, showed a high, favourable and significant GCA in all sites, and across. This suggested that it was a good general combiner. Similarly, line 18 and 1 showed good yields in crosses with tester 1 and also displayed good GCA scores. In a similar study, Hede *et al*., (1999) observed that lines which showed favourable, high and significant GCA were common parents of entries that performed well in specific environments and across environments (Hede *et al.*, 1999). Similar results were also reported (Vasal *et al.*, 1992a). The preponderance of GCA over SCA scores indicated that additive gene effects were of more importance in expressions of yield and most other agronomic traits similar to the findings of (Derera *et al.*, 2008).

Differences in hybrid performance in specific sites enabled identification of promising hybrids. Entries 74 and 25 performed well in Kakamega and Kiboko optimum trials, while entries 25 and

35 performed well under well watered conditions in Kiboko, and entry 32 being the best performer in Embu well watered trial. On the other hand, analysis of performance across environments revealed good yielders across all sites. Entries 1, 35 and 74 showed consistent and good performance across all sites, with entry 74 showing the highest mean yield across environments.

An increase in grower demands for stable genotypes has necessitated more focus on GEI, to estimate phenotypic yield. Several methods of stability analysis methods have been proposed and applied by various workers (Adugna and Labushagne, 2003; Eberhart and Rusell, 1966; Purchase *et al.*, 2000; Shukla, 1972; Wricke, 1962). Various stability measures were applied on the early generation hybrids and multi environment trials conducted in 2008. This revealed hybrids that were adapted to specific environments and those that showed above average stability in performance across the different environments. The different stability analysis procedures did not show exact same ranking but common hybrids were revealed as being among the best in the different methods. Similar results have been observed by Adugna and Labuschagne in their work on linseed (Adugna and Labushagne, 2003). Similarities in ranking were revealed when stability was analysed using Eberhart and Rusell (1966) and Finlay and Wilkinson (1963) procedures. Positive correlation between the two methods of analysis indicated that they resulted in similar genotype stability ranks. Entries 74, 100, 126 116 and 23 had above average yields and stability using both procedures The coefficient of variation method (Francis and Kannenberg, 1978) also showed the same entries as being stable and desirable. However, it did not give the exact similar ranking of genotypes. The same trends were also seen in the regional hybrid trials, where entries

42, 29 and 31 showed good yield and above average stability when analysed using the three methods.

Wricke ecovalence and Shuklas stability variance method gave the exact same ranking of genotypes when they were used to analyse the data. This was in agreement with previous findings on wheat (Purchase *et al.*, 2000). Entries 31, 33, 45, 29 and 51 from the regional hybrid trial showed the least contribution to variability (instability), and still had above average yield, which was desirable. It had entries that were common among the stable ones in other stability parameters, appearing with them.

The more recent GGE biplot analysis method also had similar entries that appeared as being stable and favourable on other methods, performing well under this analysis method. Entries 27 and 74 were the most ideal genotypes in the primary data. The regional hybrid trial also showed entries that were common with other methods of testing stability, as being stable. Entry 29 and 42 appeared as the most stable entries in this trial. Entries that performed well in specific group of environments were also identified.

5.2 CONCLUSIONS

- Entries 74 (Line 37 x tester 2) in Kakamega optimum and Kiboko drought trials, 25 (Line 13 x tester1) and 35 (Line 18 x tester 1) in Kiboko optimum trials, 32 (Line 16 x tester 2) for Embu optimum trial, were identified as good perfomers in these specific sites.
- Three hybrids (Entries 1, 35 and 74) from the early generation hybrids were identified as good performers across all environments, due to their consistency in performance.

Similarly, hybrid entries 29, 31, 33 and 42 from the regional hybrid trials data showed good performance across locations.

- Entry 1, 74 and 35 had a favourable and highly significant GCA score across all environments, suggesting that these lines were good combiners overall. These lines can be used as parents in formation of hybrids for further testing and recommendation in these environments.
- Fifty five lines were grouped to heterotic group B and the remaining 51 lines were in heterotic group A.
- The different methods of stability analysis did not result in the same ranking of genotypes, by their stability, but show some similarities and common trends.
- The GGE biplot analysis method provided a better tool for the analysis of genotypes environments and their interactions. It enables us to graphically present genotypes and environments and groups them relative to the most stable genotypes and to classify environments, to avoid unnecessary trials, and also determine the best performers in different groups of environments.

5.3 RECOMMENDATIONS

Further studies should be done on the good yielding and promising hybrids identified in this study. They could be further tested across a wider region to ascertain their consistency. Their parents, which showed good combining ability effects, should also be advanced and tested in various other crosses made using these materials. Combining ability and heterotic grouping information is critical in a breeding program.

The GGE biplot method which was identified as the most versatile and most informative in stability analysis should be incorporated in maize breeding programs. Hybrids produced from these programs should be evaluated across a wide set of environments and across different years. Analysis of data generated would provide valuable information in cultivar selection and recommendation. Hybrids identified in this study to be stable could be candidates for release as commercial varieties. Therefore further testing should be done to confirm their stability.

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APPENDICES

Appendix 1: Lines used in combining ability study

Entry	Pedigree	Entry	Pedigree
1	(1368/CML445)-B-3-1	54	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-1
2	(1368/CML445)-B-3-2	55	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-2
3	(DT-SR-W-3-3-2-1-1-B-B-B-B-B-B-B/CML445)-B-4-1	56	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-3
4	(1368/CML445)-B-3-4	57	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-4
5	(1368/CML445)-B-3-5	58	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-5
6	(1368/CML445)-B-3-6	59	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-5-6
7	(1368/CML445)-B-3-7	60	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-1
8	(1368/CML445)-B-3-8	61	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-2
9	(1368/CML445)-B-3-9	62	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-3
10	(1368/CML445)-B-6-3	63	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-6-4
11	(1368/CML445)-B-6-5	64	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-4-1
12	(1368/CML445)-B-6-6	65	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-7-1
13	(1368/CML445)-B-6-7	66	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-1
14	(1368/CML445)-B-6-8	67	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-2
15	(POP 10/CML445)-B-3-1	68	((9071 x Babamgoyo)-3-1-B-B/CML445)-B-9-3
16	(POP 10/CML445)-B-3-2	69	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-1
17	(5012/CML445)-B-3-2	70	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-2
18	(5012/CML445)-B-3-3	71	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-3
19	(5012/CML445)-B-3-5	72	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-1-5
20	(5012/CML445)-B-3-6	73	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-1
21	(5012/CML445)-B-6-1	74	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-2
22	(5012/CML445)-B-6-2	75	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-2-3
23	(5012/CML445)-B-6-3	76	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-1
24	(5012/CML445)-B-8-1	77	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-2
25	(5012/CML445)-B-12-1	78	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-3
26	(5012/CML445)-B-12-2	79	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-4
27	(5012/CML445)-B-12-3	80	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-5
28	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-1	81	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-6
29	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-2	82	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-7
30	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-3	83	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-3-8
31	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-5	84	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-1
32	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-1-6	85	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-2
33	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-1	86	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-4
34	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-3	87	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-5-5
35	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-4	88	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-6-1
36	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-4-6	89	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-6-2
37	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-5-1	90	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-7-1
38	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-7-1	91	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-7-2
39	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-1	92	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-1
40	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-2	93	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-2
41	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-3	94	((KU1403x1368)BC2-7-4-1-1-B-B-B-B/CML445)-B-9-3
42	(P43SRC9FS100-1-1-2sb-#1-B1-7-B1/CML445)-B-9-4	95	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-1
43	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-1	96	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-3
44	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-2	97	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-2-5
45	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-3	98	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-3-1
46	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-4	99	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-3-2
47	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-2-5	100	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-5-1
48	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-3-1	101	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-7-1
49	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-1	102	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-10-1
50	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-2	103	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-1
51	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-3	104	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-2
52	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-4	105	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-3
53	((KU1403 x 1368)-7-2-1-1-B-B/CML445)-B-4-5	106	(LATA-26-1-1-1-B-B-B-B-B/CML445)-B-11-4

Appendix 2.1: Across means

ENTRY	GY	AD	ASI	ER	EA	PH	EH	EPO	GLS	PS	ET	SEN	MSV	PA
1	7.09	68.33	1.67	7.52	2.50	225.13	124.50	0.55	2.17	1.42	2.17	5.25	1.00	2.38
2	5.83	68.50	1.75	8.88	2.54	224.38	135.25	0.60	1.75	1.33	2.25	4.75	1.00	2.88
3	5.69	68.92	2.42	8.22	2.75	223.13	130.00	0.58	2.17	1.50	2.42	5.63	1.00	2.63
4	5.54	71.00	2.00	6.16	2.54	217.50	122.83	0.57	2.08	1.50	2.58	5.50	0.75	2.75
5	4.88	70.67	1.33	12.16	3.08	210.75	109.88	0.52	2.25	1.58	2.17	4.75	1.88	2.50
6	4.63	70.83	3.33	8.48	3.21	218.13	118.25	0.54	1.67	1.42	2.33	4.88	0.75	3.00
7	6.68	69.58	2.58	8.77	2.33	229.25	131.13	0.57	1.75	1.42	2.08	5.13	0.63	2.50
8	6.13	69.42	1.92	8.23	2.54	227.63	129.63	0.57	1.58	1.42	2.17	4.38	0.50	2.75
9	6.29	68.50	1.75	9.02	2.63	226.38	121.00	0.53	2.17	1.42	2.08	5.25	1.00	2.75
10	5.82	69.75	1.92	9.22	2.63	228.25	131.38	0.58	1.92	1.42	2.08	5.38	1.25	2.63
11	5.67	69.67	1.83	11.25	2.67	220.63	122.38	0.55	2.25	1.50	2.08	5.50	0.63	2.63
12	6.26	69.75	1.42	6.48	2.71	235.50	141.50	0.60	2.17	1.58	2.42	5.50	1.13	3.13
13	6.00	68.00	1.58	9.89	2.92	228.13	132.38	0.58	2.33	1.58	2.00	5.63	1.75	2.38
14	5.59	68.92	1.83	8.05	2.71	227.88	126.50	0.55	2.08	1.42	2.25	5.25	0.63	2.88
15	5.52	69.08	1.25	9.49	2.88	230.38	129.13	0.57	2.08	1.83	2.33	5.63	1.13	2.50
16	6.25	69.08	1.67	4.92	2.67	223.38	130.00	0.59	2.08	1.58	2.17	5.38	0.63	2.63
17	6.78	69.17	1.25	6.08	2.54	232.00	125.38	0.54	1.92	1.58	2.08	5.13	1.00	2.25
18	6.10	70.25	1.75	7.62	2.75	224.75	132.88	0.59	1.75	1.50	2.08	5.75	0.63	2.63
19	5.85	68.50	0.08	11.47	2.75	232.38	135.63	0.58	2.17	1.42	2.58	4.25	1.13	2.63
20	6.14	69.33	1.00	8.52	2.67	231.63	137.88	0.60	2.00	1.50	2.42	5.00	0.63	2.75
21	5.80	69.58	1.25	8.26	2.83	215.63	121.88	0.57	2.33	1.42	2.33	4.50	0.75	3.00
22	5.48	71.08	1.00	11.63	2.79	227.88	137.38	0.60	2.33	1.50	2.33	4.75	0.63	2.75
23	6.81	67.92	0.92	6.32	2.54	229.88	133.13	0.58	2.25	1.50	2.50	4.38	1.00	2.75
24	6.64	69.25	1.08	6.98	2.58	226.50	137.13	0.61	1.83	1.33	2.50	4.50	0.75	2.75
25	7.05	68.00	1.08	8.29	2.71	224.75	130.75	0.58	2.25	1.42	2.33	4.00	0.75	2.50
26	7.04	68.75	1.00	5.46	2.42	217.63	130.13	0.60	1.83	1.50	2.50	4.75	0.75	2.63
27	6.72	69.83	1.25	8.08	2.63	224.13	131.00	0.58	1.50	1.42	2.17	5.13	0.88	2.63
28	6.60	70.50	1.08	7.98	2.33	242.58	146.50	0.61	1.67	1.58	2.42	4.50	0.50	2.88
29	6.24	67.83	0.50	7.19	2.38	242.25	125.50	0.52	2.58	1.50	2.42	5.00	0.75	2.63
30	5.99	68.83	0.75	5.64	2.46	227.25	119.00	0.52	2.00	1.33	2.42	5.25	0.63	2.63
31	6.75	67.67	0.33	5.46	2.33	222.63	126.88	0.57	2.25	1.50	2.33	4.75	0.88	2.63
32	6.94	69.50	1.75	5.57	2.42	206.00	121.38	0.59	1.75	1.33	2.33	4.75	0.63	2.38
33	6.56	68.25	0.17	10.74	2.96	231.00	129.75	0.56	2.58	1.33	2.75	5.63	0.88	2.63
34	6.18	68.08	0.58	5.92	2.63	238.25	144.00	0.61	2.25	1.58	2.58	5.38	1.00	2.50
35	7.20	67.92	0.58	11.53	2.54	237.13	129.25	0.55	2.17	1.33	2.67	4.88	0.75	2.38
36	6.32	68.42	1.00	3.10	2.58	245.13	144.00	0.59	1.83	1.67	2.58	4.50	1.00	2.75
37	6.19	66.83	1.42	6.97	2.58	227.13	120.50	0.53	2.92	1.50	2.67	5.63	0.75	2.63
38	6.60	68.17	1.67	10.09	2.50	229.88	134.50	0.59	1.83	1.50	2.67	4.25	0.75	2.63
39	5.53	68.75	0.25	9.94	2.96	228.00	128.75	0.57	2.25	1.42	2.67	5.50	0.63	2.63
40	5.77	68.25	1.00	8.97	2.75	227.38	127.88	0.56	2.33	1.42	2.50	5.25	0.63	2.75
41	5.04	67.25	2.17	13.59	3.04	220.13	124.88	0.58	2.50	1.58	2.58	5.38	0.75	2.63
42	4.99	68.75	1.50	11.08	2.92	225.88	130.13	0.58	2.08	1.33	2.50	5.25	0.75	2.88
43	5.36	67.17	1.92	11.32	2.79	216.13	117.75	0.55	2.75	1.58	2.42	5.63	0.63	2.63
44	5.79	68.58	1.42	7.64	2.67	221.13	129.75	0.59	2.50	1.42	2.58	4.88	0.75	2.50
45	5.34	66.50	2.42	16.95	3.00	213.63	109.25	0.51	2.92	1.33	2.42	4.63	1.00	2.50
46	5.22	67.50	2.17	10.99	2.88	212.25	116.00	0.55	2.50	1.42	2.42	6.00	1.00	2.88
47	5.30	67.08	2.17	12.69	2.92	222.63	113.13	0.51	2.67	1.58	2.58	5.63	0.88	3.00
48	5.71	67.75	1.58	7.37	2.75	238.25	135.00	0.57	2.67	1.42	2.42	4.50	0.50	2.50
49	5.39	67.00	1.92	12.53	2.79	222.00	117.88	0.53	2.75	1.58	2.42	4.63	0.88	2.63
50	6.25	68.83	1.50	6.37	2.63	227.13	129.75	0.57	2.25	1.42	2.50	5.13	0.50	2.75
51	5.66	67.92	2.33	10.08	2.83	219.13	121.13	0.56	2.67	1.33	2.42	4.88	0.75	2.88
52	5.95	68.67	2.33	5.78	2.79	222.00	121.63	0.55	2.33	1.33	2.25	4.25	1.00	2.50
53	5.74	68.67	1.25	5.94	3.00	223.00	122.38	0.55	2.67	1.50	2.25	4.75	0.88	2.63
54	6.01	69.00	2.50	8.94	2.63	221.75	124.75	0.56	2.08	1.42	2.25	4.50	0.75	2.25
55	6.32	68.50	1.92	7.16	2.96	223.38	123.00	0.55	2.50	1.42	2.25	5.75	0.75	2.50

