ADAPTABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS AMONG SELECTED VARIABLES OF SUNFLOWER (*Helianthus annuus* L.) GENOTYPES

LEONARD MHOJA SABULA

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ABSTRACT

Three genotypes of sunflower (PI 364860, K.Fedha and Record) were evaluated at three locations (Seatondale, Inyala and Uyole) and three spacing regimes (75 cm x 45 cm, 75 cm x 30 cm and 75 cm x 15 cm) during the season 2011/12 to estimate the performance of seed yield and its components. The objectives of this study were to evaluate genotype x environmental interactions among the selected variables and to determine the interrelationships and paths of influence among components of yield. Treatments were combined in a split plot arrangement in a randomized complete block design with three replications. Data were collected and analysed using GenStat 14th Edition. The genotype x environment interaction (G x E) was highly significant for all studied variables, suggesting that the performance of the genotypes were inconsistent in different environments. All the genotypes at Seatondale and Uyole sites yielded higher compared to Inyala site due to low rainfall amount, temperatures and altitudes existed at Inyala may had contributed to the lowest performance. Therefore, Seatondale and Uyole are recommended to be the best for sunflower production. The genotype PI 364860 was identified to be adaptable and stable on seed yield. Correlation coefficient analysis revealed that seed yield had positive and significant association with number of seeds per head, head diameter, seed weight per head and 100 seed weight at both genotypic and phenotypic levels. Path coefficient analysis indicated that number of seeds per head, 100 seed weight, head diameter and seed weight per head had maximum positive direct effect on yield and they interrelated positively through each other. However, number of seeds per head and diameter interacted positively with most variables in their relations with yield which themselves were the major contributors of grain yield.

DECLARATION

I, LEONARD MHOJA SABULA, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

……………………………………… 22/11/2013 ………………………………

Leonard Mhoja Sabula — Date

(MSc.Candidate)

The above declaration confirmed

……………………………………… 22/11/2013 ………………………………

Prof. Reuben S.W.O.M — Date

(MSc. Supervisor)

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DEDICATION

This work is dedicated to my parents Mr and Mrs.Sabula Karabu who laid the foundation for my education. The work is also dedicated to my beloved wife madam Stella Shani Mweka.

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LIST OF ABBREVIATIONS AND SYMBOLS

COSTECH	Commission Of Science and Technology
CV	Coefficient of variation
FAO	Food and Agriculture Organisation
LSD0.05	Least significant difference at 5 percent
RLDC	Rural Livelihood Development Company
ARI	Agricultural Research Institute
SE	Standard Error
SV	Source of variation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Sunflower (*Helianthus annuus* L.) is a major oilseed crop gaining paramount importance in the world ranks next only to soybean and groundnut in the total world production of oil seeds. It is one of the most important oil crops widely grown on many parts of the world as reported by Hu *et al.* (2010). Sunflower seed contains high oil content ranging from 35-48% with some types yielding up to 50% (Skoric and Marinkovic, 1986). However, Nazir *et al.* (1994) reported 20-27% protein contained in sunflower. High percentage of poly-unsaturated fatty acids (60%) including oleic acid (16.0%) and linoleic acid (72.5%), which control cholesterol in blood as reported by Satyabrata *et al.* (1988). Sunflower oil is considered as premium oil due to its light colour, mild flavour and ability to withstand at high cooking temperatures. Furthermore, sunflower oil contains fat-soluble vitamins A, B, E and K, well for heart proteins (Gossal *et al.*, 1988; Evertt *et al.*, 1987). Now sunflower is the biggest source of vegetable oil at world level as reported by Arshad *et al.* (2010).

Sunflower originated from America and was brought in Europe by Spanish. It was later introduced in Russia, Ukraine and Turkey which are up to now main production countries apart from USA and Argentina. Sunflower was introduced in Tanzania during colonial times and it was found to grow in almost all parts of the country. Sunflower is one of the most important oilseed crops in Tanzania, it produces edible oil, usable for bio energy and its cake is rich in protein useful for feed. The production of oilseeds in Tanzania is groundnuts (40%), sunflower (36%), sesame (15%), cotton (8%), and palm oil (1%) (Rural livelihood Development Company, 2008).

Botanically, sunflower is a member of the *Asteraceae* family. The sunflower head contains two types of flowers: the ray flowers and the disk flowers. The ray flowers or petals are broad-based and ring the outer edge of the flower head. They serve as attention getters, waving to nearby insects, luring them to the flower centre. The centre flowers, called disk flowers, are tubular in shape and require pollen from another sunflower plant to be fertilized. The insects cross-pollinate the disk flowers, which then develop into seeds. The height of the common sunflower can grow as high as 3 m and the flower head can reach 30 cm in diameter.

Ecologically, sunflowers grow in almost any type of soil except where there is standing water, tolerate most variations of wetness, and require little pest control. However, they must have lots of direct sun, with little shade while good, fertile soil will yield the largest flower heads and meatiest seeds. Also sunflowers are not picky. Being a photo insensitive crop, it has a wide range of adaptability to different agro climatic conditions as reported by Vijayakumar *et al.* (2003). Therefore, it is widely cultivated in Tanzania. The crop is grown in the eastern, central, northern and southern highlands of Tanzania. Sunflower is gaining popularity; local production of both factory and home extracted oils contribute to about 40% of the national cooking oil requirement with the remaining 60% being imported (Ugulumu, 2008). Despite the wide adaptability of the crop, the environmental variables influence its productivity and production. The environmental variables that influence crop productivity and production can be classified as either predictable or unpredictable factors. Predictable factors are those that occur in an artificial manner or are under human control, such as soil type, planting date, row spacing, plant population and rates of nutrients application. Unpredictable factors are those that fluctuate inconsistently, including rainfall, temperature and relative humidity. The relative performance of genotypes across environments determines the importance of the interaction.

Basically interaction occurs in two scenarios; genotype x environmental interaction is present but does not alter genotypic ranking and genotype x environmental interaction is present and alters genotypic ranking. Sunflower has a wide range of adaptability to different agro-climatic conditions. However, under rain fed conditions where soil moisture is a limiting factor, maintaining an optimum plant population by adopting appropriate crop geometry is an important factor in increasing yields (Subba *et al.*, 1997). Generally increasing sunflower population increases the seed yield to optimum level. Optimum population depends on cultivar, environmental and field management factors (Weiss, 2000; Robinson *et al.*, 1980).

The first goal of plant breeders in a crop breeding programme is the development of cultivars or genotypes which are stable or adapted to a wide range of diversified environments (Arshad *et al.*, 2003). The total time required for development of a sunflower plant and the time between the various stages of development depends on the genetic background of the plant and the growing environments (Schneiter and Berglund, 1998). Effective identification of superior sunflower genotypes is complicated by the presence of significant genotype × environment (G × E) interactions, such that relative cultivar yields vary across testing environments (De la Vega *et al.*, 2001). To determine the scope for selection for specific adaptation, crop environments can be characterized in terms of the way they influence the relative performance of genotypes.

Environmental variables, especially temperature, are the key factors, which affect plant growth, development and productivity (Kaleem *et al.*, 2009). Differences of yield attributes in varying environments might be due to the different climatic conditions that are based on temperature prevailing during the crop life cycle (Kll and Altunbay, 2005). Most crop species are adapted to particular set of temperature, as temperature is a major environmental factor influencing their distribution (Atkinson and Porter, 1996). Combined effects of environmental factors not only modify plant phenology, but also cause many physiological and qualitative changes. Environmental variations affect crop growth, development, yield, oil and fatty acid accumulation through agronomic, physiological and qualitative functions of the crop plant (Kaleem *et al.*, 2010a). A number of plant's developmental and physiomorphic adaptations to the environment have been reported by Hassan *et al.* (2005) to influence sunflower yields and oil quality. However, Nadarajan and Gunasekaran (2005) reported that a number of characters, which are often polygenic in nature, are highly affected by environments. Therefore, knowledge of genetic system controlling yield and its components is useful in understanding the prepotency of the parents and thus help to select parents possessing in-built genetic potential.