Appendix 2.2: Across means- contd

ENTRY	GY	AD	ASI	ER	EA	PH	EH	EPO	GLS	PS	ET	SEN	MSV	PA
56	6.38	67.92	0.83	6.00	2.33	218.75	124.75	0.57	2.00	1.42	2.42	5.00	0.63	2.63
57	5.72	67.58	1.42	10.09	2.71	231.00	123.25	0.54	2.33	1.50	2.17	5.50	0.88	2.75
58	5.50	67.33	1.50	6.11	2.75	219.50	120.13	0.55	1.67	1.67	2.50	4.13	0.50	2.75
59	5.72	67.25	1.50	9.11	2.79	226.50	124.38	0.55	1.83	1.58	2.33	4.63	1.50	2.50
60	5.73	68.33	2.42	9.92	2.75	217.75	126.00	0.58	1.83	1.42	2.42	5.00	1.25	2.63
61	5.13	67.42	2.92	13.32	3.04	210.75	109.63	0.52	2.25	1.58	2.17	5.13	1.13	2.63
62	5.74	67.50	1.58	10.79	2.88	210.25	119.00	0.56	1.83	1.50	2.25	5.25	0.63	2.63
63	6.05	66.58	1.42	13.11	2.79	224.00	117.13	0.53	2.00	1.58	2.08	4.88	0.75	2.63
64	6.17	68.08	0.92	7.17	2.67	224.25	125.75	0.56	2.17	1.58	2.42	5.13	0.63	2.88
65	5.23	67.08	2.58	11.14	2.96	208.75	109.75	0.53	2.58	1.50	2.33	4.75	0.88	2.75
66	5.66	68.08	1.75	9.78	2.67	208.75	106.00	0.51	1.67	1.50	2.42	5.38	0.63	3.25
67	5.72	67.08	0.67	9.92	2.79	214.38	103.75	0.48	2.17	1.50	2.33	5.13	1.00	2.63
68	5.79	67.25	1.00	6.00	2.46	221.75	124.13	0.56	2.58	1.33	2.25	5.00	0.75	2.63
69	5.65	66.50	1.00	8.65	2.71	210.50	114.50	0.54	2.58	1.50	2.17	5.38	0.88	2.88
70	6.06	68.50	1.17	7.70	2.50	224.00	113.00	0.50	1.83	1.42	2.58	5.13	0.63	3.00
71	5.98	68.25	0.83	7.66	2.54	208.38	111.38	0.53	2.33	1.50	2.25	4.50	1.13	2.75
72	5.66	68.75	0.25	8.51	2.75	232.38	123.38	0.53	1.92	1.50	2.33	5.13	0.63	2.88
73	5.95	67.25	0.50	11.85	2.71	214.38	104.13	0.50	1.83	1.33	2.00	4.25	0.75	2.63
74	7.59	66.92	0.92	6.85	2.33	227.25	127.75	0.56	1.50	1.50	2.25	3.75	0.88	2.63
75	5.78	66.33	0.67	9.03	2.96	221.25	114.38	0.52	2.17	1.50	2.33	4.75	0.63	2.63
76	5.45	67.75	2.83	9.68	2.67	216.25	116.13	0.54	2.42	1.42	2.08	5.63	1.00	2.88
77	5.44	67.17	2.83	12.44	2.83	205.00	107.13	0.52	2.83	1.42	2.17	5.13	0.63	2.63
78	5.67	68.08	1.33	6.68	2.50	218.75	124.00	0.56	2.25	1.58	2.17	5.25	0.63	2.75
79	5.42	67.92	1.08	10.30	2.71	216.63	119.13	0.55	2.25	1.42	2.00	4.75	0.75	2.63
80	6.00	67.08	1.00	7.21	2.79	221.50	129.75	0.59	2.33	1.42	2.42	4.75	0.75	2.75
81	5.42	67.58	1.08	9.33	3.00	212.00	120.25	0.57	2.58	1.50	2.25	4.25	0.63	3.00
82	6.09	67.67	1.25	6.09	2.63	220.88	128.63	0.58	2.42	1.42	2.17	5.00	0.88	2.63
83	6.11	67.33	0.67	4.42	2.75	222.75	122.50	0.55	2.67	1.58	2.17	5.00	0.75	2.38
84	6.24	67.50	0.92	6.21	2.67	224.00	134.13	0.60	2.33	1.42	2.42	4.75	0.75	2.63
85	5.84	67.33	0.50	10.20	2.79	216.38	122.25	0.57	2.75	1.58	2.33	5.13	0.50	2.75
86	5.47	67.83	2.58	8.28	2.96	221.38	127.25	0.58	2.08	1.50	2.50	4.63	0.63	2.88
87	5.71	67.83	2.58	10.74	3.21	222.13	116.75	0.53	2.42	1.50	2.42	3.63	0.63	2.63
88	6.43	68.50	1.50	9.11	2.71	224.00	129.88	0.58	2.17	1.50	1.83	4.63	0.63	2.25
89	5.93	66.75	0.83	9.78	2.71	223.25	118.75	0.53	3.08	1.50	2.42	4.75	0.75	2.63
90	5.81	68.83	0.75	9.46	2.54	222.66	126.75	0.57	2.25	1.42	2.50	4.38	0.88	2.75
91	5.59	69.17	1.08	10.30	2.79	212.13	113.63	0.53	2.08	1.50	2.17	4.75	1.13	2.50
92	6.07	67.92	1.83	11.51	2.58	229.25	126.38	0.55	1.75	1.33	2.25	4.75	0.75	2.38
93	5.16	68.42	1.25	10.96	3.04	214.00	112.75	0.53	2.58	1.75	2.17	5.00	1.00	2.25
94	5.20	68.58	1.08	9.68	2.96	213.38	126.25	0.59	2.58	1.58	2.42	4.50	0.75	2.38
95	5.94	67.50	1.33	11.69	2.75	219.25	118.38	0.54	2.42	1.50	2.08	5.38	0.88	2.50
96	5.84	67.67	1.67	11.58	2.92	219.00	130.75	0.60	1.75	1.42	2.17	5.13	0.88	2.75
97	5.99	67.67	2.33	15.44	2.83	213.88	106.50	0.50	2.33	1.58	2.08	4.13	0.88	2.13
98	6.27	68.67	1.50	12.17	2.54	214.00	122.00	0.57	1.92	1.42	2.25	3.50	0.50	2.50
99	6.22	68.00	1.17	9.44	2.54	214.25	110.75	0.52	2.25	1.50	2.00	4.88	0.75	2.38
100	6.58	68.92	2.08	10.82	2.58	227.13	118.88	0.52	2.00	1.50	2.17	3.88	0.75	2.63
101	5.42	67.00	1.92	13.76	2.88	217.00	112.38	0.51	2.67	1.50	2.08	4.75	0.88	2.38
102	5.87	67.92	1.33	8.44	2.71	207.00	116.25	0.56	2.00	1.33	2.00	4.38	0.75	2.25
103	5.99	68.58	1.25	13.58	2.71	221.25	118.50	0.54	2.25	1.58	2.08	4.38	0.88	2.50
104	5.45	69.58	1.42	9.98	2.58	217.00	118.88	0.55	2.00	1.42	2.08	5.00	1.13	2.38
105	6.30	68.25	1.58	13.78	2.71	221.50	106.13	0.48	1.75	1.67	2.00	4.00	1.50	2.50
106	6.00	69.67	1.17	7.51	2.67	212.00	111.75	0.53	1.92	1.42	2.25	4.00	1.00	3.13
107	5.91	67.42	1.92	8.54	2.71	212.50	117.13	0.55	1.92	1.58	2.00	5.38	1.13	2.75

Appendix 2.3: Across means - contd

ENTRY	GY	AD	ASI	ER	EA	PH	EH	EPO	GLS	PS	ET	SEN	MSV	PA
108	6.36	69.08	1.75	6.64	2.46	220.13	125.00	0.57	1.50	1.50	1.92	4.50	0.75	3.13
109	6.16	69.25	1.42	8.15	2.63	213.13	110.38	0.52	2.08	1.58	2.33	4.38	0.75	2.38
110	6.39	70.08	1.58	8.61	2.46	226.50	129.38	0.57	2.17	1.42	2.08	4.00	0.75	2.63
111	6.04	67.58	1.25	13.04	2.71	211.25	115.38	0.55	1.75	1.67	1.92	4.38	0.88	2.50
112	5.56	68.17	2.33	11.88	2.71	210.25	124.38	0.59	1.58	1.42	2.00	4.75	0.75	2.88
113	6.60	66.75	1.17	9.08	2.42	213.38	120.13	0.57	2.25	1.42	2.08	5.13	0.75	2.25
114	5.87	69.92	1.00	5.62	2.42	217.00	133.00	0.61	1.92	1.42	2.00	5.13	0.63	2.50
115	6.06	68.67	2.83	10.02	2.71	221.88	115.13	0.52	2.42	1.33	2.08	4.38	1.63	2.38
116	6.46	70.08	1.83	9.30	2.54	224.88	126.13	0.56	1.75	1.25	2.08	3.88	0.63	2.63
117	5.74	67.67	1.58	9.17	2.67	217.13	117.50	0.54	2.00	1.50	1.92	4.63	1.00	2.50
118	6.76	68.17	0.67	7.70	2.38	222.50	126.13	0.57	1.58	1.58	2.00	4.88	0.75	2.63
119	6.39	68.58	2.50	6.21	2.63	221.13	120.25	0.54	1.92	1.50	2.17	4.38	0.88	2.88
120	6.45	69.50	2.17	8.17	2.58	222.35	123.63	0.56	2.08	1.50	2.33	4.25	0.88	2.50
121	6.37	68.83	2.08	7.89	2.58	209.00	109.38	0.52	1.92	1.50	2.25	4.25	0.75	2.63
122	6.04	69.00	2.50	6.64	2.58	218.00	126.50	0.58	1.67	1.33	2.17	5.38	0.88	2.38
123	5.23	68.00	2.42	15.96	2.96	222.75	118.75	0.53	1.83	1.50	2.25	4.63	1.00	2.63
124	5.58	68.58	2.42	10.98	2.88	214.88	121.25	0.56	1.83	1.58	2.08	4.13	0.88	2.50
125	6.15	68.42	1.50	5.22	2.54	233.50	133.25	0.57	2.08	1.33	2.17	4.38	0.63	2.63
126	6.50	70.00	1.17	7.43	2.50	229.50	139.38	0.61	1.83	1.33	2.08	4.50	0.63	2.63
127	5.85	67.67	1.67	8.26	2.79	223.88	116.88	0.53	2.75	1.67	2.25	3.50	0.75	2.38
128	6.66	67.83	1.33	4.20	2.50	217.88	124.75	0.57	2.00	1.42	2.00	3.50	0.88	2.75
129	5.31	66.42	5.33	9.29	3.08	210.88	107.63	0.51	2.92	1.50	2.17	5.25	0.63	3.00
130	5.27	67.33	3.58	10.58	3.04	216.38	117.00	0.54	2.33	1.67	2.42	5.50	1.00	2.75
131	6.16	66.67	1.75	10.25	2.71	209.75	116.38	0.56	2.00	1.50	2.33	4.75	0.88	2.63
132	4.96	68.42	2.17	9.91	3.08	207.25	115.00	0.56	1.75	1.58	2.50	4.50	0.75	3.00
133	5.59	66.92	1.58	12.90	2.96	205.50	105.88	0.52	2.58	1.58	2.25	4.75	1.13	2.75
134	5.08	67.42	2.00	9.19	2.92	208.00	117.25	0.57	2.08	1.33	2.75	4.63	0.75	2.63
135	5.04	67.42	2.42	8.99	3.17	206.75	107.38	0.52	2.67	1.33	2.42	4.75	0.63	2.88
136	5.51	67.92	1.92	6.36	2.88	217.50	121.50	0.56	2.17	1.42	2.75	4.50	0.63	2.63
137	6.36	67.75	0.92	9.74	2.63	219.50	115.75	0.53	2.50	1.42	2.00	4.75	0.63	2.25
138	5.90	68.67	1.08	8.19	2.54	210.88	124.50	0.59	2.42	1.33	2.17	5.38	1.00	2.75
139	5.27	69.75	2.75	8.19	2.92	214.38	104.38	0.48	1.92	1.50	2.17	5.25	1.25	2.75
140	6.28	69.17	1.33	7.69	2.50	218.00	120.00	0.55	1.92	1.58	2.33	5.00	0.88	2.50
141	5.97	68.83	2.17	9.12	2.71	216.38	123.38	0.57	2.17	1.42	2.00	4.00	0.88	2.25
142	6.16	68.17	1.92	6.69	2.42	223.58	117.13	0.52	1.92	1.50	2.42	5.00	0.63	2.13
143	6.12	68.83	1.58	7.91	2.46	226.88	124.50	0.55	1.92	1.42	2.25	4.50	0.75	2.38
144	6.00	69.75	2.92	8.80	2.63	214.63	113.25	0.53	1.58	1.50	2.42	4.88	1.00	2.50
145	6.60	67.83	1.83	10.06	2.58	211.00	113.00	0.54	2.25	1.58	2.00	5.00	0.88	2.38
146	6.14	68.25	2.33	9.52	2.63	218.75	118.75	0.54	1.58	1.50	2.00	5.25	0.50	2.50
147	5.76	67.92	2.33	10.59	2.79	212.63	110.63	0.52	2.25	1.42	2.08	4.63	0.88	2.25
148	6.25	67.25	2.08	6.73	2.50	209.38	117.75	0.56	2.00	1.50	2.25	4.75	1.00	2.50
149	6.06	68.67	2.00	10.16	2.67	211.75	112.13	0.53	2.00	1.42	2.17	4.63	1.63	2.63
150	6.21	69.58	1.42	7.20	2.42	222.00	129.63	0.59	1.92	1.50	2.25	4.38	0.75	2.75
151	5.81	66.17	1.00	8.91	3.04	204.00	107.75	0.53	2.67	1.50	2.50	5.50	1.25	2.75
152	5.31	66.42	1.17	10.15	2.83	203.00	111.50	0.55	2.33	1.33	2.33	4.50	0.75	2.88
153	5.77	66.67	1.25	10.48	3.04	209.88	103.00	0.49	2.42	1.58	2.33	5.13	0.75	2.63
154	5.56	67.25	2.08	6.88	2.50	205.38	107.63	0.52	2.33	1.42	2.33	4.88	0.75	2.75
155	5.22	65.83	1.50	6.90	3.13	208.25	107.00	0.51	2.25	1.42	2.25	5.63	1.13	3.00
156	5.98	65.92	1.83	7.92	2.79	217.88	112.88	0.52	1.83	1.33	2.58	5.63	0.63	2.75
157	5.47	66.25	1.92	11.44	3.04	214.88	111.13	0.52	2.08	1.50	2.42	4.88	0.88	2.63
158	5.74	67.92	1.83	7.52	2.75	218.13	125.75	0.58	1.50	1.42	2.50	4.38	0.63	2.75
159	5.65	65.67	1.50	11.06	3.04	209.13	110.88	0.53	2.92	1.42	2.25	5.50	1.13	2.75
160	5.81	66.75	1.92	9.48	2.96	219.38	115.00	0.52	2.42	1.33	2.58	5.50	0.63	2.75
161	6.02	66.17	1.50	12.86	3.33	210.25	109.88	0.52	2.67	1.42	2.25	5.38	0.88	3.00
162	5.65	68.25	0.92	10.09	2.92	222.50	128.13	0.58	2.42	1.58	2.33	4.75	0.88	2.63

Apendix 2.4: Across means- contd

ENTRY	GY	AD	ASI	ER	EA	PH	EH	EPO	GLS	PS	ET	SEN	MSV	PA
163	6.24	66.58	1.42	8.91	2.63	226.75	117.63	0.53	2.42	1.58	2.33	4.00	0.75	2.63
164	6.12	67.08	1.17	8.17	2.58	224.13	125.88	0.56	2.67	1.50	2.58	5.50	0.50	2.75
165	5.80	66.67	0.75	8.70	2.88	213.88	106.50	0.50	2.58	1.58	2.17	4.88	0.88	2.50
166	5.85	68.33	0.33	4.65	2.79	223.00	123.83	0.56	2.25	1.42	2.33	4.88	0.88	2.88
167	5.76	68.75	1.58	9.52	2.75	217.25	117.00	0.54	2.00	1.50	2.08	5.25	0.88	2.38
168	5.71	69.00	2.75	8.94	2.58	228.50	120.38	0.53	1.92	1.33	2.33	4.38	0.88	2.75
169	5.60	68.58	2.50	9.86	2.96	222.00	110.13	0.49	2.08	1.75	2.00	5.25	0.88	2.75
170	5.71	69.08	1.83	9.22	2.79	212.50	116.75	0.55	1.83	1.58	2.25	5.00	0.75	2.63
171	6.27	69.00	1.75	11.95	2.67	229.50	122.13	0.53	1.50	1.50	2.08	5.13	0.75	2.63
172	6.21	70.00	2.25	7.64	2.67	222.13	126.50	0.57	1.75	1.50	2.08	5.00	0.88	2.75
173	5.97	69.17	2.42	9.10	2.46	223.38	119.13	0.53	2.00	1.50	2.25	4.38	0.88	2.25
174	5.46	68.25	2.00	8.62	2.88	210.00	117.25	0.56	1.75	1.42	2.33	4.13	0.63	2.63
175	6.31	65.67	1.58	10.21	2.71	206.25	106.63	0.52	2.25	1.58	2.17	5.13	0.75	2.38
176	6.36	69.33	2.17	6.58	2.54	217.50	118.25	0.55	1.67	1.50	2.08	5.50	1.00	2.38
177	5.93	66.75	1.50	10.80	2.75	214.13	107.50	0.50	2.33	1.42	2.17	4.63	0.75	2.50
178	5.90	68.75	1.67	9.54	2.75	217.00	116.63	0.53	1.83	1.50	2.25	4.50	0.88	2.63
179	5.46	66.17	1.83	17.30	2.83	214.13	102.13	0.48	2.08	1.50	2.17	5.38	0.75	3.00
180	5.47	67.33	2.17	10.92	2.67	212.25	111.63	0.52	1.75	1.42	2.25	5.38	0.63	2.75
181	4.93	67.58	2.33	18.05	2.96	211.00	107.13	0.51	2.33	1.50	2.08	5.25	0.75	2.50
182	5.42	68.42	2.33	10.43	2.79	210.38	117.75	0.56	1.92	1.42	2.17	5.50	0.75	3.00
183	4.78	66.83	1.75	18.42	3.25	200.13	102.50	0.51	1.75	1.33	2.25	5.25	0.63	2.63
184	5.57	67.00	1.50	10.59	2.83	205.63	108.50	0.53	1.67	1.50	2.25	5.00	0.88	2.38
185	5.48	68.33	0.92	16.20	3.13	209.25	113.75	0.54	1.67	1.42	2.00	4.88	0.88	2.38
186	6.25	67.83	1.08	9.65	2.46	227.25	130.88	0.58	1.58	1.42	2.25	5.13	0.63	2.25
187	4.85	67.83	2.92	15.71	3.04	209.13	111.75	0.54	2.17	1.42	2.33	5.00	0.88	2.38
188	5.11	68.42	2.75	12.04	2.71	218.38	118.75	0.54	1.83	1.42	2.50	4.50	0.75	2.25
189	4.62	66.33	2.50	8.95	3.00	215.38	106.00	0.49	2.58	1.50	2.33	4.75	1.00	2.75
190	6.00	67.75	1.42	6.79	2.63	218.25	119.38	0.54	2.17	1.42	2.33	4.88	0.75	2.63
191	5.01	68.08	2.25	8.75	3.04	215.88	106.88	0.49	2.25	1.50	2.08	3.88	0.88	2.50
192	5.58	67.75	2.00	9.04	2.67	222.50	123.50	0.56	1.83	1.33	2.25	4.75	0.75	2.50
193	5.22	67.25	2.92	8.52	3.04	208.00	107.00	0.51	2.50	1.50	2.25	5.50	1.25	2.75
194	5.73	67.58	1.67	5.03	2.58	219.25	123.00	0.56	2.17	1.42	2.58	4.75	0.63	2.75
195	4.82	66.83	2.92	12.20	3.04	210.25	113.75	0.54	2.17	1.50	2.33	4.63	1.00	2.88
196	5.48	68.00	2.75	9.91	2.71	211.63	117.13	0.55	1.75	1.58	2.25	4.63	0.63	2.88
197	5.22	66.67	1.67	8.44	2.79	212.13	116.50	0.56	2.50	1.58	2.42	4.50	0.75	2.50
198	5.28	67.92	2.08	10.15	2.92	209.38	116.00	0.56	1.83	1.42	2.58	5.00	1.00	3.00
199	5.19	68.00	2.58	8.91	2.96	210.00	116.88	0.56	2.75	1.50	2.25	4.63	1.00	2.88
200	5.87	67.83	1.83	6.00	2.67	218.63	124.00	0.57	2.00	1.58	2.50	3.75	0.50	2.50
201	4.03	68.17	2.92	11.53	3.25	210.75	103.25	0.49	2.08	2.33	2.08	4.50	0.63	3.00
202	5.74	68.00	2.33	10.01	2.71	214.25	121.25	0.56	2.25	1.42	2.42	5.38	0.75	2.88
203	5.71	67.17	2.00	11.99	2.71	211.38	109.00	0.52	2.50	1.58	2.33	3.88	0.63	2.88
204	5.78	68.17	1.92	5.24	2.58	215.38	118.75	0.55	2.08	1.50	2.42	4.13	0.88	2.88
205	5.71	67.50	3.42	8.14	2.88	219.75	122.63	0.56	2.42	1.42	2.17	5.00	0.75	2.75
206	5.98	68.42	1.50	7.36	2.63	228.75	132.13	0.58	2.25	1.33	2.50	5.50	0.63	2.63
207	5.22	68.25	2.58	11.13	2.96	230.13	127.88	0.56	2.75	1.50	2.17	5.00	0.75	2.50
208	6.42	67.83	1.75	6.14	2.29	231.25	108.75	0.47	1.92	1.42	2.08	4.63	0.63	2.88
209	4.77	66.50	3.08	8.77	3.17	218.75	116.25	0.53	2.92	1.58	2.17	5.00	1.25	2.63
210	5.71	67.08	2.25	6.75	2.71	226.38	128.38	0.57	2.25	1.50	2.25	4.38	1.00	2.63
211	4.92	68.83	2.67	12.00	3.21	213.63	116.50	0.54	2.00	1.50	1.92	4.38	1.00	3.00
212	5.95	69.58	2.08	6.00	2.71	215.00	124.00	0.58	2.00	1.33	2.50	4.50	1.13	2.88
213	4.35	68.42	2.83	10.37	3.00	223.88	125.75	0.56	2.67	1.50	2.25	5.50	1.00	3.25
214	5.23	70.08	2.50	5.68	2.71	224.25	122.00	0.54	2.25	1.58	2.25	4.75	1.00	3.13
215	5.85	70.25	0.83	12.35	2.67	230.50	126.50	0.55	2.33	1.50	2.17	4.75	0.63	3.00
CV	20.54567	2.04753	76.4947	66.00	15.55	6.64	10.97	8.75	17.92	18.37	11.90	14.87	52.07	13.68
LSD	0.96	1.1172	1.046	4.88	0.34	14.29	12.95	0.05	0.44	0.31	0.31	1.00	0.60	0.50
Max	7.59	71.08	5.33	18.42	3.33	245.13	146.50	0.61	3.08	2.33	2.75	6.00	1.88	3.25
Mean	5.83	68.13	1.71	9.23	2.74	219.25	120.31	0.55	2.16	1.48	2.28	4.84	0.83	2.65
Min	4.03	65.67	0.08	3.10	2.29	200.13	102.13	0.47	1.50	1.25	1.83	3.50	0.50	2.13

Appendix 3.1: Across GCA

LINE	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
1	0.613*	0.312	0.006	5.598	3.233*	0.68	-3.619	-3.619	-0.193	-0.104	-0.068	0.17	-0.218*	-0.016
2	-0.227	1.854***	0.506	1.161	1.728	-0.738	-1.21	-1.21	-0.026	0.021	0.224**	0.045	-0.093	0.047
3	-1.089***	2.645***	0.631	-4.714	-2.45	-0.65	-2.581	-2.581	-0.193	0.021	-0.026	0.482***	0.407***	0.109
4	0.562*	1.395***	0.548	9.286**	4.25**	-1.217	-3.001	-3.001	-0.485***	-0.063	-0.151	-0.268	-0.301**	-0.016
5	0.208	1.02**	0.131	8.161*	0.189	-0.388	-1.995	-1.995	-0.11	-0.063	-0.193*	0.295*	-0.114	0.047
6	0.12	1.604***	-0.077	8.911**	4.35**	-0.439	-1.044	-1.044	0.057	0.063	-0.026	0.045	-0.051	0.234
7	-0.049	0.354	0.006	8.848*	2.585	0.139	-0.541	-0.541	0.057	0.021	-0.151	0.357**	0.074	-0.016
8	0.044	0.979**	-0.244	7.723*	5.291**	-1.324	2.319	2.319	-0.068	0.229**	-0.026	0.045	0.032	-0.078
9	0.598*	1.604***	-0.202	9.223**	1.587	-0.179	0.217	0.217	-0.318	0.063	-0.193*	-0.018	-0.093	-0.203
10	0.153	0.812**	-1.161***	12.848***	-0.98	0.008	-3.472	-3.472	-0.068	-0.021	0.224**	0.045	-0.03	0.047
11	-0.202	2.229***	-0.577	2.598	-0.202	-0.234	6.22**	6.22**	0.182	-0.021	0.057	-0.143	0.074	0.234
12	0.878**	0.479	-0.702*	9.036**	-0.786	0.51	5.912**	5.912**	-0.11	-0.063	0.224**	0.045	-0.176	0.109
13	1.201***	0.27	-0.661*	2.036	-2.359	0.618	2.369	2.369	-0.11	-0.021	0.14	-0.08	-0.176	-0.078
14	0.815**	2.062***	-0.536	14.198***	-0.22	-0.705	-1.23	-1.23	-0.568***	0.021	0.015	-0.143	-0.26*	0.109
15	0.273	0.229	-1.077**	15.598***	-0.789	1.259	0.042	0.042	0.14	-0.063	0.14	-0.143	-0.322**	-0.016
16	0.999***	0.479	-0.661*	-4.839	0.842	0.715	-1.261	-1.261	-0.151	-0.063	0.057	-0.08	-0.364***	-0.141
17	0.528	0.062	-1.327***	15.473***	1.275	0.467	5.86**	5.86**	0.265*	-0.021	0.39***	0.107	0.053	-0.078
18	0.914***	0.062	-0.911**	21.973***	1.458	0.904	8.162***	8.162***	-0.151	0.021	0.349***	0.045	-0.176	-0.078
19	0.547*	-0.605*	-0.161	9.348**	0.454	0.611	4.61*	4.61*	0.224	0.021	0.39***	-0.08	-0.197	-0.016
20	-0.197	0.395	-1.077**	8.536*	1.97	-0.601	7.549***	7.549***	0.14	-0.063	0.307***	-0.205	0.115	0.047
21	-0.831**	-0.105	0.131	3.848	-2.322	1.85*	-1.302	-1.302	0.14	-0.021	0.265**	-0.08	0.24*	0.109
22	-0.269	-0.23	-0.036	-0.527	-1.237	-0.883	-0.88	-0.88	0.474**	0.021	0.224**	-0.143	-0.01	-0.078
23	-0.563*	-1.105***	0.589	-6.214	0.168	0.289	-0.245	-0.245	0.557***	-0.104	0.14	0.17	0.199	0.047
24	-0.34	-0.688*	0.173	11.286**	-0.627	0.078	1.516	1.516	0.515***	0.021	0.224**	-0.143	0.095	0.109
25	-0.02	-0.188	0.006	5.411	-1.642	0.285	2.561	2.561	0.349**	0.021	0.182*	-0.143	-0.03	0.047
26	-0.04	0.187	0.631	1.411	0.27	-0.21	10.878***	10.878***	0.349**	-0.146	0.057	0.045	0.074	0.047
27	0.031	0.729*	0.173	3.223	-1.552	-1.074	5.574**	5.574**	0.224	-0.021	-0.026	-0.018	0.074	-0.203
28	0.504	0.104	-0.327	1.911	-1.946	0.86	4.831**	4.831**	0.099	-0.063	0.057	-0.143	-0.093	-0.078
29	-0.234	-0.646*	-0.244	6.098	0.79	0.935	-1.192	-1.192	-0.151	0.104	0.057	-0.143	-0.01	0.109
30	-0.12	-0.313	0.256	2.973	0.346	0.683	-1.728	-1.728	-0.318*	0.021	0.099	0.545***	0.032	-0.078
31	-0.406	-0.646*	0.548	-8.652*	-1.56	0.666	4.795**	4.795*	-0.11	0.063	-0.068	0.045	0.22*	-0.016
32	0.266	-0.771*	-0.536	4.973	-0.502	0.282	-0.981	-0.981	-0.068	0.104	-0.026	-0.143	-0.01	0.109
33	-0.4	-0.521	0.464	-10.402**	4.175**	-0.838	0.223	0.223	-0.026	0.021	0.099	-0.08	0.074	0.359**
34	-0.09	-0.938**	-0.869**	-1.089	1.823	-0.32	-1.647	-1.647	0.224	-0.063	0.015	0.045	-0.114	-0.016
35	0.014	-0.605	-0.619	-1.902	-0.117	-0.029	-2.665	-2.665	0.057	-0.021	0.099	-0.08	-0.135	0.297*
36	-0.025	0.395	-1.161***	1.223	-0.798	0.106	-3.668	-3.668*	-0.026	0.021	0.015	0.045	-0.093	0.172
37	0.926***	-1.021**	-0.994**	1.661	-1.082	-1.393	-4.981**	-4.981**	-0.485***	-0.063	-0.151	-0.018	-0.218*	-0.016
38	-0.227	-1.063***	0.048	-0.402	-2.173	-0.015	-3.378	-3.378	0.14	-0.021	-0.068	-0.018	0.074	0.109
39	-0.287	-0.48	0.381	-7.277*	0.818	0.875	0.299	0.299	0.39**	0.021	-0.11	-0.205	-0.072	0.047
40	-0.132	-0.605	-0.661*	-0.089	0.441	-0.893	-3.473	-3.473	0.14	-0.063	-0.068	-0.08	0.011	0.047
41	-0.092	-0.48	-0.536	-2.714	1.52	0.032	-1.633	-1.633	0.349**	-0.021	-0.068	-0.08	0.074	0.172
42	0.329	-0.688*	-0.911**	4.223	-0.132	0.657	-2.728	-2.728	0.349**	0.021	0.015	-0.08	-0.03	-0.141
43	-0.191	-0.521	-0.161	-0.277	2.366	-0.34	0.938	0.938	0.265*	0.063	0.14	-0.268	0.136	0.172
44	0.225	0.062	0.339	3.911	0.334	-0.337	0.338	0.338	0.14	0.021	-0.151	-0.205	0.22*	-0.203
45	0.026	-0.313	-0.911**	3.801	-1.797	0.617	-2.87	-2.87	0.515***	-0.021	0.182*	-0.018	-0.114	0.047
46	-0.018	0.437	-0.244	1.536	-0.094	0.643	-3.56	-3.56	-0.235	-0.063	-0.068	0.107	-0.051	-0.203
47	-0.665*	0.395	-0.536	-5.464	-1.202	-0.111	-1.123	-1.123	0.432**	0.188	0.015	0.045	0.261**	-0.328*
48	0.047	-0.521	-0.202	-0.027	-0.645	0.215	-1.125	-1.125	-0.068	-0.021	-0.151	0.045	0.095	-0.016
49	0.289	0.062	0.214	-5.214	1.116	-1.133	-0.161	-0.161	-0.026	0.021	-0.11	-0.143	-0.051	-0.328*
50	0.554*	0.354	-0.077	1.536	0.211	-0.625	-3.728	-3.728*	-0.026	0.021	-0.193*	-0.08	-0.176	-0.141
51	-0.195	-0.646*	-0.077	-7.152*	-0.19	0.02	-4.528*	-4.528*	0.182	-0.063	-0.235**	-0.018	0.053	-0.328*
52	-0.122	0.979**	-0.369	-0.027	-0.572	0.305	-3.048	-3.048	-0.026	0.021	-0.193*	0.17	-0.093	-0.203
53	0.305	0.854**	-0.327	-2.402	-2	-1.818*	-2.078	-2.078	-0.318*	0.063	-0.151	0.42**	-0.051	0.172