Interrelationship between yield and its components is inevitable and mutual association of plant characters, which is determined by correlation coefficient. However, information on the relative importance of direct and indirect effects of each component characters towards yield is not provided by such studies. Path coefficient is helpful in partitioning the correlation into direct and indirect effects so that relative contribution of each component character to the yield could be assessed (Singh and Narayanam, 2007). In other words, path analysis measures the direct and indirect contribution of various independent characters on a dependent character.

1.2 Problem statement and Justification

Inadequate of improved cultivars has been identified as a fundamental biological constraint to the sunflower industry in Tanzania. This forces smallholder farmers to use their own seeds (low yielding varieties). In Tanzania it is estimated that about 150 000 to 200 000 farmers are involved in sunflower growing, however, only 35% of farmers use improved varieties (Rural Livelihood Development Company, 2008). In 2009 the average yield was 0.42tonnes/ha in Tanzania while in Ukraine (the greatest producer) was 1.52 ton/ha (FAO, 2009). The Oilseed Research Sub programme at Ilonga has identified PI 364 860 and PI 289 624 accessions to have high yields and oil content. Eberhart and Russel (1966) coined that there are stable genes in genotypes that express stability of performance across environments. These genes could be used in breeding programmes to combine in the same genetic background with high performance and stability. Farmers are most interested in varieties that produce high yields under their growing conditions and plant breeders want to fulfil these needs (Mulusew *et al.*, 2008). Hence, information on G x E interaction is of paramount importance for sunflower breeders and farmers under a set of environments.

For efficient selection programme, interrelationship between yield and its components is inevitable. Mutual association of plant characters, which is determined by correlation coefficient, is used to find out the degree (strength), mutual relationship between various plant characters and the component character on which selection can be relied upon the genetic improvement of yield. In Tanzania some studies on adaptability and path coefficient analysis have been conducted on other crops such as done by (Bucheyeki *et al.*, 2010, 2008; Mbwaga *et al.*, 2007; Kihupi, 1998). However, very little was known for sunflower, hence needed to be estimated. Adaptability study and interrelationships between variables for breeding is of profound importance and unavoidable. The present study was set out to to study the adaptability of genotypes and interrelationships among components of selected genotypes in sunflower for more efficient decision in breeding programme.

1.3 Objectives

1.3.1 Overall objective

To identify adaptable genotypes and selection criteria to be used on breeding for selected traits in sunflower crop.

1.3.2 Specific objectives

I. To evaluate genotype x environmental interactions among the selected variables.

II. To determine the interrelationships and paths of influence among components of yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Genotypes by Environment Interaction

When cultivars are compared at different environments, their performance relative to each other may not be the same. One cultivar may have the highest yield in some environments and a second may excel in others. Changes in relative performance of genotypes across different environments are referred to genotype x environmental interaction. Genotype by environmental interaction study is very interested by plant breeders due to its potentiality in coming up with the adaptable and stable genotype as required by farmers. Some studies in genotype x environmental interaction have been done elsewhere for sunflower and in Tanzania for crops other than sunflower. The genotype x location interaction measures the consistency performance among genotypes at different locations. Whereas, the consistency performance of genotypes in different spacing regimes is indicated by the genotype x spacing interaction.

In order to study the consistency performance of genotypes across environments, genotype by environment interaction was investigated for sunflower grain yield in French official trials from two different networks. Early flowering genotypes performed better in early environments while late genotypes gave much better yields in late environments as reported by Foucteau *et al.* (2001). Other field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore, India during the North East Monsoon (October-December) to study the effect of planting pattern on the yield attributes, yield and quality of rain fed sunflower. The results revealed that the yield attributes of sunflower were higher at the closest spacing of 30 cm × 25 cm than at the widest spacing of 30 × 37.5 cm.

The seed yield was higher at closer (30 cm × 25 cm) spacing in 1997 and at wider spacing (30 cm × 37.5 cm) in 1998 as reported by Vijayakumar *et al.* (2003).

Additionally, Gubbels and Dedio (1986) reported that a population of 4.5 plants m^{-2} was optimum for Saturn, Modern 12, CMH 103 and MF 707 cultivars. However, in another experiment (Gubbels and Dedio, 1989) further showed that seed weight per head decreased with increasing population in MRS 34 and Sunwheat 101 cultivars. Narwal and Malik (1985) found that increasing population significantly increased unfilled seeds.

Another study was done to evaluate the adaptability and stability of sunflower genotypes on grain and oil yield, in Central Brazil. Grunvald *et al.*, (2008), found that the varieties BRSGira 02 and Nutrissol were widely adapted. However, hybrids Agrobel 959, MG50 and V03005 and the varieties Catissol and Multissol were adapted to favourable environments whereas the hybrids BRHS 02 and BRHS 04 were adapted to unfavourable environments.

Stability in performance is one of the most desirable properties of a genotype to be released as a cultivar for wide range of application. The significance of genotype x environment (G x E) interaction in variety evaluation programme is well recognized (Miller *et al.*, 1958). Finlay and Wilkinson (1963) pointed out that the slope of the linear regression (bi) of the yield (Yij) of jth genotype and j^{th} environment, on the mean yield (yj) of all the genotypes in jth environment is helpful in testing the genotypic stability. They pointed that a genotype which has a bi = 1 has average stability but genotypes which have slope greater than one and less than one are below and above average stability respectively. In addition to the bi, the deviation mean square (s^2d) which describes the contribution of genotype to the G x E interaction is used (Eberhart and Russell, 1966).

Elsewhere seed yield (t/ha) showed highly significant relationship ($P < 0.01$) of genotype x environment interaction (Salah *et al.*, 2009).

2.2 Correlation and Path Coefficient Analysis

Knowledge of phenotypic correlation between yield and its components has been of immense help in the selection of suitable plant types .The association of character may be due to either genetic linkage or pleiotrophy. Knowledge of correlation that exists among important characters may facilitate in the interpretation of results and provide a basis for planning more efficient breeding programme in sunflower crop.

Correlation and path coefficient analyses were studied in twenty four diverse genotypes of sunflower in order to understand the relationships and contributions of eight characters to grain yield. Yield (kg per plant) exhibited highly significant and positive correlation with number of seeds per head, head diameter and 1000 seed weight at both genotypic and phenotypic levels. Path coefficient analysis revealed that number of seeds per head, 1000 seed weight and head diameter had the highest and positive direct effect on yield (Abrar and Shubhra, 2010). Genotypic correlation coefficients were higher as compared to phenotypic and environmental correlation coefficient in most of the cases. Days to flower initiation, completion and days to maturity had positive and highly significant correlations with plant height. Head diameter had negative association with all the traits except 100 seed weight where it had highly significant genotypic correlation (0.480) as denoted by Arshad *et al.* (2010).

However, correlation studies in sunflower revealed that seed yield was positively associated with a number of yield components. Among yield components, correlation of number of filled seeds per head was maximum followed by 100 seed weight, seed filling per cent, head diameter, plant height and stem diameter. Path coefficient analysis showed that the direct effect on seed yield was maximum for number of filled seeds per head followed by 100 seed weight. The maximum indirect effect for any character was through number of filled seeds per head and 100 seed weight, while they were also major direct contributors of seed yield in sunflower (Shankar *et al.*, 2006).

Another study by Tahir *et al.* (2002) revealed the interrelationship among the studied variables. The highest correlation of seed yield was observed with number of filled seeds per plant, followed by seed filling percentage and head diameter. Number of filled seeds per plant exhibited maximum direct effect on seed yield. Head diameter also had a considerable effect on seed yield. Also, Rao *et al.* (2003) reported that the characters studied associated among themselves with the seed yield in the elite lines of sunflower.