Appendix 3.2: Across GCA- Contd

LINE	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
54	0.288	0.145	0.131	-2.839	3.845*	0.957	-1.47	-1.47	-0.443***	0.063	-0.318***	0.107	-0.155	0.297*
55	0.433	1.562***	-0.202	0.661	-0.167	0	-0.417	-0.417	-0.026	0.021	-0.068	-0.08	-0.197	-0.141
56	-0.047	-0.23	0.089	-8.402*	2.895	0.443	7.611***	7.611***	-0.485***	0.063	-0.318***	-0.018	-0.03	0.047
57	0.393	0.229	-0.619	-3.964	2.732	1.274	-2.23	-2.23	-0.068	-0.063	-0.235**	-0.143	-0.322**	-0.266*
58	0.416	1.27***	0.631	4.223	-1.248	-0.659	-2.725	-2.725	-0.068	-0.188	-0.193*	0.295*	-0.114	-0.141
59	0.408	-0.188	-0.577	0.661	-0.31	0.055	1.689	1.689	-0.36**	0.063	-0.318***	0.045	-0.218*	-0.078
60	0.577*	0.937**	0.631	2.586	-1.869	-0.282	-1.409	-1.409	-0.151	0.021	-0.026	0.045	-0.135	0.047
61	0.359	0.812**	0.589	-5.652	0.462	-0.384	2.27	2.27	-0.36**	-0.063	-0.068	-0.018	-0.155	-0.141
62	-0.437	0.187	0.714*	-0.339	-1.224	-1.506	-2.433	-2.433	-0.318*	0.063	-0.11	0.107	0.178	-0.078
63	0.483	1.104***	-0.369	12.348***	-1.206	0.69	-5.032**	-5.032**	-0.193	-0.146	-0.151	-0.205	-0.218*	-0.016
64	0.415	-0.355	-0.202	1.723	-0.624	-0.196	-0.97	-0.97	0.224	0.063	-0.151	-0.018	-0.093	-0.078
65	-0.555*	-1.23***	2.756***	-5.527	-1.434	0.194	3.131	3.131	0.474***	0.104	0.015	-0.018	0.324**	0.234
66	-0.284	-0.563	0.256	-10.652**	-1.741	0.113	-3.85*	-3.85*	-0.276*	0.063	0.14	-0.018	0.157	0.172
67	-0.511	-0.938**	0.089	-12.402***	-1.978	0.088	-2.053	-2.053	0.182	-0.021	0.224**	0.107	0.199	0.047
68	-0.566*	-0.438	0.464	-7.027*	-1.137	0.62	-3.281	-3.281	0.265*	-0.104	0.307***	-0.205	0.282**	0.109
69	0.285	0.104	-0.702*	-3.964	-1.533	0.868	0.029	0.029	0.307*	-0.104	-0.193*	-0.018	-0.155	-0.141
70	-0.068	1.354***	0.339	-2.964	3.503*	-0.185	-4.189*	-4.189*	-0.235	0.063	-0.026	0.232	-0.03	-0.016
71	0.223	0.395	0.339	0.823	-1.29	-0.522	-1.097	-1.097	-0.11	-0.021	-0.068	-0.08	-0.176	-0.453***
72	0.215	1.187***	0.548	1.598	-1.504	-0.438	-3.626	-3.626	-0.401**	-0.021	0.057	0.045	-0.197	-0.203
73	0.524	-0.063	0.381	-4.277	-2.133	-0.592	-0.014	-0.014	-0.235	0.063	-0.276**	-0.143	-0.135	-0.203
74	0.161	-0.521	0.506	-8.152*	-1.476	-0.881	2.305	2.305	-0.026	-0.021	-0.11	0.107	-0.093	-0.266*
75	0.289	1.02**	0.006	-2.277	1.315	-0.595	1.666	1.666	-0.193	-0.021	-0.068	0.357**	-0.197	0.047
76	-0.288	-1.813***	-0.619	-15.652***	1.471	2.73**	-1.561	-1.561	0.349**	-0.063	0.14	0.17	0.199	0.172
77	-0.176	-1.146***	-0.036	-11.527**	-0.672	-0.185	1.598	1.598	0.224	0.021	0.057	-0.08	0.032	0.047
78	-0.244	-2.23***	-0.036	-6.089	-1.337	0.298	2.769	2.769	-0.11	-0.104	0.14	0.045	0.22*	0.234
79	-0.241	-1.021**	0.173	-2.652	1.004	0.673	2.204	2.204	-0.36**	-0.021	0.182*	-0.08	0.157	0.047
80	-0.115	-1.896***	0.006	-4.902	-1.96	0.384	-0.453	-0.453	0.515***	-0.104	0.14	0.045	0.261**	0.109
81	-0.007	-0.896**	-0.494	-2.777	-0.574	0.19	9.122***	9.122***	0.39**	0.021	0.015	0.045	0.386***	0.172
82	0.338	-1.271***	-0.411	6.286	-1.086	0.176	3.437	3.437	0.39**	0.063	0.182*	-0.205	-0.135	0.047
83	-0.017	-0.605	-1.161***	-0.714	1.092	2.373**	1.065	1.065	0.265*	0.021	-0.026	0.045	0.095	0.047
84	-0.111	0.77*	0.464	3.723	0.799	-0.599	3.896*	3.896*	-0.193	-0.063	-0.068	0.045	-0.072	-0.078
85	-0.188	0.729*	0.464	-1.902	1.433	-0.394	-1.358	-1.358	-0.193	0.188*	-0.151	-0.018	0.136	0.047
86	0.394	1.395***	0.298	6.661	-1.217	-0.637	-1.554	-1.554	-0.526***	0.021	-0.193*	-0.018	-0.072	0.047
87	-0.129	0.604	0.506	-2.464	-1.198	-0.047	-0.455	-0.455	-0.276*	-0.021	0.015	-0.08	-0.072	-0.203
88	0.489	-0.605	0.173	-7.277*	-0.785	1.004	0.464	0.464	-0.193	0.063	-0.151	0.045	-0.114	-0.266*
89	0.071	-0.355	-0.119	-3.589	0.741	-0.08	1.854	1.854	-0.068	-0.021	-0.068	-0.018	0.011	-0.078
90	-0.379	-1.355***	0.298	-5.964	-1.224	-1.795*	-0.803	-0.803	-0.235	-0.021	-0.068	-0.143	0.011	0.234
91	-0.667*	-0.105	0.631	-8.464*	-1.935	-0.645	0.814	0.814	-0.026	-0.021	-0.151	-0.08	0.136	0.109
92	-0.673*	-1.188***	-0.077	-16.277***	-0.993	-0.405	-2.21	-2.21	-0.443***	-0.063	-0.026	-0.08	0.303**	-0.141
93	0.02	-0.021	-0.702*	-0.902	-2.393	-0.808	-6.043**	-6.043**	-0.526***	-0.063	-0.151	-0.08	0.053	-0.328*
94	-0.863**	0.02	1.131***	-5.402	0.58	0.225	-2.756	-2.756	-0.151	-0.063	0.14	-0.018	0.136	-0.328*
95	-0.533	-1.063***	0.256	-2.339	1.287	-1.137	-2.259	-2.259	0.224	-0.021	0.057	0.045	0.074	0.047
96	-0.549*	-0.188	0.423	0.036	0.991	-0.373	10.524***	10.524***	-0.11	-0.063	-0.11	-0.018	0.115	-0.141
97	-0.367	-0.688*	0.589	-5.527	-0.758	0.793	-1.756	-1.756	0.182	-0.021	0.14	0.107	0.074	0.109
98	-0.694**	-0.688*	1.131***	-8.214*	-1.364	-0.892	0.106	0.106	-0.193	0.063	0.015	-0.018	0.136	0.234
99	-0.596*	-0.813**	0.173	-8.402*	-1.235	1.378	-5.598**	-5.598**	0.015	0.021	0.224**	0.045	0.115	0.109
100	-0.313	-0.188	0.506	-4.839	-0.086	-0.425	-1.022	-1.022	0.224	0.063	0.099	-0.08	0.074	0.047
101	-0.957***	-0.021	0.923**	-6.652	0.127	0.733	-0.233	-0.233	0.015	0.396***	-0.026	-0.143	0.24*	0.297*
102	-0.1	-0.438	0.256	-5.777	-1.512	-0.141	-2.033	-2.033	0.14	0.063	0.099	-0.08	-0.093	0.234
103	-0.003	-0.146	0.756*	5.098	0.813	0.12	0.918	0.918	0.182	-0.104	0.057	-0.143	0.011	0.047
104	-0.024	-0.063	0.464	11.536**	-0.802	-0.686	-1.695	-1.695	0.182	-0.021	-0.151	-0.143	-0.114	0.047
105	-0.601*	-1.313***	0.964**	3.411	-0.69	0.027	0.298	0.298	0.432**	0.063	-0.068	0.295*	0.199	-0.016
106	-0.412	1.104***	0.673*	-4.839	3.995*	0.266	6.274**	6.274**	-0.151	-0.063	-0.068	0.232	0.22*	0.297*
T1	-0.077	-0.359***	0.024	-1.266**	-0.332	-0.216*	1.902**	1.069	0.154***	0.028	-0.044	0.067	0.08	-0.037***
T2	0.077	0.359***	-0.024	1.266**	0.332	0.216*	-1.902**	-1.069	-0.154***	-0.028	0.044	-0.067	-0.08	0.037***

Appendix 4.1: Across SCA

LINE	TESTER	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
1	1	0.71**	0.28	-0.07	1.64	1.35	-0.49	-0.65	-1.75	0.05	0.01	0.003	-0.067	-0.1	-0.21
1	2	-0.71**	-0.28	0.07	-1.64	-1.35	0.49	0.65	1.75	-0.05	-0.01	-0.003	0.067	0.1	0.21
2	1	0.15	-0.68*	0.18	4.08	0.03	0.02	-2.55	-0.04	-0.11	-0.03	-0.039	0.058	0.02	-0.03
2	2	-0.15	0.68*	-0.18	-4.08	-0.03	-0.02	2.55	0.04	0.11	0.03	0.039	-0.058	-0.02	0.03
3	1	0.2	0.28	-1.02***	-2.42	0.36	-0.04	-0.47	0.77	0.14	0.06	-0.039	0.495***	-0.14	-0.21
3	2	-0.2	-0.28	1.02***	2.42	-0.36	0.04	0.47	-0.77	-0.14	-0.06	0.039	-0.495***	0.14	0.21
4	1	0.35	0.44	0.31	2.08	2.43	-0.08	-1.99	-0.8	-0.07	-0.03	0.003	-0.005	-0.18*	-0.09
4	2	-0.35	-0.44	-0.31	-2.08	-2.43	0.08	1.99	0.8	0.07	0.03	-0.003	0.005	0.18*	0.09
5	1	0.31	-0.27	-0.11	0.33	0.86	-0.2	-2.98	-1.17	-0.03	-0.03	0.044	-0.192	-0.08	0.1
5	2	-0.31	0.27	0.11	-0.33	-0.86	0.2	2.98	1.17	0.03	0.03	-0.044	0.192	0.08	-0.1
6	1	-0.21	0.32	0.18	-6.17	0.38	0.54	-3.11*	1.31	-0.11	-0.07	-0.122	-0.317*	-0.1	-0.21
6	2	0.21	-0.32	-0.18	6.17	-0.38	-0.54	3.11*	-1.31	0.11	0.07	0.122	0.317*	0.1	0.21
7	1	0.29	-0.1	-0.15	1.39	0.34	0.6	-0.57	-0.15	-0.03	0.06	-0.081	0.495***	0.02	-0.21
7	2	-0.29	0.1	0.15	-1.39	-0.34	-0.6	0.57	0.15	0.03	-0.06	0.081	-0.495***	-0.02	0.21
8	1	-0.29	0.36	-0.23	4.77	0.08	0.38	-4.6	1.21	-0.15	0.1	0.128	0.183	0.02	-0.03
8	2	0.29	-0.36	0.23	-4.77	-0.08	-0.38	4.6**	-1.21	0.15	-0.1	-0.128	-0.183	-0.02	0.03
9	1	0.41	-0.18	-0.27	4.89	-3.06*	0	0.26	-1.84	-0.07	0.01	0.044	0.12	-0.18*	-0.15
9	2	-0.41	0.18	0.27	-4.89	3.06*	0	-0.26	1.84	0.07	-0.01	-0.044	-0.12	0.18*	0.15
10	1	-0.07	-0.06	-0.48	1.64	2.27	0.74	-1.72	0.41	-0.07	-0.07	0.128	0.183	-0.04	-0.03
10	2	0.07	0.06	0.48	-1.64	-2.27	-0.74	1.72	-0.41	0.07	0.07	-0.128	-0.183	0.04	0.03
11	1	0.24	-0.39	0.1	-4.86	-0.16	0.49	0.71	-2.75*	-0.15	-0.07	0.044	-0.005	-0.06	0.16
11	2	-0.24	0.39	-0.1	4.86	0.16	-0.49	-0.71	2.75(	0.15	0.07	-0.044	0.005	0.06	-0.16
12	1	0.16	-0.31	-0.11	2.95	-0.48	0.17	3.4*	-1.4	0.05	0.06	0.044	0.058	-0.1	0.04
12	2	-0.16	0.31	0.11	-2.95	0.48	-0.17	-3.4*	1.4	-0.05	-0.06	-0.044	-0.058	0.1	-0.04
13	1	0.08	-0.02	0.02	4.83	0.89	-1.69*	1.34	0.35	0.05	-0.07	-0.039	-0.067	0.07	-0.03
13	2	-0.08	0.02	-0.02	-4.83	-0.89	1.69*	-1.34	-0.35	-0.05	0.07	0.039	0.067	-0.07	0.03
14	1	0.14	0.03	0.06	-7.96*	-1.02	-0.91	1.79	-1.02	-0.24*	-0.11	-0.081	0.12	0.07	-0.09
14	2	-0.14	-0.03	-0.06	7.96*	1.02	0.91	-1.79	1.02	0.24*	0.11	0.081	-0.12	-0.07	0.09
15	1	0.2	-0.14	-0.15	8.77*	0.11	0.37	-0.53	-0.29	0.14	0.06	0.044	-0.005	-0.12	0.04
15	2	-0.2	0.14	0.15	-8.77*	-0.11	-0.37	0.53	0.29	-0.14	-0.06	-0.044	0.005	0.12	-0.04
16	1	-0.02	-0.56	-0.73**	9.58**	-0.88	1.34	-1.98	-1.12	0.1	0.06	0.044	0.058	-0.12	0.16
16	2	0.02	0.56	0.73**	-9.58**	0.88	-1.34	1.98	1.12	-0.1	-0.06	-0.044	-0.058	0.12	-0.16
17	1	0.27	0.44	-0.23	-2.36	0.58	0.12	-0.73	1.34	0.01	-0.15	0.128	-0.13	0.09	0.1
17	2	-0.27	-0.44	0.23	2.36	-0.58	-0.12	0.73	-1.34	-0.01	0.15	-0.128	0.13	-0.09	-0.1
18	1	0.52*	0.11	-0.23	-2.73	-0.47	-0.02	0.12	3.15*	0.01	-0.19*	0.086	-0.192	-0.1	-0.15
18	2	-0.52*	-0.11	0.23	2.73	0.47	0.02	-0.12	-3.15*	-0.01	0.19*	-0.086	0.192	0.1	0.15
19	1	-0.13	-0.31	-0.15	-0.11	-0.83	0.94	5.85***	-2.63	0.39**	-0.03	0.044	-0.067	-0.04	0.04
19	2	0.13	0.31	0.15	0.11	0.83	-0.94	-5.85***	2.63	-0.39**	0.03	-0.044	0.067	0.04	-0.04
20	1	-0.04	0.61*	-0.4	1.58	0.89	0.44	3.86*	-0.59	-0.2	-0.03	0.128	-0.067	0.02	-0.03
20	2	0.04	-0.61*	0.4	-1.58	-0.89	-0.44	-3.86*	0.59	0.2	0.03	-0.128	0.067	-0.02	0.03
21	1	0.1	-0.39	0.31	-1.61	0.23	-0.22	0.94	0.18	0.05	0.1	0.086	-0.067	-0.02	-0.09
21	2	-0.1	0.39	-0.31	1.61	-0.23	0.22	-0.94	-0.18	-0.05	-0.1	-0.086	0.067	0.02	0.09
22	1	-0.14	-0.35	0.23	-1.23	0.2	-0.62	2.81	0.77	-0.03	0.06	-0.039	-0.13	-0.02	0.1
22	2	0.14	0.35	-0.23	1.23	-0.2	0.62	-2.81	-0.77	0.03	-0.06	0.039	0.13	0.02	-0.1
23	1	0.14	-0.14	0.1	1.95	-2.31	1.39	-0.17	1.91	0.05	-0.07	0.044	-0.067	-0.02	-0.15
23	2	-0.14	0.14	-0.1	-1.95	2.31	-1.39	0.17	-1.91	-0.05	0.07	-0.044	0.067	0.02	0.15
24	1	-0.13	0.03	0.27	-6.55	-1.52	0.16	2.84	1.59	-0.15	0.06	0.128	0.12	0	0.29*
24	2	0.13	-0.03	-0.27	6.55	1.52	-0.16	-2.84	-1.59	0.15	-0.06	-0.128	-0.12	0	-0.29*
25	1	-0.35	-0.56	0.18	-1.3	-0.06	0.85	-0.11	2.01	0.1	0.06	0.003	0.12	0	-0.03
25	2	0.35	0.56	-0.18	1.3	0.06	-0.85	0.11	-2.01	-0.1	-0.06	-0.003	-0.12	0	0.03
26	1	-0.07	-0.02	-0.02	-0.17	1.06	-1.87*	-3	1.08	0.01	-0.03	0.128	-0.192	-0.06	0.22
26	2	0.07	0.02	0.02	0.17	-1.06	1.87*	3	-1.08	-0.01	0.03	-0.128	0.192	0.06	-0.22

Appendix 4.2: Across SCA –contd

LINE	TESTER	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
27	1	-0.06	0.19	-0.65*	1.89	0.74	0.49	1.41	-2.57	0.14	0.01	0.044	-0.005	0.11	0.22
27	2	0.06	-0.19	0.65*	-1.89	-0.74	-0.49	-1.41	2.57	-0.14	-0.01	-0.044	0.005	-0.11	-0.22
28	1	0.05	0.65*	0.52	3.58	0.78	-0.05	4.16**	-0.49	0.1	-0.03	-0.039	-0.005	0.23**	-0.03
28	2	-0.05	-0.65*	-0.52	-3.58	-0.78	0.05	-4.16**	0.49	-0.1	0.03	0.039	0.005	-0.23**	0.03
29	1	0.19	0.48	-0.07	7.02	-0.69	-0.25	-1.22	0.92	0.18	-0.11	-0.122	0.12	-0.1	0.04
29	2	-0.19	-0.48	0.07	-7.02	0.69	0.25	1.22	-0.92	-0.18	0.11	0.122	-0.12	0.1	-0.04
30	1	0.07	-0.18	-0.48	5.64	-0.73	0.29	0.57	-1.48	-0.15	0.06	0.003	0.058	-0.06	-0.03
30	2	-0.07	0.18	0.48	-5.64	0.73	-0.29	-0.57	1.48	0.15	-0.06	-0.003	-0.058	0.06	0.03
31	1	-0.23	0.32	0.64*	1.52	-0.09	-1.4	1.16	0.2	0.05	0.01	0.003	0.183	0	0.04
31	2	0.23	-0.32	-0.64*	-1.52	0.09	1.4	-1.16	-0.2	-0.05	-0.01	-0.003	-0.183	0	-0.04
32	1	0.01	-0.39	0.23	1.14	0.37	-1	-0.2	1.9	-0.24*	-0.03	-0.122	-0.005	-0.02	-0.09
32	2	-0.01	0.39	-0.23	-1.14	-0.37	1	0.2	-1.9	0.24*	0.03	0.122	0.005	0.02	0.09
33	1	-0.14	-0.14	0.39	1.27	-3.55**	1.25	3.53*	-0.39	0.3**	-0.03	0.003	0.058	0.07	-0.21
33	2	0.14	0.14	-0.39	-1.27	3.55**	-1.25	-3.53*	0.39	-0.3**	0.03	-0.003	-0.058	-0.07	0.21
34	1	0.04	0.28	-0.19	-2.42	1.77	1.29	-1.06	0.89	-0.36**	0.06	0.086	0.058	0.09	0.04
34	2	-0.04	-0.28	0.19	2.42	-1.77	-1.29	1.06	-0.89	0.36**	-0.06	-0.086	-0.058	-0.09	-0.04
35	1	-0.13	-0.64*	-0.11	-5.48	-1.35	-0.34	-2.87	-0.59	0.22	0.01	-0.164*	0.058	0.02	-0.03
35	2	0.13	0.64*	0.11	5.48	1.35	0.34	2.87	0.59	-0.22	-0.01	0.164*	-0.058	-0.02	0.03
36	1	0.24	0.11	0.27	-10.73**	0	-1.14	-1.39	-1.5	0.05	-0.03	0.003	0.183	-0.18*	-0.03
36	2	-0.24	-0.11	-0.27	10.73**	0	1.14	1.39	1.5	-0.05	0.03	-0.003	-0.183	0.18*	0.03
37	1	-0.75**	0.53	-0.23	-5.17	0.34	-0.66	-3.08*	1.43	0.01	-0.11	-0.081	-0.13	0.11	0.04
37	2	0.75**	-0.53	0.23	5.17	-0.34	0.66	3.08*	-1.43	-0.01	0.11	0.081	0.13	-0.11	-0.04
38	1	0.24	-0.35	-1.11***	3.77	-0.41	1.52*	-1.8	-1.39	-0.28*	0.01	0.169*	-0.255	0.07	-0.09
38	2	-0.24	0.35	1.11***	-3.77	0.41	-1.52*	1.8	1.39	0.28*	-0.01	-0.169*	0.255	-0.07	0.09
39	1	-0.04	-0.1	0.73*	-5.61	-0.23	-1.1	0.46	1.81	0.14	-0.11	0.044	-0.067	0.09	-0.03
39	2	0.04	0.1	-0.73*	5.61	0.23	1.1	-0.46	-1.81	-0.14	0.11	-0.044	0.067	-0.09	0.03
40	1	-0.22	0.78**	0.02	-1.17	-0.48	-0.21	-1.24	0.47	-0.2	-0.03	-0.164*	-0.067	-0.12	-0.03
40	2	0.22	-0.78**	-0.02	1.17	0.48	0.21	1.24	-0.47	0.2	0.03	0.164*	0.067	0.12	0.03
41	1	-0.26	0.32	-0.11	-3.17	0.22	0.72	1.25	0.55	-0.07	0.01	0.086	-0.192	0.11	0.22
41	2	0.26	-0.32	0.11	3.17	-0.22	-0.72	-1.25	-0.55	0.07	-0.01	-0.086	0.192	-0.11	-0.22
42	1	0.01	0.28	-0.15	0.64	1.15	-1.4	-1.95	-1.97	0.01	0.06	-0.081	-0.067	-0.04	-0.09
42	2	-0.01	-0.28	0.15	-0.64	-1.15	1.4	1.95	1.97	-0.01	-0.06	0.081	0.067	0.04	0.09
43	1	0.26	0.11	-1.07***	-1.23	2.2	-0.9	-2.74	-0.11	0.18	0.01	-0.039	-0.13	-0.16	-0.03
43	2	-0.26	-0.11	1.07***	1.23	-2.2	0.9	2.74	0.11	-0.18	-0.01	0.039	0.13	0.16	0.03
44	1	-0.29	0.03	0.52	0.33	0.11	-0.41	3.16*	-0.25	-0.03	-0.03	0.336***	-0.067	0.17	0.22
44	2	0.29	-0.03	-0.52	-0.33	-0.11	0.41	-3.16*	0.25	0.03	0.03	-0.336***	0.067	-0.17	-0.22
45	1	0.14	-0.68*	0.02	1.56	0.32	-0.38	-1.61	-0.91	0.26*	0.01	0.003	-0.13	0	-0.03
45	2	-0.14	0.68*	-0.02	-1.56	-0.32	0.38	1.61	0.91	-0.26*	-0.01	-0.003	0.13	0	0.03
46	1	-0.16	0.98***	-0.4	-7.3*	2.66*	0.35	-1.24	-1.67	0.01	0.06	0.003	0.12	0.02	0.1
46	2	0.16	-0.98***	0.4	7.3*	-2.66*	-0.35	1.24	1.67	-0.01	-0.06	-0.003	-0.12	-0.02	-0.1
47	1	0.06	0.28	0.06	1.58	0.65	0.99	-1.16	-0.43	-0.15	0.06	-0.081	0.058	-0.04	-0.03
47	2	-0.06	-0.28	-0.06	-1.58	-0.65	-0.99	1.16	0.43	0.15	-0.06	0.081	-0.058	0.04	0.03
48	1	0.13	0.28	-0.19	1.39	0.29	-0.51	-2.38	-1.01	0.18	0.01	0.003	-0.067	-0.16	-0.09
48	2	-0.13	-0.28	0.19	-1.39	-0.29	0.51	2.38	1.01	-0.18	-0.01	-0.003	0.067	0.16	0.09
49	1	-0.06	-0.14	0.39	1.2	3.41**	-0.38	1.58	0.56	0.05	0.06	-0.039	0.12	0.07	-0.15
49	2	0.06	0.14	-0.39	-1.2	-3.41**	0.38	-1.58	-0.56	-0.05	-0.06	0.039	-0.12	-0.07	0.15
50	1	-0.1	-0.1	-0.48	-5.17	1.84	-0.48	-1.54	-1.76	-0.03	-0.03	-0.039	-0.067	-0.1	-0.09
50	2	0.1	0.1	0.48	5.17	-1.84	0.48	1.54	1.76	0.03	0.03	0.039	0.067	0.1	0.09
51	1	-0.15	-0.1	0.27	6.27	-0.18	0.19	-1.52	1.59	0.18	0.06	0.086	-0.005	0	0.1
51	2	0.15	0.1	-0.27	-6.27	0.18	-0.19	1.52	-1.59	-0.18	-0.06	-0.086	0.005	0	-0.1
52	1	0.35	-0.14	-0.11	3.39	-1.03	-0.4	-2.73	0.73	-0.03	0.06	0.044	-0.192	-0.02	0.1
52	2	-0.35	0.14	0.11	-3.39	1.03	0.4	2.73	-0.73	0.03	-0.06	-0.044	0.192	0.02	-0.1
53	1	0.23	-0.35	0.18	6.02	-0.14	0.67	-0.23	2.07	-0.24*	0.1	-0.081	0.183	-0.06	-0.28*
53	2	-0.23	0.35	-0.18	-6.02	0.14	-0.67	0.23	-2.07	0.24*	-0.1	0.081	-0.183	0.06	0.28*