Arshad *et al.* (2007) in his study reported the highest phenotypic and genotypic coefficients of variation in number of filled seeds per head (48.127 and 47.776, respectively) followed by seed yield (45.723 and 45.522), plant height (21.069 and 20.581) and test weight (20.227 and 20.099). Partitioning of genotypic correlations into direct and indirect effects through various yield-contributing characters helps to identify selection criteria in sunflower breeding. The direct effects of days to flower initiation, plant height and head diameter were positive while the remaining characters exhibited negative direct effects in that study. The highest direct effect (1.68) was exhibited by days to flower initiation, followed by plant height (0.34). Beside this, head diameter had also positive direct effect (0.24) on seed yield. (Farratullah and Khalil, 2006 ; Arshad and Ghafoor, 2004; Madhavilatha *et al.*, 2004) earlier reported similar findings in sunflower and chickpea.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The experiment was conducted during 2011/12 cropping season in the southern highlands of Tanzania at three locations namely; Uyole which is located at 08^0 56'S and $033^0$06'E at an elevation of 1795 meters above sea level, Inyala which is located at 08^0 51'S and 033^0 38' E at an elevation of 1505 meters above sea level (Mbeya region) and Seatondale 07^0 45' S and 35^0 39' E at an elevation of 1693 meters above sea level (Iringa region).

3.2 Experimental Design and Treatments Application

Selected sunflower genotypes, which are PI 364860, K.Fedha and Record varieties used in this study, these were collected from ARI-Ilonga. Three genotypes and three spacing regimes were randomized in each of three locations (Appendix 1). A split plot arrangement in a Randomized Complete Block Design (RCBD) with three replications was applied at each location and combined analysis, where spacing regimes used as main plot and genotypes as sub-plot under the same plot size of 3.0 m by 4.5 m (sub-plot/genotypes). The distance between subplots was 0.5 m made a main plot size of 10 m by 4.5 m. The treatments were replicated three times per locatiòn and planted in four rows per plot in which two central rows were harvested for data collection and the other two regarded as guard rows. The spacing regimes that were used are 75 cm x 45 cm, 75 cm x 30 cm and 75 cm x 15 cm giving a total of nine (3 x 3) micro environments for assessment. DAP fertilizer was applied at planting at the recommended rate of 60 kg P/ha, while Urea was applied in a split fashion, at planting and at four weeks after planting using the recommended rate of 30 kg N/ha. Other approved cultural practices were used at each location during the study. Ten plants per two harvesting rows per plot were randomly selected from which selected variables were measured. Interrelationships and paths of influence were studied in seven selected variables collected from genotypes planted at the recommended spacing of 75 cm x 30 cm. This was done in order to understand the relationship and contribution of six characters towards the seed yield.

3.3 Data Collection

Both vegetative and reproductive data were collected. The data collected included stem girth, plant height, days to 50% flowering, days to 50% physiological maturity, head diameter, number of seeds per head, seed weight per head, 100seed weight and seed yield per plot, which was converted into hectare basis.

3.3.1 Stem girth (cm)

Stem girth was measured with the help of thread and meter rod at three places of each plant, *i.e.*, bottom, middle and top, and averages were worked out. Mean of the 10 plants in each was recorded. It was measured at development stage R-8 when the back of the head is yellow but the bracts remain green.

3.3.2 Plant height (cm)

Plant height was measured from ground level to the receptacle of the head. Mean value of 10 plants in each plot was recorded. It was measured at development stage R-8 when the back of the head is yellow but the bracts remain green.

3.3.3 Days to 50% flowering

Days to 50% flowering was measured as days after planting to the time coinciding with reproductive stage R-2. This is when the immature bud elongates 0.5 cm to 2.0 cm above the nearest leaf attached to the stem. Disregard leaves attached directly to the back of the bud.

3.3.4 Days to 50% physiological maturity

Days to 50% physiological maturity was taken as days after planting to the time coinciding with the reproductive stage R-9. The physiological maturity is attained when plants' bracts become yellow and brown.

3.3.5 Head diameter (cm)

Head diameter was measured at harvest. This is when all plants coincided with the reproductive stage R-9 when the bracts become yellow and brown.

3.3.6 Number of seeds per head

Number of seeds per head was taken after harvest. This was done by counting total number present in each head and averaged for 10 plants to give a mean seed number per head.

3.3.7 100 seed weight (g)

100 seed weight as one the yield component was also measured. It was measured by weighing 100 seeds from each plot taken as a representative sample.

3.3.8 Seed yield per plant/head (g)

Seed yield per plant was taken by averaging the yield of 10 plants. These 10 plants were randomly selected.

3.3.9 Seed yield (kg/ha)

Seed yield was taken by weighing total seeds harvested from each plot of $6.75m^2$ after sun drying to constant weight. All measurements obtained in each plot were converted to kg/ha.

3.4 Data Analysis

3.4.1 Estimation of main effects

Analysis of variance (ANOVA) of a split-split plot design is divided into the main plot, subplot and sub-subplot analyses as denoted by Gomez and Gomez (1984). Analysis of variance was performed on data collected for all locations and spacing regimes using the statistical model after De Souza *et al.* (2003) as follows;

$$Y_{ijkl} = u + R_{k(l)} + L_i + \varepsilon_{(RL)} + S_j + LS_{ij} + \varepsilon_{(RLS)} + G_k + GL_{ki} + GS_{kj} + GLS_{kij} + \varepsilon_{(RLSG)}, \quad (1)$$

Where;

(1) Y_{ijkl} is the i^{th} observation in the i^{th} location, j^{th} spacing regime on k^{th} genotype and l^{th} plot

$R_{l(i)}$ = i^{th} replication effect within locations

$L_{(i)}$ = i^{th} location effect

$\varepsilon_{(RL)}$= error

$S_{(j)}$ = j^{th} spacing effect

$LS_{(ij)}$ = interaction effect of i^{th} location and j^{th} spacing

$\varepsilon_{(RLS)}$= error

$G_{(K)}$ = k^{th} genotype effect

$GL_{(kl)}$ = interaction of k^{th} genotype and i^{th} location

$GS_{(kj)}$ = interaction effect of k^{th} genotype j^{th} spacing

$GLS_{(klj)}$ = interaction effect of i^{th} location, k^{th} fertilizer and l^{th} genotype

$\varepsilon_{(RLSG)}$= error.

3.4.2 Analysis of variance for a single site

Collected data were analyzed using GenStat 14^{th} edition software.

Data were subjected to analysis of variance for each location using the procedure given by Gomez and Gomez (1984) for RCBD in split plot. Statistical model used for each location was;

$Y_{ijk} = \mu + A_i + B_j + AB_j + e_{ijk}$ .... (2)

Where by:

Y_{ijk} - the measurement obtained for the unit in i^{th} genotype of the k^{th} replicate of the j^{th} observation

μ = Overall mean

A_i = Effect of ith level of factor A (Spacing regime)

B_j = effect of j^{th} level of factor B (Genotype)

$A_i\,B_j$ = the interaction of Spacing and Genotype

e_{ijk} = random error

3.4.3 Stability analysis

A linear regression analysis for genotype performance assessed across environments was performed using deviation from regression value (b) and deviations mean square (s^2_{di}). Elberhart and Russel (1966) advocated the importance of deviation from regression when deciding the suitability of genotypes for different environmental conditions. In this case, a genotype with deviation from regression approaching zero and regression coefficient equal to unity is regarded to be suitable for a given environment .The following linear regression model was used.

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}, \quad \text{.......} \quad (3)$$

Where,

Y_{ij} = the variety mean of the i^{th} variety at the j_{th} environment

μ_i = the i^{th} variety mean over all environments

β_i = the regression coefficient that measures the response of the i^{th} variety to varying environments

δ_{ij} = the deviation from regression of the i^{th} variety at the j^{th} environment

I_j = the environmental index.

3.4.4 Simple correlation analysis

Simple correlations among yield and yield components were measured using Portable PASW Statistics 18 package for each location and for combined locations.

3.4.5 Genotypic and phenotypic correlations

Genotypic and phenotypic correlations were computed using the formula cited by Robinson *et al.* (1951).