Appendix 4.3: Across SCA- contd

LINE	TESTER	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
54	1	-0.15	-0.47	0.06	-2.55	-1.62	1.51*	2.86	-0.12	0.05	0.01	0.086	0.12	0.05	-0.15
54	2	0.15	0.47	-0.06	2.55	1.62	-1.51*	-2.86	0.12	-0.05	-0.01	-0.086	-0.12	-0.05	0.15
55	1	-0.04	-0.06	-0.11	-5.42	-1.05	-0.2	-0.32	-1.3	-0.2	0.06	0.169*	-0.067	0	-0.09
55	2	0.04	0.06	0.11	5.42	1.05	0.2	0.32	1.3	0.2	-0.06	-0.169*	0.067	0	0.09
56	1	0.32	0.07	-0.57*	1.77	1.03	-0.75	6.71***	-0.49	-0.07	0.1	0.003	-0.005	-0.08	-0.15
56	2	-0.32	-0.07	0.57*	-1.77	-1.03	0.75	-6.71***	0.49	0.07	-0.1	-0.003	0.005	0.08	0.15
57	1	0.44	-1.22***	0.06	-0.55	0.62	-2.01**	1.34	0.66	0.01	-0.03	0.086	-0.005	-0.08	-0.09
57	2	-0.44	1.22***	-0.06	0.55	-0.62	2.01**	-1.34	-0.66	-0.01	0.03	-0.086	0.005	0.08	0.09
58	1	-0.12	-0.35	0.48	-0.23	-0.87	0.07	-1.2	-0.71	0.18	0.01	0.044	0.433**	0	-0.09
58	2	0.12	0.35	-0.48	0.23	0.87	-0.07	1.2	0.71	-0.18	-0.01	-0.044	-0.433**	0	0.09
59	1	-0.43	0.11	0.43	-1.42	1.37	0.58	1.58	-0.34	0.05	-0.07	0.003	0.058	0.07	-0.03
59	2	0.43	-0.11	-0.43	1.42	-1.37	-0.58	-1.58	0.34	-0.05	0.07	-0.003	-0.058	-0.07	0.03
60	1	0.04	-0.1	0.14	0.65	0.4	0.86	0.59	-2.05	-0.24*	-0.03	-0.039	-0.067	-0.06	0.22
60	2	-0.04	0.1	-0.14	-0.65	-0.4	-0.86	-0.59	2.05	0.24*	0.03	0.039	0.067	0.06	-0.22
61	1	0.24	0.28	-0.23	-3.23	-2.61*	0.13	2.02	-0.45	-0.03	0.06	0.086	-0.13	-0.08	0.16
61	2	-0.24	-0.28	0.23	3.23	2.61*	-0.13	-2.02	0.45	0.03	-0.06	-0.086	0.13	0.08	-0.16
62	1	-0.1	0.07	-0.02	5.2	-1.36	0.38	0.68	1.42	-0.15	-0.07	0.128	-0.005	-0.04	0.1
62	2	0.1	-0.07	0.02	-5.2	1.36	-0.38	-0.68	-1.42	0.15	0.07	-0.128	0.005	0.04	-0.1
63	1	-0.1	-0.43	0.14	3.27	0.88	0.01	-1.01	-2.18	-0.03	-0.03	0.086	-0.067	-0.06	0.04
63	2	0.1	0.43	-0.14	-3.27	-0.88	-0.01	1.01	2.18	0.03	0.03	-0.086	0.067	0.06	-0.04
64	1	-0.33	0.28	0.14	4.27	1.26	-0.1	-1.3	0.96	0.22	0.1	0.169*	-0.13	0.07	-0.15
64	2	0.33	-0.28	-0.14	-4.27	-1.26	0.1	1.3	-0.96	-0.22	-0.1	-0.169*	0.13	-0.07	0.15
65	1	0.1	-0.1	0.85**	-1.48	0.41	-0.45	4.3**	-1.71	0.14	-0.11	-0.081	-0.255	-0.06	0.16
65	2	-0.1	0.1	-0.85**	1.48	-0.41	0.45	-4.3**	1.71	-0.14	0.11	0.081	0.255	0.06	-0.16
66	1	0.68**	-0.52	-0.23	2.52	0.14	-0.29	-0.68	-0.9	-0.03	-0.07	-0.039	-0.005	-0.27**	-0.15
66	2	-0.68**	0.52	0.23	-2.52	-0.14	0.29	0.68	0.9	0.03	0.07	0.039	0.005	0.27**	0.15
67	1	0.33	0.11	-0.23	0.02	-0.6	0.28	-0.09	0.78	0.1	0.1	-0.206**	0.12	-0.06	0.1
67	2	-0.33	-0.11	0.23	-0.02	0.6	-0.28	0.09	-0.78	-0.1	-0.1	0.206**	-0.12	0.06	-0.1
68	1	-0.16	0.11	0.23	-4.11	1.03	1.54*	0.83	0.25	0.1	-0.07	-0.122	-0.067	0.07	0.16
68	2	0.16	-0.11	-0.23	4.11	-1.03	-1.54*	-0.83	-0.25	-0.1	0.07	0.122	0.067	-0.07	-0.16
69	1	0.31	-0.1	-0.11	5.58	-0.01	0.34	-1.21	-0.29	-0.11	0.01	-0.039	-0.255	-0.04	-0.21
69	2	-0.31	0.1	0.11	-5.58	0.01	-0.34	1.21	0.29	0.11	-0.01	0.039	0.255	0.04	0.21
70	1	-0.43	0.65*	0.68*	-0.55	-3.72**	0.32	-0.68	-0.82	-0.15	-0.07	-0.039	0.12	0.13	0.16
70	2	0.43	-0.65*	-0.68*	0.55	3.72**	-0.32	0.68	0.82	0.15	0.07	0.039	-0.12	-0.13	-0.16
71	1	-0.02	0.69*	0.1	-2.33	0.56	1.48*	1.39	0.15	-0.03	-0.07	-0.164*	0.058	0.07	0.1
71	2	0.02	-0.69*	-0.1	2.33	-0.56	-1.48*	-1.39	-0.15	0.03	0.07	0.164*	-0.058	-0.07	-0.1
72	1	0.13	-0.1	-0.69*	7.39*	0.4	0.71	-0.86	-1.51	0.01	-0.07	-0.039	-0.192	-0.16	-0.03
72	2	-0.13	0.1	0.69*	-7.39*	-0.4	-0.71	0.86	1.51	-0.01	0.07	0.039	0.192	0.16	0.03
73	1	0.31	0.15	-0.27	-2.61	-0.45	-1.46	-1.33	-0.8	0.18	0.01	0.044	0.12	-0.1	-0.03
73	2	-0.31	-0.15	0.27	2.61	0.45	1.46	1.33	0.8	-0.18	-0.01	-0.044	-0.12	0.1	0.03
74	1	-0.16	0.69*	0.1	2.89	0.31	0.65	3.27*	0.86	-0.03	-0.07	-0.039	-0.13	0.07	-0.09
74	2	0.16	-0.69*	-0.1	-2.89	-0.31	-0.65	-3.27*	-0.86	0.03	0.07	0.039	0.13	-0.07	0.09
75	1	0	-0.1	0.27	-3.86	1.31	-0.51	-0.93	0.41	-0.11	-0.07	0.003	0.37**	0.05	-0.03
75	2	0	0.1	-0.27	3.86	-1.31	0.51	0.93	-0.41	0.11	0.07	-0.003	-0.37**	-0.05	0.03
76	1	0.33	0.23	-0.11	1.77	-3.59**	-0.07	-1.24	-1.69	0.01	0.06	0.128	0.183	0.02	-0.03
76	2	-0.33	-0.23	0.11	-1.77	3.59**	0.07	1.24	1.69	-0.01	-0.06	-0.128	-0.183	-0.02	0.03
77	1	0.18	0.07	-0.44	3.52	-1.47	-0.04	-0.43	0.73	-0.11	0.06	0.044	-0.067	0.19*	-0.03
77	2	-0.18	-0.07	0.44	-3.52	1.47	0.04	0.43	-0.73	0.11	-0.06	-0.044	0.067	-0.19*	0.03
78	1	-0.31	0.32	-0.19	-3.55	0.41	-0.06	1.96	-1.58	0.05	0.01	-0.122	0.183	0.09	0.16
78	2	0.31	-0.32	0.19	3.55	-0.41	0.06	-1.96	1.58	-0.05	-0.01	0.122	-0.183	-0.09	-0.16
79	1	-0.06	-0.47	0.02	-0.36	-0.98	0.59	3.7*	0.89	0.14	0.01	0.003	0.058	0.07	-0.03
79	2	0.06	0.47	-0.02	0.36	0.98	-0.59	-3.7*	-0.89	-0.14	-0.01	-0.003	-0.058	-0.07	0.03
80	1	-0.01	-0.18	-0.23	-3.86	0.8	-0.4	0.88**	-0.28	0.1	0.01	-0.122	0.183	-0.04	0.04
80	2	0.01	0.18	0.23	3.86	-0.8	0.4	-0.88	0.28	-0.1	-0.01	0.122	-0.183	0.04	-0.04

Appendix 4.4: Across SCA- Contd

LINE	TESTER	GY	AD	ASI	PH	RL	SL	HC	ER	GLS	PS	ET	MSV	EA	PA
81	1	0.26	-0.68*	0.27	-4.86	-2.01	-0.93	-0.46	0.32	-0.03	-0.11	0.003	-0.067	0.13	0.22
81	2	-0.26	0.68*	-0.27	4.86	2.01	0.93	0.46	-0.32	0.03	0.11	-0.003	0.067	-0.13	-0.22
82	1	0.14	0.11	0.1	2.58	-0.06	0.2	2.21	-0.7	-0.28*	0.01	-0.081	0.058	-0.06	-0.03
82	2	-0.14	-0.11	-0.1	-2.58	0.06	-0.2	-2.21	0.7	0.28*	-0.01	0.081	-0.058	0.06	0.03
83	1	0.05	-0.47	0.18	-3.3	1.25	-1.97**	3.4*	0.95	0.01	0.06	-0.039	-0.067	-0.04	-0.15
83	2	-0.05	0.47	-0.18	3.3	-1.25	1.97**	-3.4*	-0.95	-0.01	-0.06	0.039	0.067	0.04	0.15
84	1	0.1	0.23	-0.61*	-4.36	-1.44	-0.11	0.13	-0.78	-0.11	0.06	-0.081	-0.067	0	-0.15
84	2	-0.1	-0.23	0.61*	4.36	1.44	0.11	-0.13	0.78	0.11	-0.06	0.081	0.067	0	0.15
85	1	0.02	0.11	0.31	6.02	-1.24	-1.17	-1.91	-0.75	-0.03	0.06	-0.081	-0.005	0	0.1
85	2	-0.02	-0.11	-0.31	-6.02	1.24	1.17	1.91	0.75	0.03	-0.06	0.081	0.005	0	-0.1
86	1	0.11	-0.14	-0.27	4.95	0.02	-0.93	0.76	1.09	-0.28*	-0.03	0.044	-0.13	-0.08	-0.03
86	2	-0.11	0.14	0.27	-4.95	-0.02	0.93	-0.76	-1.09	0.28*	0.03	-0.044	0.13	0.08	0.03
87	1	0.33	0.82**	0.18	7.95*	-0.4	-0.59	1.43	-0.83	-0.03	0.01	0.003	0.058	-0.29***	-0.15
87	2	-0.33	-0.82**	-0.18	-7.95*	0.4	0.59	-1.43	0.83	0.03	-0.01	-0.003	-0.058	0.29***	0.15
88	1	0.05	-1.47***	-0.32	-4.36	-0.81	-0.33	-2.52	0.75	0.14	0.01	0.086	-0.192	0	0.04
88	2	-0.05	1.47***	0.32	4.36	0.81	0.33	2.52	-0.75	-0.14	-0.01	-0.086	0.192	0	-0.04
89	1	0.1	-0.64*	-0.11	-0.17	-1.26	-0.04	-2.07	-0.44	0.1	-0.07	0.003	-0.13	-0.08	-0.03
89	2	-0.1	0.64*	0.11	0.17	1.26	0.04	2.07	0.44	-0.1	0.07	-0.003	0.13	0.08	0.03
90	1	0.07	-0.22	-0.19	2.2	-0.92	0.2	0.32	2.12	0.01	0.01	0.003	-0.005	0	0.16
90	2	-0.07	0.22	0.19	-2.2	0.92	-0.2	-0.32	-2.12	-0.01	-0.01	-0.003	0.005	0	-0.16
91	1	-0.17	-0.06	-0.02	1.58	0.87	0.09	-1.57	2.74*	0.05	0.01	0.003	-0.067	0	-0.21
91	2	0.17	0.06	0.02	-1.58	-0.87	-0.09	1.57	-2.74*	-0.05	-0.01	-0.003	0.067	0	0.21
92	1	-0.32	0.28	0.1	-1.48	-0.12	0.18	0.49	2.84*	-0.11	-0.11	0.044	-0.192	0.13	0.16
92	2	0.32	-0.28	-0.1	1.48	0.12	-0.18	-0.49	-2.84*	0.11	0.11	-0.044	0.192	-0.13	-0.16
93	1	-0.31	0.61*	-0.11	-7.73*	0.85	1.16	-2.2	2.21	-0.11	-0.03	-0.081	0.058	0.25**	0.1
93	2	0.31	-0.61*	0.11	7.73*	-0.85	-1.16	2.2	-2.21	0.11	0.03	0.081	-0.058	-0.25**	-0.1
94	1	-0.06	0.07	0.06	-3.36	-0.86	-1.21	-3.34*	0.77	0.01	-0.03	-0.039	-0.005	0.09	0.1
94	2	0.06	-0.07	-0.06	3.36	0.86	1.21	3.34*	-0.77	-0.01	0.03	0.039	0.005	-0.09	-0.1
95	1	-0.61*	-0.35	0.52	-0.17	-0.21	1.32	-0.97	0.01	0.05	0.01	0.044	0.058	0.11	0.1
95	2	0.61*	0.35	-0.52	0.17	0.21	-1.32	0.97	-0.01	-0.05	-0.01	-0.044	-0.058	-0.11	-0.1
96	1	-0.21	0.53	0.1	-2.05	-0.5	0.36	-0.99	-1.22	0.05	0.06	-0.039	-0.005	0.11	0.04
96	2	0.21	-0.53	-0.1	2.05	0.5	-0.36	0.99	1.22	-0.05	-0.06	0.039	0.005	-0.11	-0.04
97	1	-0.18	0.19	0.6*	-4.36	-0.41	-0.51	0.46	0.68	0.01	0.01	-0.122	0.245	0.15	0.04
97	2	0.18	-0.19	-0.6*	4.36	0.41	0.51	-0.46	-0.68	-0.01	-0.01	0.122	-0.245	-0.15	-0.04
98	1	-0.26	-0.22	0.06	0.58	-0.34	-0.23	3.63*	0.08	0.05	-0.07	0.086	0.12	0.09	0.04
98	2	0.26	0.22	-0.06	-0.58	0.34	0.23	-3.63*	-0.08	-0.05	0.07	-0.086	-0.12	-0.09	-0.04
99	1	0.04	-0.27	-0.23	2.64	-0.26	-0.18	-1.78	-1.92	0.18	0.06	-0.039	-0.192	-0.14	-0.21
99	2	-0.04	0.27	0.23	-2.64	0.26	0.18	1.78	1.92	-0.18	-0.06	0.039	0.192	0.14	0.21
100	1	-0.26	0.44	0.35	-3.05	-0.26	0.31	0.37	0.39	0.22	-0.07	-0.081	0.183	0.07	0.22
100	2	0.26	-0.44	-0.35	3.05	0.26	-0.31	-0.37	-0.39	-0.22	0.07	0.081	-0.183	-0.07	-0.22
101	1	-0.78**	0.44	0.27	-0.48	-0.56	0.83	1.84	-0.31	-0.24*	0.43***	-0.122	-0.13	0.19*	0.1
101	2	0.78**	-0.44	-0.27	0.48	0.56	-0.83	-1.84	0.31	0.24*	-0.43***	0.122	0.13	-0.19*	-0.1
102	1	0.04	-0.14	0.02	-0.73	1.24	-0.5	-0.38	2.31	0.05	0.01	0.003	-0.192	-0.02	0.04
102	2	-0.04	0.14	-0.02	0.73	-1.24	0.5	0.38	-2.31	-0.05	-0.01	-0.003	0.192	0.02	-0.04
103	1	-0.06	-0.1	0.93***	-3.23	2.01	1.17	-1.75	-0.68	-0.07	0.01	-0.122	-0.005	0.05	0.1
103	2	0.06	0.1	-0.93***	3.23	-2.01	-1.17	1.75	0.68	0.07	-0.01	0.122	0.005	-0.05	-0.1
104	1	-0.52*	0.57	0.39	0.7	1.06	0.44	-1.37	1.42	0.26*	0.01	0.086	-0.005	0.25**	-0.15
104	2	0.52*	-0.57	-0.39	-0.7	-1.06	-0.44	1.37	-1.42	-0.26*	-0.01	-0.086	0.005	-0.25*	0.15
105	1	-0.39	0.07	0.39	-2.55	0.5	0.34	-1.18	-0.06	0.18	0.01	0.003	0.058	0.15	0.04
105	2	0.39	-0.07	-0.39	2.55	-0.5	-0.34	1.18	0.06	-0.18	-0.01	-0.003	-0.058	-0.15	-0.04
106	1	-0.44	-0.02	0.27	0.58	2.03	-0.17	0.59	1.93	-0.15	0.06	-0.247**	-0.13	0.17	0.1
106	2	0.44	0.02	-0.27	-0.58	-2.03	0.17	-0.59	-1.93	0.15	-0.06	0.247**	0.13	-0.17	-0.1

Appendix 5.1: Stability parameters for primary data

					Eberhart and Russel		Finlay and Wilkinson						Eberhart and Russel		Finlay and Wilkinson
Entry	**Mean**	**Wricke**	**CV**	**Shukla**	**b- Values**	**Standard dev**	**b**	**Entry**	**Mean**	**Wricke**	**CV**	**Shukla**	**b-Values**	**Standard dev**	**b**
1	7.09	34.31	29.75	6.91	1.03	2.04	1.03	**54**	6.01	40.86	40.85	8.23	1.27	1.62	1.27
2	5.83	28.22	37.31	5.68	1.18	1.15	1.19	**55**	6.32	15.73	32.89	3.16	1.17	0.56	1.17
3	5.69	14.59	37.08	2.93	1.22	0.75	1.22	**56**	6.38	9.87	26.44	1.97	0.94	0.71	0.94
4	5.54	19.11	24.51	3.84	0.69	0.23	0.69	**57**	5.72	10.36	31.14	2.07	1.07	0.66	1.06
5	4.88	21.08	40.46	4.24	1.07	1.06	1.07	**58**	5.50	15.08	27.03	3.02	0.78	0.95	0.78
6	4.63	12.48	38.18	2.50	1.00	1.23	1.00	**59**	5.72	26.46	30.33	5.32	0.88	0.46	0.88
7	6.68	17.69	29.63	3.55	1.09	0.67	1.09	**60**	5.73	28.71	28.10	5.78	0.69	0.88	0.69
8	6.13	18.85	24.07	3.79	0.76	0.99	0.76	**61**	5.13	28.02	30.48	5.64	0.65	0.39	0.65
9	6.29	12.98	29.59	2.60	1.04	0.49	1.04	**62**	5.74	17.75	32.62	3.56	0.99	1.49	0.99
10	5.82	9.45	27.68	1.89	0.88	0.71	0.88	**63**	6.05	13.67	29.03	2.74	1.01	1.09	1.01
11	5.67	13.96	31.78	2.80	0.96	0.87	0.96	**64**	6.17	6.22	28.22	1.24	1.04	0.52	1.04
12	6.26	23.44	28.90	4.71	0.92	0.62	0.92	**65**	5.23	20.83	37.37	4.19	1.07	1.05	1.07
13	6.00	26.80	37.49	5.39	1.24	0.92	1.24	**66**	5.66	40.98	30.05	8.25	0.66	2.08	0.66
14	5.59	22.89	32.19	4.60	0.89	0.70	0.88	**67**	5.72	20.36	29.85	4.09	0.90	1.72	0.90
15	5.52	30.41	37.59	6.12	1.11	1.15	1.11	**68**	5.79	16.81	32.02	3.37	1.06	1.25	1.06
16	6.25	22.06	30.22	4.43	0.99	1.11	0.99	**69**	5.65	21.71	33.35	4.36	0.99	1.64	0.99
17	6.78	16.57	31.12	3.33	1.23	0.51	1.24	**70**	6.06	14.82	24.23	2.97	0.74	0.66	0.75
18	6.10	15.26	31.70	3.06	1.08	1.44	1.08	**71**	5.98	19.09	36.17	3.83	1.24	1.22	1.24
19	5.85	14.23	20.09	2.85	0.60	0.62	0.60	**72**	5.66	14.98	27.94	3.00	0.82	0.85	0.82
20	6.14	15.47	33.19	3.10	1.16	1.36	1.17	**73**	5.95	17.20	24.25	3.45	0.71	0.40	0.71
21	5.80	20.79	33.65	4.18	1.02	0.81	1.03	**74**	7.59	30.68	25.30	6.17	0.88	1.56	0.89
22	5.48	17.94	26.39	3.60	0.71	1.18	0.71	**75**	5.78	19.10	26.34	3.83	0.78	0.75	0.78
23	6.81	9.33	24.18	1.86	0.96	0.97	0.95	**76**	5.45	19.89	29.89	3.99	0.76	0.86	0.76
24	6.64	18.09	27.85	3.63	0.95	1.10	0.95	**77**	5.44	13.45	34.63	2.70	1.08	1.28	1.08
25	7.05	28.77	30.32	5.79	1.17	1.75	1.18	**78**	5.67	16.45	24.71	3.30	0.69	1.04	0.69
26	7.04	19.20	28.94	3.86	1.09	0.41	1.09	**79**	5.42	34.20	44.13	6.88	1.32	1.72	1.32
27	6.72	50.49	41.84	10.17	1.52	1.11	1.52	**80**	6.00	8.26	30.75	1.65	1.05	0.72	1.05
28	6.60	7.10	23.47	1.41	0.88	0.60	0.89	**81**	5.42	15.85	30.26	3.18	0.89	1.78	0.88
29	6.24	14.17	29.04	2.84	0.96	1.03	0.96	**82**	6.09	17.10	24.86	3.43	0.77	1.18	0.76
30	5.99	31.11	26.88	6.26	0.66	1.40	0.66	**83**	6.11	15.59	26.34	3.13	0.86	0.70	0.86
31	6.75	34.47	33.87	6.94	1.16	1.55	1.16	**84**	6.24	25.49	30.51	5.13	0.97	0.88	0.96
32	6.94	44.35	33.32	8.93	1.09	1.70	1.10	**85**	5.84	15.84	32.85	3.18	1.03	0.89	1.03
33	6.56	19.33	28.46	3.88	0.97	1.67	0.97	**86**	5.47	10.08	33.10	2.01	1.07	0.99	1.07
34	6.18	17.11	28.11	3.43	0.95	0.52	0.94	**87**	5.71	13.31	32.18	2.67	1.06	1.27	1.07
35	7.20	17.90	29.52	3.59	1.21	1.14	1.21	**88**	6.43	22.12	34.24	4.45	1.23	0.74	1.23
36	6.32	16.74	29.73	3.36	0.97	1.09	0.97	**89**	5.93	15.08	26.29	3.02	0.84	1.26	0.84
37	6.19	25.30	30.98	5.09	0.95	0.98	0.95	**90**	5.81	19.31	29.29	3.88	0.94	1.67	0.93
38	6.60	37.91	32.64	7.63	1.02	2.16	1.02	**91**	5.59	34.57	30.61	6.96	0.74	1.52	0.74
39	5.53	22.09	36.25	4.44	1.09	1.16	1.09	**92**	6.07	21.98	36.77	4.42	1.27	1.58	1.28
40	5.77	29.90	33.58	6.02	0.88	1.01	0.88	**93**	5.16	7.21	31.47	1.44	0.89	0.63	0.89
41	5.04	31.54	37.95	6.35	0.92	0.89	0.92	**94**	5.20	11.40	38.25	2.28	1.13	0.42	1.13
42	4.99	15.65	22.68	3.14	0.58	0.64	0.58	**95**	5.94	11.85	35.68	2.37	1.30	0.42	1.30
43	5.36	38.18	36.64	7.69	0.87	0.91	0.87	**96**	5.84	17.89	33.54	3.59	1.08	1.49	1.07
44	5.79	8.96	30.59	1.79	1.04	1.11	1.04	**97**	5.99	21.99	38.21	4.42	1.36	1.72	1.36
45	5.34	18.14	43.32	3.64	1.39	1.06	1.39	**98**	6.27	34.45	37.80	6.94	1.27	1.60	1.27
46	5.22	11.74	30.58	2.35	0.87	0.45	0.87	**99**	6.22	16.29	26.09	3.27	0.87	0.78	0.87
47	5.30	10.20	34.21	2.04	0.99	0.81	0.99	**100**	6.58	38.03	26.96	7.66	0.73	1.49	0.73
48	5.71	18.24	33.85	3.66	1.06	1.34	1.06	**101**	5.42	19.09	32.69	3.83	0.96	0.82	0.96
49	5.39	10.57	31.62	2.11	1.02	1.22	1.02	**102**	5.87	29.92	24.68	6.02	0.57	0.92	0.57
50	6.25	31.16	30.65	6.27	0.90	1.26	0.90	**103**	5.99	21.13	36.65	4.24	1.30	0.89	1.30
51	5.66	10.45	34.50	2.09	1.18	0.62	1.18	**104**	5.45	60.34	36.02	12.16	0.60	2.09	0.60
52	5.95	26.41	34.71	5.31	1.02	1.53	1.02	**105**	6.30	39.68	32.80	7.99	0.97	1.36	0.96
53	5.74	43.88	43.57	8.84	1.26	1.30	1.26	**106**	6.00	43.87	27.35	8.84	0.53	2.18	0.54
								107	5.91	20.77	28.81	4.17	0.81	1.62	0.81

Appendix 5.2: Stability parameters for primary data-contd

					Eberhart and Russel		Finlay and Wilkinson						Eberhart and Russel		Finlay and Wilkinson
Entry	**Mean**	**Wricke**	**CV**	**Shukla**	**b- Values**	**Standard dev**	**b**	**Entry**	**Mean**	**Wricke**	**CV**	**Shukla**	**b- Values**	**Standard dev**	**b**
108	6.36	15.23	34.80	3.05	1.29	1.15	1.29	**162**	5.65	18.23	39.87	3.66	1.33	0.54	1.33
109	6.16	27.04	37.90	5.44	1.29	1.13	1.29	**163**	6.24	15.62	35.09	3.13	1.31	1.15	1.31
110	6.39	6.20	26.93	1.23	0.98	0.59	0.98	**164**	6.12	17.44	28.01	3.50	0.85	1.15	0.85
111	6.04	24.30	37.18	4.89	1.27	1.85	1.27	**165**	5.80	16.31	33.01	3.27	1.06	0.90	1.07
112	5.56	35.20	34.96	7.09	0.88	0.68	0.88	**166**	5.85	9.52	29.20	1.90	0.99	1.17	0.98
113	6.60	32.86	32.74	6.61	1.11	1.12	1.11	**167**	5.76	22.69	31.06	4.56	0.93	0.72	0.93
114	5.87	17.12	27.48	3.44	0.80	1.25	0.80	**168**	5.71	7.40	29.23	1.47	0.95	0.93	0.95
115	6.06	27.10	35.71	5.45	1.14	1.79	1.15	**169**	5.60	22.60	29.08	4.54	0.80	0.55	0.80
116	6.46	16.87	26.06	3.39	0.88	0.72	0.88	**170**	5.71	34.57	29.59	6.96	0.75	0.98	0.75
117	5.74	18.26	34.04	3.67	1.05	0.61	1.05	**171**	6.27	22.54	38.15	4.53	1.41	0.76	1.41
118	6.76	11.74	32.37	2.35	1.32	0.79	1.32	**172**	6.21	23.33	30.07	4.69	0.93	0.69	0.93
119	6.39	45.84	29.80	9.23	0.67	2.16	0.67	**173**	5.97	14.96	31.18	3.00	0.98	0.92	0.99
120	6.45	22.66	31.43	4.55	1.09	0.76	1.09	**174**	5.46	17.49	29.19	3.51	0.86	0.51	0.86
121	6.37	13.85	23.21	2.78	0.75	1.12	0.75	**175**	6.31	19.42	34.87	3.90	1.26	1.39	1.26
122	6.04	18.89	31.18	3.79	1.00	0.83	0.99	**176**	6.36	15.49	28.04	3.11	1.00	1.73	1.00
123	5.23	20.14	37.27	4.05	1.07	1.24	1.07	**177**	5.93	9.17	30.30	1.83	1.04	0.67	1.04
124	5.58	45.48	37.04	9.16	0.88	0.86	0.88	**178**	5.90	22.11	32.32	4.44	1.00	1.08	1.00
125	6.15	23.19	32.85	4.66	1.04	1.85	1.04	**179**	5.46	19.47	37.68	3.91	1.18	1.65	1.18
126	6.50	13.20	24.34	2.64	0.82	1.13	0.82	**180**	5.47	21.66	35.75	4.35	1.04	0.68	1.03
127	5.85	16.53	36.50	3.32	0.82	1.11	1.24	**181**	4.93	13.95	38.61	2.80	1.09	1.36	1.09
128	6.66	15.79	29.66	3.17	1.09	1.44	1.09	**182**	5.42	14.17	29.32	2.84	0.84	0.75	0.84
129	5.31	35.19	41.67	7.08	1.09	1.60	1.09	**183**	4.78	45.29	45.02	9.12	0.99	1.63	1.00
130	5.27	16.46	32.77	3.30	0.92	1.04	0.92	**184**	5.57	9.70	32.96	1.94	1.03	0.53	1.03
131	6.16	11.17	31.95	2.24	1.17	1.07	1.18	**185**	5.48	19.41	31.60	3.90	0.90	1.55	0.90
132	4.96	11.13	32.19	2.23	0.86	0.69	0.85	**186**	6.25	12.79	30.21	2.56	1.10	1.06	1.10
133	5.59	32.30	38.13	6.50	1.11	2.39	1.11	**187**	4.85	18.80	43.05	3.77	1.24	1.25	1.24
134	5.08	24.04	39.16	4.83	1.02	1.47	1.02	**188**	5.11	22.07	27.14	4.44	0.60	1.30	0.60
135	5.04	9.50	30.63	1.90	0.92	0.70	0.92	**189**	4.62	15.60	37.34	3.13	0.93	0.82	0.93
136	5.51	24.85	27.78	5.00	0.74	1.44	0.74	**190**	6.00	12.49	33.58	2.50	1.15	0.76	1.15
137	6.36	23.59	24.73	4.74	0.79	1.31	0.79	**191**	5.01	12.49	29.03	2.50	0.78	0.77	0.78
138	5.90	12.71	29.67	2.55	0.94	0.71	0.93	**192**	5.58	8.76	30.56	1.75	0.98	0.60	0.98
139	5.27	28.61	30.46	5.76	0.70	1.56	0.70	**193**	5.22	26.08	39.40	5.24	1.05	1.71	1.05
140	6.28	24.59	29.88	4.94	0.99	1.78	0.99	**194**	5.73	16.90	29.65	3.39	0.91	1.32	0.91
141	5.97	10.38	35.46	2.08	1.29	0.68	1.29	**195**	4.82	26.25	34.95	5.28	0.79	2.16	0.79
142	6.16	14.15	31.51	2.84	1.11	0.98	1.11	**196**	5.48	15.37	25.64	3.08	0.72	0.98	0.72
143	6.12	33.34	35.77	6.71	1.14	0.83	1.14	**197**	5.22	17.98	28.84	3.61	0.73	1.23	0.73
144	6.00	30.82	28.24	6.20	0.71	1.95	0.71	**198**	5.28	26.51	30.01	5.33	0.72	1.07	0.72
145	6.60	7.23	25.91	1.44	1.03	0.72	1.03	**199**	5.19	26.56	36.93	5.34	0.95	0.84	0.95
146	6.14	12.80	30.68	2.56	1.07	0.84	1.07	**200**	5.87	19.64	33.39	3.95	1.04	0.69	1.04
147	5.76	62.81	45.79	12.66	1.27	1.08	1.27	**201**	4.03	7.60	42.01	1.51	1.01	0.64	1.02
148	6.25	16.68	29.15	3.35	0.97	1.29	0.97	**202**	5.74	14.21	36.47	2.85	1.20	1.27	1.20
149	6.06	16.98	32.03	3.41	1.09	1.12	1.09	**203**	5.71	20.64	39.99	4.15	1.36	1.08	1.36
150	6.21	30.56	30.44	6.15	0.91	1.48	0.91	**204**	5.78	22.07	39.66	4.44	1.29	1.02	1.29
151	5.81	17.88	34.85	3.59	1.14	0.99	1.14	**205**	5.71	29.40	34.29	5.91	0.97	1.44	0.97
152	5.31	9.92	23.93	1.98	0.72	0.54	0.72	**206**	5.98	6.39	27.19	1.27	0.93	0.90	0.93
153	5.77	56.96	46.29	11.48	1.39	1.40	1.39	**207**	5.22	34.42	47.19	6.93	1.37	1.51	1.37
154	5.56	23.00	31.72	4.62	0.84	1.13	0.84	**208**	6.42	29.17	37.14	5.87	1.28	1.39	1.28
155	5.22	23.36	42.10	4.70	1.25	1.57	1.26	**209**	4.77	12.71	44.16	2.55	1.23	0.86	1.23
156	5.98	24.80	39.35	4.99	1.35	1.75	1.35	**210**	5.71	18.97	37.18	3.81	1.23	1.78	1.23
157	5.47	29.76	29.09	5.99	0.73	1.14	0.73	**211**	4.92	27.44	40.87	5.52	1.03	0.66	1.03
158	5.74	21.48	27.49	4.32	0.76	1.12	0.76	**212**	5.95	52.66	38.05	10.61	0.98	1.11	0.98
159	5.65	22.32	39.06	4.49	1.21	0.58	1.21	**213**	4.35	24.44	37.17	4.91	0.78	1.38	0.77
160	5.81	17.21	32.45	3.45	1.03	0.60	1.03	**214**	5.23	5.55	30.40	1.10	0.97	0.73	0.97
161	6.02	20.86	33.14	4.19	1.07	1.80	1.07	**215**	5.85	25.43	39.69	5.11	1.35	1.57	1.35