Genotypic correlation;

$r = (\delta g_{12} / (\delta g_1)(\delta g_2)$ .... (4)

Whereas:

δg_{12} = the genotypic covariance between the two traits

δg_1 = the genotypic variance of the first trait

δg_2 = the genotypic variance of the second trait

Phenotypic correlation;

$r = (\delta ph_{12}) / (\delta ph_1)(\delta ph_2)$ ....(5)

Whereas: δph_{12} = the phenotypic covariance between two traits

δph_1 = the phenotypic variance of the first trait

δph_2 = the phenotypic variance of the second trait

3.4.6 Path coefficient analysis

Path coefficient is simply a standardized partial regression coefficient and measures the direct influence of one variable upon another and permits the separation of the correlation coefficients into components of direct and indirect effects. The use of method requires cause and effect situation among the variables. The relationships among yield components of vegetative as well as reproductive variables; plant height, days to 50% flowering, head diameter, number of seeds per head, seed weight per head and 100 seed weight on seed yield were determined at each location and across locations as combined analysis. The relationships between correlation coefficients and path coefficients were established using the statistical model arranged in matrix notation as outlined by Wright (1921) and adopted by Dewey and Lu (1959)

I. $r_{17} = P_{17} + r_{12}P_{27} + r_{13}P_{37} + r_{14}P_{47} + r_{15}P_{57} + r_{16}P_{67}$

II. $r_{27} = r_{12}P_{17} + P_{27} + r_{23}P_{37} + r_{24}P_{47} + r_{25}P_{57} + r_{26}P_{67}$

III. $r_{37} = r_{13}P_{17} + r_{23}P_{27} + P_{37} + r_{34}P_{47} + r_{35}P_{57} + r_{36}P_{67}$

IV. $r_{47} = r_{14}P_{17} + r_{24}P_{27} + r_{34}P_{37} + P_{47} + r_{45}P_{57} + r_{46}P_{67}$

V. $r_{57} = r_{15}P_{17} + r_{25}P_{27} + r_{35}P_{37} + r_{45}P_{47} + P_{57} + r_{56}P_{67}$

VI. $r_{67} = r_{16}P_{17} + r_{26}P_{27} + r_{36}P_{37} + r_{46}P_{47} + r_{56}P_{57} + P_{67}$

VII. $I = P^2X_7 + P^2_{27} + P^2_{37} + P^2_{47} + P^2_{57} + 2P_{17}r_{12}P_{27} + 2P_{17}\, r_{13}P_{37} + 2P_{17}r_{14}P_{47} +$
$2P_{17}r_{15}P_{57} + 2P_{17}r_{16}P_{67} + 2P_{27}r_{23}P_{37} + 2P_{27}r_{24}P_{47} + 2P_{27}r_{25}P_{57} + 2P_{27}r26P_{67} + 2P_{37}r_{34}P_{47}$
$+ 2P_{37}r_{35}P_{57} + 2P_{37}r_{36}P_{67} + 2P_{47}r45P_{57} + 2P_{47}r_{46}P_{67} + 2P_{57}r_{56}P_{67}$ ....(6)

CHAPTER FOUR

4.0 RESULTS

Results of analysis of variance for the various variables are shown in Table 1. Locations indicated significant difference for all studied variables while spacing differed significantly for plant height, stem girth, days to 50% flowering, days to 50% physiological maturity, head diameter, seed weight per head, 100 seed weight and seed yield per hectare. Genotype differences were registered for all variables except for 100 seed weight. Location x spacing interaction was significant for plant height, stem girth, days to 50% flowering, days to 50% physiological maturity and head diameter. Genotype x location interaction displayed significant difference for all studied variables, while genotype x location x spacing interaction was not significant for all variables.

Table 1: Analysis of variance for studied variables (Mean squares)

SV	DF	PH(Cm)	SG(cm)	D50%FL	D50%PM	HD(cm)	NS/H	SW/H(g)	100SW(g)	Y/Ha (kg)
Rep	2	54.6	0.06	0.24	2.24	12.30**	120 137	410.9	0.13	104 393
Locat	2	60748.4***	86.04***	320.16***	396.38***	787.77***	1 880 014***	20344.7***	11.84***	29 060 547***
Error	12	114.6	0.59	4.46	9.68	1.75	74324	688.4	0.57	145 6830
Spacing	2	428.1*	4.55***	114.98***	76.83**	25.16***	210 250	2431.5*	1.4*	28 659 020***
LxS	4	666.2**	4.24***	7.98***	8.55***	14.85***	26 676	96.4	0.21	1 876 997
Error	12	121.4	0.22	4.66	14.2	2.45	111 946	640.4	0.31	967 953
Genotype	2	14919.8***	18.26***	1033.72***	1200.31***	106.74***	1 221 307***	5206.5***	0.09	.87 938***
GxL	4	1429.4***	4.92***	8.72***	5.64	12.99**	94 209*	679.8**	1.19***	593 091**
GxS	4	79	0.3*	3.09	5.53	0.02	14 252	96	0.18	368 964*
GxLxS	8	75.7	0.54	2.16	3.75	2.75	19 879	104.2	0.14	283 530
O.Error	36	107.1	0.56	1.40	6.07	2.39	26 777	120.7	0.2	139 727

* = Significant at 0.05,

** = Significant at 0.01 and

*** = Significant at 0.001.

Key;

DF=degree of freedom

PH= Plant Height

SG=Sterm Girth

D50%FL= Days to 50% Flowering

D50%PM= Days to 50% Physiological Maturity

HD=Head Diameter

NS/H= Number of Seeds per Head

SW/H= Seed Weight per Head

100SW= Hundred Seed Weight

Y/Ha= Seed Yield per Hectare

cm= centimetre

g=gram

kg=kilogram

ha= Hectare

4.1 Main effects of locations for the studied variables

Generally, locations influenced the studied variables. The overall performance of genotypes for the variables was better at Seatondale followed by Uyole and lastly Inyala. Effects of location for the various variables are as shown in Table 2.

4.1.1 Days to 50% flowering (days)

There was no significant difference on days to 50% flowering between Seatondale (82.81 days) and Uyole (82.67 days), though they differed significantly from Inyala (76.78 days). This indicated that all the genotypes flowered earlier at Inyala than at Seatondale and Uyole.

4.1.2 Days to 50% physiological maturity (days)

Seatondale (108.5 days) and Uyole(110.2 days) expressed no significant difference on days to 50% physiological maturity except for Inyala(102.9 days) which differed significantly and matured earlier than the other sites.

4.1.3 Plant height (cm)

There was a significant difference among the three locations in terms of plant height. Plants at Seatondale were taller (239.6 cm) followed by Uyole(229.7 cm) then Inyala (153.0 cm).

4.1.4 Stem girth

There was a significant difference among the three locations in terms of stem girth. Plants at Seatondale had bigger stem girth (11.74 cm) followed by Uyole(10.07 cm) then lastly Inyala (8.17 cm).

4.1.5 Head diameter

There was a significant difference among the three locations in terms of head diameter. Plants' heads at Seatondale (24.37 cm) were bigger than at Uyole (20.18 cm) and at Inyala (13.65 cm).

4.1.6 Number of seeds/head

There was no significant difference for number of seeds per head between Seatondale (1170) and Uyole (1114). However, the two sites differed significantly from Inyala (688).

4.1.7 Seed weight/head (g)

Seatondale (101.67 g) differed significantly ($P<0.01$) from Uyole (66.13 g) and Inyala (47.66 g). However, no significant differences were detected on seed weight per head at Uyole and Inyala

4.1.8 100 seed weight (g)

Seatondale (6.99 g) differed significantly from Inyala (5.99 g) and Uyole (5.75 g). However, at Uyole and Inyala there was no significant difference on 100-seed weight.

4.1.9 Seed yield (kg/ha)

There was no significant difference for seed yield between Seatondale (3731 kg/ha) and Uyole (2988 kg/ha). Nonetheless, the two sites differed significantly from Inyala (1682 kg/ha) on seed yield.

Table 2: Main effects of locations for selected variables

Genotype/ Location	PH (cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/ H	SW/H (g)	100 SW (g)	Y/(kg/ ha
Seatondale	239.6a	11.74a	82.81a	108.5a	24.37a	1170a	101.67a	6.99a	3731a
Inyala	153.0c	8.17c	76.78b	102.9b	13.65c	688b	47.66b	5.99b	1682b
Uyole	229.7b	10.07b	82.67a	110.2a	20.18b	1114 a	66.13b	5.75b	2988a
Mean	207.4	9.993	80.75	107.20	19.40	991	71.8	6.243	2800
SE±	10.35	0.75	1.18	2.46	1.55	163.6	10.98	0.44	373.8
CV%	5.0	7.5	1.5	2.3	8.0	16.5	15.3	7.1	13.3
$LSD_{0.05}$	5.71	0.41	0.65	1.36	0.85	90.3	6.06	0.24	206.3

Key;

PH= Plant Height

SG= Stem Girth

D50%Fl= Days to fifty percent Flowering

D50%PM= Days to fifty percent Physiological Maturity

HD= Head Diameter

NS/H= Number of Seeds per Head

SW/H= Seed Weight per Head

100SW= Hundred Seed Weight

Y= Seed Yield

cm= centimeter

g= Gram

kg= Kilogram

ha= Hectare

4.2 Effects of Spacing for the Studied Variables at Seatondale Site

The spacing regimes influenced the studied variables in different ways. For example seed yield detected significant difference ($P<0.01$) following the trend of 75 cm x 15 cm> 75 cm x 30 cm> 75 cm x 45 cm (Table 3).

4.2.1 Days to 50% flowering (days)

At Seatondale site, there was no significant difference for days to 50% flowering between 75 cm x 15 cm (85.22 days) and 75 cm x 30 cm (83.56 days). However, the two differed significantly from 75 cm x 45 cm (79.67 days).

4.2.2 Days to 50% physiological maturity (days)

At Seatondale site there was a significant difference ($P<0.01$) among the three spacing regimes for days to 50% physiological maturity. The earliest maturity was expressed by the spacing regime 75 cm x 45 cm (106.2days), followed by 75 cm x 30 cm (108.4 days) and 75 cm x 15 cm (110.8 days).

4.2.3 Plant height (cm)

The spacing regimes did not significantly influence plant height. However, plants at spacing regimes of 75 cm x 15 cm (238 cm) and 75 cm x 30 cm (238 cm) were shorter than those at spacing regime 75 cm x 45 cm (242.8 cm).

4.2.4 Stem girth (cm)

There was no significant difference for stem girth at all three spacing regimes. The trend for stem girth was 75 cm x 30 cm (11.96 cm) > 75 cm x 15 cm (11.84 cm) >75 cm x 45 cm (11.40 cm).

4.2.5 Head diameter (cm)

There was no significant difference for head diameter in all three spacing regimes. The trend for head diameter was 75 cm x 45 cm (24.92 cm) > 75 cm x 15 cm (24.13 cm) >75 cm x 30 cm (24.07 cm).

4.2.6 Number of seeds/head

There was no significant difference for number of seeds/head in all three spacing regimes. The trend for number of seeds/head was 75 cm x 45 cm (1211 seeds/head) > 75 cm x 30 cm (1200 seeds/head) >75 cm x 15 cm (1101 seeds/head).

4.2.7 Seed weight/head (g)

There was no significant difference for seed weight/head in all three spacing regimes. The trend for seed weight/head was 75 cm x 30 cm (110.6 g) > 75 cm x 45 cm (105.8 g) >75 cm x 15 cm (88.7 g).

4.2.8 100 seed weight (g)

There was no significant difference for 100seed weight in all three spacing regimes. The trend for 100 seed weight was 75 cm x 30 cm (7.06 g) > 75 cm x 45 cm (7.04 g) >75 cm x 15 cm (6.89 g).

4.2.9 Yield (kg/ha)

There was a significant ($P<0.05$) difference among the three spacing regimes for yield (kg/ha). Yield at 75 cm x 15 cm (4955 kg/ha) differed significantly from 75 cm x 30 cm (3652 kg/ha) and 75 cm x 45 cm (2586 kg/ha), while spacing of 75 cm x 30 cm differed significantly ($P<0.01$) from 75 cm x 45 cm.

Table 3: Effects of spacing for studied variables at Seatondale site

Spacing regimes	PH (cm)	SG (cm)	D50%FL	D50% PM	HD (cm)	NS/H No.	SW/H (g)	100 SW(g)	Y/Ha (kg)
75x45cm	242.8	11.40	79.67b	106.2b	24.92	1211	105.8	7.04	2586c
75x30cm	238.0	11.96	83.56a	108.4ab	24.07	1200	110.6	7.06	3652b
75x15cm	238.0	11.8	85.22a	110.8a	24.13	1101	88.7	6.89	4955a
Mean	239.6	11.74	82.81	108.48	24.37	1170	101.67	6.99	3731.
SE±	10.33	0.75	0.89	2.2	1.51	129.5	4.97	0.37	235.7
CV%	4.3	6.4	1.1	2.0	6.2	11.1	4.9	5.3	6.3
$LSD_{0.05}$	17.86	1.175	3.517	3.975	3.251	202.6	22.740	0.7258	1007

Key;

PH= Plant Height

SG= Stem Girth

D50%Fl= Days to fifty percent Flowering

D50%PM= Days to fifty percent Physiological Maturity

HD= Head Diameter

NS/H= Number of Seeds per Head

SW/H= Seed Weight per Head

100SW= Hundred Seed Weight

Y= Seed Yield

cm= centimeter

g= Gram

kg= kilogram

ha= Hectare

4.3 Effects of Spacing for Studied Variables at Inyala Site

The spacing regimes influenced the studied variables in different ways. For example seed yield detected significant difference ($P<0.01$) following the trend of 75 cm x 15 cm> 75 cm x 30 cm> 75 cm x 45 cm (Table 4).

4.3.1 Days to 50% flowering (days)

There was a significant difference among the spacing regimes for days to 50% flowering. The earliest flowering was experienced on spacing regime of 75 cm x 45 cm (75.78 days), followed by 75 cm x 30cm (76.33 days) while the latest flowering was experienced on spacing of 75 cm x 15 cm 978.22 days).

4.3.2 Days to 50% physiological maturity (days)

There was no significant difference among spacing regimes for days to 50% physiological maturity. The trend was 75 cm x 45 cm (102.4days)> 75 cm x 30cm (102.3 days) > 75 cm x 15 cm (103.9 days).

4.3.3 Plant height (cm)

There was no significant difference among spacing regimes for plant height. Nevertheless, the trend for tallness was 75 cm x 30 cm (154 cm)> 75 cm x 15 cm (153.2 cm)> 75 cm x 45 cm (151.7cm).

4.3.4 Stem girth (cm)

There was no significant difference between 75 cm x 30 cm (8.55 cm) and 75 cm x 45 cm (8.13 cm). Nevertheless, 75 cm x 30 cm differed significantly from 75 cm x 15 cm (7.83 cm).

4.3.5 Head diameter (cm)

There was no significant difference among spacing regimes for head diameter. However, the trend was 75 cm x 30 cm (14.31 cm)> 75 cm x 45 cm (13.42 cm)> 75 cm x 15cm (13.23 cm).

4.3.6 Number of seeds/head

There was no significant difference among spacing regimes for number of seeds/head. However, the trend was 75 cm x 45 cm (777)> 75 cm x 30 cm (711)> 75 cm x 15 cm (576).

4.3.7 Seed weight/head (g)

There was no significant difference among spacing regimes for seed weight/head, however the trend was 75 cm x 30 cm (54.50 g)> 75 cm x 45 cm (49.64 g)> 75 cm x 15 cm (38.83 g).

4.3.8 100 seed weight (g)

There was no significant difference between spacing of 75 cm x 45 cm (5.99 g) and 75 cm x 30 cm (6.28 g). However, the spacing of 75 cm x 30 cm differed significantly from spacing of 75 cm x 15 cm (5.69 g).

4.3.9 Seed yield (kg/ha)

There was a significant difference among the spacing regimes for seed yield (kg/ha). The spacing of 75 cm x 15 cm (2194 kg) differed significantly from 75 cm x 30 cm (1692 kg) and 75 cm x 45 cm (1159 kg).