Appendix 6: Table of means for GY and other secondary traits, for regional data across environments.

Entry	GY	AD	PH	EH	EPO	EPP	PS	ET	SEN	TEX	MSV	EA	PA
1	2.70	82.39	203.25	103.25	0.50	0.82	1.81	2.13	2.53	1.63	1.11	2.82	2.92
2	2.34	80.72	194.50	98.32	0.50	0.81	1.79	2.27	2.66	1.75	0.80	3.06	3.13
3	3.55	74.92	205.68	104.79	0.51	0.89	1.75	2.10	2.60	1.50	1.11	2.43	2.68
4	3.71	76.05	212.36	106.86	0.50	0.92	1.77	2.08	2.33	1.63	1.20	2.43	2.66
5	2.97	77.55	205.89	97.39	0.47	0.86	1.71	2.18	2.64	1.50	0.84	2.65	2.52
6	3.65	79.16	215.21	107.32	0.50	0.88	1.73	2.18	2.63	1.50	1.06	2.51	2.79
7	4.32	76.44	218.21	113.32	0.52	0.87	1.65	2.02	2.26	1.50	0.70	2.22	2.71
8	3.64	78.97	214.46	107.14	0.50	0.85	1.75	2.00	2.63	1.50	1.29	2.57	2.74
9	3.87	75.31	210.07	104.86	0.50	0.89	1.92	2.23	2.38	1.88	1.11	2.57	2.82
10	3.98	73.39	208.07	100.14	0.48	0.92	1.71	2.24	2.47	1.63	0.90	2.44	2.75
11	3.90	75.28	212.11	107.21	0.51	0.84	1.79	2.17	2.67	1.50	0.88	2.46	2.81
12	3.07	74.83	204.96	100.93	0.49	0.84	1.90	2.42	2.14	1.63	0.98	2.69	2.77
13	4.09	76.72	215.71	109.64	0.51	0.90	1.90	2.33	2.34	1.50	0.91	2.39	2.66
14	3.64	75.86	207.68	103.04	0.49	0.87	1.81	2.13	2.57	1.88	1.14	2.51	2.72
15	3.73	74.83	213.36	109.00	0.51	0.90	1.77	2.43	2.31	1.50	0.91	2.43	2.83
16	4.17	75.81	209.71	109.82	0.53	0.89	1.67	2.12	2.53	1.75	0.69	2.57	2.74
17	3.44	75.56	211.00	111.82	0.53	0.86	1.96	2.45	2.69	1.75	1.11	2.70	3.04
18	3.70	76.68	213.57	113.39	0.53	0.87	1.81	2.22	2.36	1.63	1.29	2.63	2.88
19	4.05	77.89	222.96	112.57	0.50	0.99	1.85	2.15	2.71	1.50	1.20	2.31	2.97
20	3.44	73.86	200.93	99.14	0.49	0.87	1.88	2.52	2.14	1.63	0.80	2.71	2.87
21	3.62	79.08	213.43	116.75	0.55	0.95	1.77	2.30	2.58	1.63	1.05	2.56	2.99
22	4.40	79.11	218.68	113.21	0.52	0.89	1.81	2.03	2.31	1.75	1.10	2.33	2.85
23	4.07	79.61	215.50	114.43	0.53	0.95	1.77	2.32	2.61	2.00	1.00	2.39	2.77
24	3.77	75.89	205.61	105.36	0.51	0.88	1.81	2.08	2.55	1.88	1.16	2.56	2.73
25	3.88	75.92	207.14	100.82	0.48	0.91	1.94	2.35	2.38	2.00	1.10	2.40	2.77
26	3.39	79.97	208.32	108.79	0.53	0.83	1.79	2.38	2.43	1.63	1.11	2.68	2.80
27	3.81	77.47	210.36	110.54	0.53	0.92	1.65	2.08	2.24	1.88	1.03	2.47	2.78
28	3.98	77.33	217.29	112.00	0.52	0.88	1.71	1.92	2.47	2.13	0.98	2.44	2.82
29	4.57	77.03	213.50	107.36	0.50	0.94	1.54	1.87	2.63	1.88	1.16	2.20	2.79
30	4.05	78.00	215.79	113.96	0.53	0.88	1.71	1.93	2.57	2.13	1.35	2.32	2.74
31	4.48	78.86	218.68	115.64	0.53	0.90	1.60	1.88	2.41	1.63	1.03	2.10	2.70
32	3.80	76.08	213.54	109.50	0.51	0.95	1.88	2.48	2.30	1.75	0.89	2.53	2.80
33	4.41	76.67	223.43	115.89	0.52	0.89	1.79	2.33	2.47	2.13	0.86	2.67	3.08
34	3.85	73.14	199.89	97.18	0.49	0.92	1.83	2.52	2.20	1.88	0.98	2.51	2.63
35	3.80	78.06	220.57	114.75	0.52	0.93	1.77	2.37	2.00	1.75	1.30	2.53	3.05
36	3.81	76.89	221.04	114.25	0.51	0.88	1.90	2.50	2.56	2.25	1.38	2.59	3.01
37	3.20	74.75	210.18	103.36	0.49	0.86	1.94	2.48	2.08	1.75	1.10	2.72	2.76
38	3.72	77.86	216.07	111.46	0.51	0.96	1.94	2.45	2.28	1.75	1.31	2.49	3.09
39	3.56	76.47	209.46	106.29	0.51	0.90	1.90	2.45	2.66	2.13	1.48	2.55	2.92
40	3.60	75.56	210.75	102.00	0.48	0.87	1.96	2.48	2.33	2.50	1.18	2.72	2.83
41	3.62	77.11	205.25	100.18	0.49	0.82	2.04	2.20	2.00	2.13	1.25	2.78	2.78
42	4.48	74.83	214.71	107.71	0.50	0.96	1.98	2.55	2.26	2.38	1.10	2.38	2.69
43	3.73	76.69	217.39	113.46	0.52	0.88	1.90	2.37	2.13	1.88	1.20	2.65	2.84
44	3.83	75.50	193.07	99.00	0.51	0.94	1.81	2.38	2.20	2.50	0.95	2.63	2.63
45	3.55	79.89	222.21	111.75	0.50	0.95	1.79	2.27	2.55	2.00	1.38	2.65	2.79
46	3.37	74.75	202.82	100.39	0.49	0.87	1.83	2.78	1.84	1.75	0.85	2.73	2.72
47	4.25	75.19	221.68	113.00	0.51	0.86	1.71	1.97	2.50	1.63	0.98	2.28	2.51
48	3.97	77.86	220.14	110.75	0.50	0.92	1.73	2.22	2.11	1.63	1.38	2.47	2.78
49	3.30	74.94	210.57	105.29	0.50	0.90	1.92	2.38	2.41	1.63	1.39	2.70	2.94
50	3.53	75.61	218.25	119.82	0.55	0.90	1.94	2.10	2.39	1.50	2.05	2.59	3.05
51	3.49	78.58	224.79	122.18	0.54	0.87	1.79	2.18	2.33	1.50	1.58	2.56	2.98
MEAN	3.74	76.79	212.18	108.08	0.51	0.89	1.81	2.25	2.40	1.78	1.11	2.54	2.81
MAX	4.57	82.39	224.79	122.18	0.55	0.99	2.04	2.78	2.71	2.50	2.05	3.06	3.13
MIN	2.34	73.14	193.07	97.18	0.47	0.81	1.54	1.87	1.84	1.50	0.69	2.10	2.51
CV	27.29	2.3	6.83	10.52	9.11	18	18.38	18.8	16.15	16.55	43.78	20.23	14.9
LSD	0.41	1.96	7.61	5.96	0.02	0.07	0.19	0.21	0.38	0.41	0.43	1.96	0.22

Appendix 7: **Six parameters for measuring stability of performance of genotypes using GY , for regional data**

					Eberhart and Russel		Finlay and Wilkinson
Entry	Yield	Wricke	Shukla	CV	Slope	Standard dev	slope
1	2.92	20.06	1.25	54.44	0.98	0.29	1.06
2	2.53	34.92	2.22	61.09	0.80	0.39	0.89
3	3.55	47.26	3.02	38.77	0.85	0.41	0.91
4	3.71	47.80	3.06	35.10	0.81	0.45	0.82
5	3.13	39.80	2.53	50.36	0.95	0.31	1.05
6	3.68	29.41	1.86	41.33	1.04	0.35	1.05
7	4.13	30.89	1.95	40.82	1.16	0.37	0.98
8	3.67	39.08	2.49	44.92	1.05	0.40	1.05
9	4.06	33.92	2.15	42.57	1.03	0.40	1.07
10	3.97	31.56	2.00	32.75	0.79	0.41	0.85
11	4.02	57.78	3.70	40.13	0.91	0.59	1.04
12	3.22	39.12	2.49	48.88	0.88	0.43	0.9
13	3.84	43.04	2.75	41.35	1.04	0.37	0.97
14	3.83	22.97	1.44	39.56	0.93	0.30	0.96
15	3.67	35.51	2.26	40.87	1.00	0.36	0.96
16	4.36	46.50	2.97	41.67	1.13	0.49	1.26
17	3.57	25.80	1.62	44.39	1.04	0.35	1.02
18	3.63	24.14	1.52	44.39	1.10	0.32	1.06
19	4.09	47.32	3.02	44.57	1.23	0.50	1.15
20	3.52	24.67	1.55	38.11	0.87	0.33	0.91
21	3.75	42.31	2.70	47.11	1.08	0.32	1.09
22	4.30	55.08	3.53	39.72	1.15	0.39	1.20
23	4.18	48.76	3.12	40.52	1.03	0.44	1.15
24	3.90	40.98	2.61	39.35	0.88	0.29	0.99
25	3.88	35.19	2.23	39.68	0.98	0.41	1.00
26	3.35	34.41	2.18	45.14	0.96	0.43	0.98
27	3.78	30.22	1.91	40.31	1.03	0.39	0.99
28	3.98	50.98	3.26	34.78	0.82	0.42	0.9
29	4.50	61.62	3.95	35.85	0.99	0.57	0.87
30	4.06	46.10	2.94	44.16	1.13	0.37	1.06
31	4.33	93.77	6.05	34.98	0.79	0.54	0.72
32	3.69	51.57	3.30	44.59	1.07	0.39	0.95
33	4.27	68.38	4.39	48.52	1.44	0.43	1.15
34	3.90	37.41	2.38	33.44	0.77	0.32	0.91
35	3.73	43.87	2.80	49.49	1.22	0.46	1.09
36	3.84	56.80	3.64	46.89	1.07	0.39	1.12
37	3.30	35.12	2.23	48.31	0.92	0.47	1.00
38	3.81	41.75	2.66	39.95	0.90	0.46	0.99
39	3.62	49.19	3.15	50.78	1.20	0.44	1.09
40	3.65	48.66	3.11	41.19	0.89	0.43	0.98
41	3.69	43.53	2.78	40.63	0.89	0.55	0.90
42	4.42	58.58	3.76	33.74	0.90	0.66	0.97
43	3.66	44.19	2.82	45.67	1.10	0.43	1.00
44	3.71	22.59	1.41	42.64	1.13	0.34	0.96
45	3.52	55.13	3.53	45.46	0.97	0.55	0.94
46	3.57	46.87	2.99	49.05	0.94	0.46	1.09
47	4.24	32.24	2.04	40.54	1.15	0.44	1.19
48	3.98	43.81	2.80	41.11	1.05	0.45	0.98
49	3.39	25.62	1.61	39.58	0.81	0.33	0.89
50	3.40	31.11	1.97	45.00	0.99	0.42	0.92
51	3.52	36.99	2.35	47.66	1.17	0.45	1.05