Table 4: Effects of spacing for studied variables at Inyala site

Spacing	PH (Cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H(g)	100 SW(g)	Y/Ha (kg)
75x45cm	151.7	8.13ab	75.78c	102.4	13.42	777	49.64	5.99ab	1159c
75x30cm	154.0	8.55a	76.33b	102.3	14.3	711	54.50	6.28a	1692b
75x15cm	153.2	7.83b	78.22a	103.9	13.23	576	38.83	5.69b	2194a
Mean	153.0	8.17	76.78	102.89	13.65	688	47.7	5.985	1682
SE±	10.19	1.01	1.21	1.75	1.97	166.6	12.36	0.39	349.2
CV%	6.7	12.4	1.6	1.7	14.5	24.2	25.9	6.6	20.8
$LSD_{0.05}$	17.95	1.495	1.777	3.714	2.992	269.2	23.90	0.6808	589.8

4.4 Effects of Spacing for Studied Variables at Uyole Site

The spacing regimes influenced the studied variables in different ways. For example seed yield detected significant difference (P<0.01) following the trend of 75 cm x 15 cm> 75 cm x 30 cm> 75 cm x 45 cm (Table 5).

4.4.1 Days to 50% flowering (days)

There was a significant difference (P<0.01 between 75 cm x15 cm (85 days) and 75 cm x45 cm (80days). However, there was no significant difference detected between 75 cm x15 cm and 75 cm x30 cm (83 days) as well as between 75 cm x 30cm and 75 cm x 45cm.

4.4.2 Days to 50% physiological maturity (days)

There was a significant difference among spacing regimes for days to 50% physiological maturity. Spacing 75 cm x 45cm (118 days) differed significantly (P<0.01) from 75 cm x 30 cm (109 days) and 75 cm x 15 cm (104 days).

4.4.3 Plant height (cm)

There was a significant difference ($P<0.01$) for plant height among spacing regimes. The shortest plants were experienced on spacing of 75 cm x 45 cm (215.4 cm) while the tallest on spacing of 75 cm x 15 cm (242.7 cm).

4.4.4 Stem girth (cm)

There was a significant difference among spacing regimes for stem girth. 75 cm x 45 cm (11.09 cm) differed significantly from 75 cm x 30 cm (10.24 cm) and 75 cm x 15 cm (8.89 cm).

4.4.5 Head diameter (cm)

There was a significant difference among spacing regimes for head diameter. 75x45cm (22.26 cm) differed significantly from 75 cm x 30 cm (20.67 cm) and 75 cm x 15 cm (17.62 cm).

4.4.6 Number of seeds/head

There was a significant difference for number of seeds/head between 75 x 15cm (1334) and the other two. However, 75 cm x 30 cm (1009) and 75 cm x 45 cm (1000) did not show significant difference.

4.4.7 Seed weight/head (g)

There was no significant difference among spacing regimes for seed weight/head. However, the trend was 75 cm x 30 cm (76.84 g)> 75 cm x 45 cm (63.72 g)> 75 cm x 15 cm (57.82 g).

4.4.8 100 seed weight (g)

There was no significant difference among spacing regimes for 100-seed weight. However, the trend was 75 cm x 30 cm (6.12 g)> 75 cm x 45 cm (5.6 g)> 75 cm x 15 cm (5.52 g).

4.4.9 Seed yield (kg/ha)

There was a significant difference for seed yield (kg/ha) between 75 cm x 15 cm (4412 kg) and 75 cm x 45 cm (1640 kg). Nevertheless, there was no significant difference between 75 cm x 30 cm (2912 kg) and 75 cm x 45 cm (1640 kg).

Table 5: Effects of spacing for studied variables at Uyole site

Spacing	PH (Cm)	SG(cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H (g)	100SW (g)	Y/Ha (kg)
75x45cm	215.4b	11.09a	80b	118a	22.26a	1000b	63.72	5.6	1640b
75x30cm	231.1ab	10.24b	83ab	109b	20.67b	1009b	76.84	6.12	2912ab
75x15cm	242.7a	8.89c	85a	104c	17.62c	1334a	57.82	5.52	4412a
Mean	229.7	10.07	82.67	110	20.18	1114	66.1	5.75	2988
SE±	10.53	0.29	1.39	3.21	1.00	189.2	13.58	0.54	491.7
CV%	4.6	2.9	1.7	2.9	5.0	17.0	20.5	9.3	16.5
$LSD_{0.05}$	19.40	0.7399	3.395	7.478	1.746	715.5	47.38	1.088	1892

4.5 Effects of Spacing Combined Over Three Locations

Generally, spacing regimes combined over three locations influenced the studied variables significantly ($P<0.01$). For example seed yield in all three locations followed the trend of 75 cm x 15 cm> 75 cm x 30 cm> 75 cm x 45 cm (Table 6).

4.5.1 Days to 50% flowering (days)

There was a significant difference among spacing regimes over all three locations for days to 50% flowering whereby the earliest flowering was experienced by 75 cm x 45 cm. Spacing regime 75 cm x 15 cm (83days) differed significantly from 75 cm x 30 cm (81 days) and 75 cm x 45 cm (79 days).

4.5.2 Days to 50% physiological maturity (days)

There was a significant difference for days to 50% physiological maturity between 75 cm x 15 cm (109 days) and the other two, but there was no significant difference between 75 cm x 30 cm (107 days) and 75 cm x 45 cm (106 days).

4.5.3 Plant height (cm)

There was no significant difference for plant height between 75 cm x 30 cm (207.7 cm) and 75 cm x 15 cm (211.3 cm). However, the two spacing regimes differed significantly ($P<0.01$) from 75 cm x 45 cm (203.3 cm).

4.5.4 Stem girth (cm)

There was no significant difference for stem girth between 75 cm x 30 cm (10.25 cm) and 75 cm x 45 cm (10.21 cm) but differed significantly from 75 cm x 15 cm (9.52 cm). This indicated that plants with bigger stems were recorded at wider spacing and intermediate spacing whereas the smallest at narrower spacing.

4.5.5 Head diameter (cm)

There was no significant difference for head diameter between 75 cm x 45 cm (20.2 cm) and 75 cm x 30 cm (19.68 cm). However, the spacing regimes of 75 cm x 45 cm and 75 cm x 30 cm differed significantly from 75 cm x 15 cm (18.33 cm).

4.5.6 Number of seeds/head

There was no significant difference among spacing regimes for number of seeds/head. Although, the trend for number of seeds per head was 75 cm x 30 cm (1049)> 75 cm x 45 cm (1034)> 75 cm x 15 cm (889).

4.5.7 Seed weight/head (g)

There was a significant difference for seed weight/head between 75 cm x 30 cm (80.63 g) and 75 cm x 15 cm (61.77 g). However, the spacing of 75 cm x 30cm and 75 cm x 45 cm (73.05 g) did not differ significantly.

4.5.8 100 seed weight (g)

There was a significant difference for 100 seed weight between 75 cm x30 cm (6.49 g) and 75 cm x 15 cm (6.03 g), but the difference was not significant from 75x45cm (6.21g).

4.5.9 Seed yield (kg/ha)

There was a significant difference among spacing regimes for seed yield. Spacing 75 cm x 15 cm (3854 kg) differed significantly from 75 cm x 30 cm (2752 kg) and 75 cm x 45 cm (1795 kg).

Table 6: Effects of spacing combined over three locations

Spacing	PH	SG	DFL	DPM	HD	NS/H	SW/H	100 SW	Y/Ha
75x45cm	203.3b	10.21a	79c	106b	20.20a	1034a	73.05a	6.21a	1795c
75x30cm	207.7a	10.25a	81b	107b	19.68a	1049a	80.63a	6.49a	2752b
75x15cm	211.3a	9.52b	83a	109a	18.33b	889b	61.77b	6.03b	3854a
Mean	207.4	9.99	81	107	19.40	991	71.8	6.24	2800.33
SE±	10.35	0.75	1.18	2.46	1.55	164	10.98	0.44	373.8
CV%	5.0	7.5	1.5	2.3	8.0	17	15.3	7.1	13.3
$LSD_{0.05}$	5.71	0.4117	0.653	1.36	0.853	90	6.06	0.24	206.3

4.6 Effects of Genotypes at Seatondale

The studied genotypes detected significant difference over the studied variables. For example PI 364860 generally performed best in all variables except for 100 seed weight (Table 7).

4.6.1 Days to 50% flowering (days)

There was a significant difference among the genotypes for days to 50% flowering. PI 364860 (76.33 days) differed significantly from K.Fedha (82.44 days) and Record (89.67 days). PI 364860 experienced the earliest flowering while latest flowering was by Record.

4.6.2 Days to 50% physiological maturity (days)

There was a significant difference among the genotypes for days to 50% physiological maturity. PI 364860 (101.6 days) differed significantly from K.Fedha (109.2 days) and Record (114.7 days). PI 364860 experienced earliest maturity while latest maturity was by Record.

4.6.3 Plant height (cm)

There was a significant difference for plant height between PI 364860 (217.6 cm) and K.Fedha (249.2 cm) as well as Record (252.0 cm), while K.Fedha and Record did not differ significantly. However, PI 364860 had the shortest and Record had the tallest plants.

4.6.4 Stem girth (cm)

There was no significant difference for stem girth among the studied genotypes. Nevertheless, the trend was PI 364860 (12.03 cm)> K.Fedha (11.84 cm)> Record (11.33 cm).

4.6.5 Head diameter (cm)

There was a significant difference for head diameter between PI 364860 (26.02 cm) and the other two. However, there was no significant difference between K.Fedha (23.70 cm) and Record (23.40 cm).

4.6.6 Number of seeds/head

Number of seeds/head showed significant difference between PI 364860 (1324) and K.Fedha (1134) and Record (1053). However, there was no significant difference between K.Fedha and Record.

4.6.7 Seed weight/head (g)

Seed weight/head showed significant difference between PI 364860 (108 g) and K.Fedha (100.7 g) and Record (96.3 g). However, there was no significant difference between K.Fedha and Record.

4.6.8 100 seed weight (g)

The 100 seed weight showed significant difference between PI 364860 (6.61g) and K.Fedha (7.05 g) and Record (7.32 g). However, there was no significant difference between K.Fedha and Record.

4.6.9 Seed yield (kg/ha)

There was no significant difference between PI 364860 (4014 kg) and K.Fedha (3777 kg), but these genotypes differed significantly from Record (3401 kg).

Table 7: Effects of genotypes at Seatondale site

Genotype	PH (Cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H (g)	100 SW(g)	Y/Ha (kg)
Record	252.0 a	11.33	89.67a	114.7a	23.40b	1053b	96.3b	7.32a	3401b
K.Fedh	249.2 a	11.84	82.44b	109.2b	23.70b	1134b	100.7b	7.05a	3777a
PI 364860	217.6b	12.03	76.33c	101.6c	26.02a	1324a	108.0a	6.61b	4014a
Mean	239.6	11.74	82.81	108.48	24.37	1170	101.67	6.99	3731
SE±	10.33	0.747	0.892	2.198	1.505	129.5	4.974	0.3739	235.7
CV%	4.3	6.4	1.1	2.0	6.2	11.1	4.9	5.3	6.3
$LSD_{0.05}$	10.61	0.767	0.917	2.258	1.546	133.0	5.109	0.3841	242.0

4.7 Effects of Genotypes at Inyala Site

The studied genotypes showed significant difference over all the studied variables. For example PI 364860 generally performed best in all variables (Table 8).

4.7.1 Days to 50% flowering (days)

There was a significant difference among the genotypes for days to 50% flowering. PI 364860 (72 days) differed significantly (P<0.01) from K.Fedha (77 days) and Record (82 days). Genotype PI 364860 took the shortest period to attain 50% flowering whereas Record took the longest.

4.7.2 Days to 50% physiological maturity (days)

There was a significant difference among the genotypes for days to 50% physiological maturity. Genotype PI 364860 which took 96 days to reach 50% physiological maturity differed significantly (P<0.01) from K.Fedha (103 days) and Record (109 days). Genotype PI 364860 took the shortest period to attain 50% physiological maturity whereas Record took the longest.

4.7.3 Plant height (cm)

Genotype PI 364860 differed significantly from K.Fedha and Record. However, significant difference was not detected between K.Fedha and Record. Genotype PI 364860 had the shortest plants whereas Record had the tallest.

4.7.4 Stem girth (cm)

There was no significant difference for stem girth among genotypes. Nevertheless, the trend was PI 364860 (8.59 cm)> K.Fedha (8.38 cm)> Record (7.54 cm).

4.7.5 Head diameter (cm)

There was a significant difference (P<0.01) among genotypes in head diameter. Genotype PI 364860 had the biggest heads while Record the smallest.

4.7.6 Number of seeds/head

All genotypes showed significant difference ($P<0.01$) in number of seeds/head. Genotype PI 364860 (1024) differed significantly from K.Fedha (647.4) and Record (392). The trend for this variable was PI 364860> K.Fedha> Record.

4.7.7 Seed weight/head (g)

All genotypes showed significant difference ($P<0.01$) in seed weight/head. Genotype PI 364860 (71.73 g) differed significantly ($P<0.01$) from K.Fedha (44.85 g) and Record (26.40 g). The trend for this variable was PI 364860> K.Fedha> Record.

4.7.8 100 seed weight (g)

Genotype PI 364860 and K.Fedha did not differ significantly in 100 seed weight. However, these genotypes differed significantly from Record in this variable.

4.7.9 Seed yield (kg/ha)

There was a significant difference among all genotypes for seed yield. The genotype PI 364860 (2410 kg) differed significantly from K.Fedha (1621 kg) as well as Record (1014 kg).

Table 8: Effects of genotypes at Inyala site

Genotype	PH (Cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H (g)	100SW (g)	Y/Ha (kg)
Record	161.3a	7.54	82a	109a	12.34b	392c	26.40c	5.59b	1014c
K.Fedh	160.8a	8.38	77b	103b	13.71ab	647.4b	44.85b	6.09a	1621b
PI 364860	136.8b	8.59	72c	96c	14.91a	1024.3a	71.73a	6.28a	2410a
Mean	153.0	8.17	76.78	102.89	13.65	688.	47.7	5.99	1682
SE±	10.19	1.014	1.210	1.753	1.974	173.6	12.36	0.3930	349.2
CV%	6.7	12.4	1.6	1.7	14.5	25.2	25.9	6.6	20.8
$LSD_{0.05}$	10.46	1.042	1.242	1.801	2.028	130.4	12.70	0.4036	358.6

4.8 Effects of Genotypes at Uyole Site

The studied genotypes showed significant difference in all studied variables. For example PI 364860 generally performed best in all variables (Table 9).

4.8.1 Days to 50% flowering (days)

There was a significant difference among the genotypes for days to 50% flowering. PI 364860 (76.11 days) differed significantly from K.Fedha (82.22 days) and Record (89.67 days). Genotype PI 364860 flowered much earlier whereas Record flowered latest.

4.8.2 Days to 50% physiological maturity (days)

There was a significant difference among the genotypes for days to 50% physiological maturity. Genotype PI 364860 (103.8 days) differed significantly ($P<0.01$) from K.Fedha (109.2 days) and Record (117.7 days). PI 364860 experienced the earliest maturity while Record was the latest.

4.8.3 Plant height (cm)

There was a significant difference for plant height among all genotypes. The genotype PI 364860 (187.1 cm) differed significantly from K.Fedha (243.8 cm) as well as Record (258.3 cm). However, PI 364860 was the shortest and Record the tallest.

4.8.4 Stem girth (cm)

There was a significant difference among genotypes in stem girth. The genotype PI 364860 (11.89 cm) differed significantly from K.Fedha (9.63 cm) and Record (8.70 cm).

4.8.5 Head diameter (cm)

There was a significant difference among genotypes in head diameter. The genotype PI 364860 (23.71 cm) differed significantly from K.Fedha (19.72 cm) and Record (17.11 cm).

4.8.6 Number of seeds/head

Genotype PI 364860 (1334) differed significantly ($P<0.01$) from K.Fedha (1009) and Record (1000). However, the significant difference was not detected between K.Fedha and Record for this variable.

4.8.7 Seed weight/head (g)

The significant difference showed among genotypes. Genotype PI 364860 (81.20 g) differed significantly from K.Fedha (60.79 g) and Record (56.40 g). However, the difference was not showed between K.Fedha and Record.

4.8.8 100 seed weight (g)

All genotypes did not differ significantly in 100 seed weight. However, genotype PI 364860 had much higher 100 seed weight than others whereas Record was the least. The trend was PI 364860 (5.9 g) > K.Fedha (5.722 g)> Record (5.622 g).

4.8.9 Seed yield (kg/ha)

There was a significant difference between PI 364860 (3666 kg) and the other two genotypes in seed yield. Nevertheless, there was no significant difference between K.Fedha (2663 kg) and Record (2635 kg).

Table 9: Effects of genotypes at Uyole site

Genotype	PH (Cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H (g)	100SW (g)	Y/Ha (kg)
Record	258.3a	8.70c	89.67a	117.7a	17.11c	1000b	56.40b	5.622a	2635b
K.Fedh	243.8b	9.63b	82.22b	109.2b	19.72b	1009b	60.79b	5.722a	2663b
PI 364860	187.1c	11.89a	76.11c	103.8c	23.71a	1334a	81.20a	5.900a	3666a
Mean	229.7	10.074	82.67	110.22	20.18	1114.	66.1	5.75	2988
SE±	10.53	0.2887	1.394	3.209	1.002	189.2	13.58	0.536	491.7
CV%	4.6	2.9	1.7	2.9	5.0	17.0	20.5	9.3	16.5
$LSD_{0.05}$	10.82	0.2965	1.432	3.296	1.029	194.3	13.95	0.551	505.0

4.9 Effects of Genotypes Combined Over Three Locations

Generally all genotypes detected differences in all studied variables across locations. For example genotype PI 364860 performed better in all variables than the other genotypes (Table 10).

4.9.1 Days to 50% flowering (days)

There was a significant difference among all genotypes for days to 50% flowering over all locations. PI 364860 (74.67 days) differed significantly from K.Fedha (80.56 days) and Record (87.04 days). Genotype PI 364860 attained 50% flowering earliest while Record flowered latest.

4.9.2 Days to 50% physiological maturity (days)

There was a significant difference among all genotypes for days to 50% physiological maturity over all locations. PI 364860 (100.6 days) differed significantly ($P<0.01$) from K.Fedha (107.1 days) and Record (113.9 days). Genotype PI 364860 matured earliest whereas Record matured latest.

4.9.3 Plant height (cm)

There was a significant difference among all genotypes for plant height over all locations. Genotype PI 364860 (180.5 cm) differed significantly from K.Fedha (217.9 cm) and Record (223.9 cm). The shortest plants were experienced by PI 364860 and tallest plants by Record.

4.9.4 Stem girth (cm)

There was a significant difference among all genotypes for stem girth across locations. Genotype PI 364860 (10.84 cm) differed significantly from K.Fedha (9.95 cm) and Record (9.19 cm). Genotype PI 364860 had plants with the biggest stems whereas Record experienced the smallest.

4.9.5 Head diameter (cm)

There was a significant difference among genotypes in head diameter across locations. The genotype PI 364860 (21.55 cm) differed significantly from K.Fedha (19.05 cm) and Record (17.62 cm).

4.9.6 Number of seeds/head

All genotypes showed significant difference in number of seeds/head across locations. Genotype PI 364860 (1227) differed significantly from K.Fedha (930.1) and Record (815.2). Genotype PI 364860 had heads with the largest number of seeds/head whereas Record was the least.

4.9.7 Seed weight/head (g)

The genotypes used in the study detected significant difference in seed weight/head across locations. The genotype PI 364860 (86.98) differed significantly from K.Fedha (68.77) and Record (59.71).

4.9.8 100 seed weight (g)

No significant difference among genotypes was detected in 100 seed weight. However, the trend was K.Fedha (6.29g)> PI 364860 (6.26 g) > Record (6.18 g).

4.9.9 Seed yield (kg/ha)

There was a significant difference among genotypes in seed yield. The genotype PI 364860 (3363 kg) differed significantly from K.Fedha (2687 kg) as well as Record (2350 kg). Genotype PI 364860 yielded the highest whereas Record was the least.

Table 10: Effects of genotypes combined over three locations

Genotype	PH Cm)	SG (cm)	D50% FL	D50% PM	HD (cm)	NS/H	SW/H (g)	100S W(g)	Y/Ha (kg)
Record	223.9a	9.19c	87.04a	113.9a	17.62c	815.2c	59.71c	6.18	2350c
K.Fedha	217.9b	9.95b	80.56b	107.1b	19.05b	930.1b	68.77b	6.29	2687b
PI 364860	180.5c	10.84a	74.67c	100.6c	21.55a	1227.3a	86.98a	6.26	3363a
Mean	207.4	9.99	80.75	107.20	19.40	991	71.8	6.24	2800
SE±	10.35	0.75	1.18	2.46	1.55	163.6	10.98	0.44	373.8
CV%	5.0	7.5	1.5	2.3	8.0	16.5	15.3	7.1	13.3
$LSD_{0.05}$	5.71	0.4117	0.653	1.360	0.853	90.3	6.06	0.2431	206.3

4.10 Effects of Genotypes X Location Interaction for the Studied Variables

The genotype x location interaction was detected in the studied variables. The results of genotype x location interaction for the studied variables are shown in Table 11-18.

4.10.1 Effects of genotype x location interaction for days to 50% flowering

The significant interaction between genotype and location was detected for days to 50% flowering. The earliest 50% flowering was obtained at Inyala with PI 364860 (72 days), while the latest was obtained at Seatondale and Uyole with Record taking the longest period to attain 50% flowering (90 days).

4.10.2 Effects of genotype x location interaction for days to 50% physiological maturity

The significant interaction between genotype and location was detected for days to 50% physiological maturity. The earliest 50% physiological maturity was obtained at Inyala with PI 364860 (96 days), while the latest was obtained at Uyole with Record taking the longest period to attain 50% physiological maturity (118 days).

4.10.3 Effects of genotype x location interaction for plant height

The interaction effect was significant for plant height. Generally, the shortest plants were obtained at Inyala whereas the tallest plants were recorded at Seatondale. Genotype PI 364860 was overall the shortest (136.8 cm) at Inyala while Record was the tallest at Uyole (258 cm).

4.10.4 Effects of genotype x location interaction for head diameter

The interaction effect was detected in head diameter across locations. Generally, the smallest headed plants were obtained at Inyala whereas the biggest headed plants were recorded at Seatondale. Genotype PI 364860 was overall with the biggest heads (26.02 cm) at Seatondale while Record was with the smallest at Inyala (12.34 cm).

4.10.5 Effects of genotype x location interaction for number of seeds/head

The highest number of seeds/head was obtained at Uyole with PI 364860 (1334 seeds) while the least was at Inyala with Record (392 seeds).

4.10.6 Effects of genotype x location interaction for seed weight/head

The highest seed weight/head was attained at Seatondale whereas the lowest seed weight/head were obtained at Inyala. Genotype PI 364860 had the highest seed weight/head at Seatondale (108g) while Record had the lowest seed weight/head at Inyala (26.4 g).

4.10.7 Effects of genotype x location interaction for 100 seed weight

The highest 100 seed weight was obtained at Seatondale whereas the lowest was found at Inyala. Record had the highest 100 seed weight at Seatondale (7.32 g) as well as the lowest at Inyala (5.59 g).

4.10.8 Effects of genotype x location interaction for seed yield

Interaction effect also was detected in seed yield across locations. Highest seed yield was obtained at Seatondale whereas the least seed yield was found at Inyala. Genotype PI 364860 yielded the highest in seed yield at Seatondale (4014 kg/ha) whereas Record the lowest at Inyala (1014 kg/ha).

Table 11: Effects of genotypes X location for days to 50% flowering (days)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±0.47
Seatondale	90	82	76	83
Inyala	82	77	72	77
Uyole	90	82	76	83
Mean (±) 1.18	87	80	75	
CV% 1.5				
$LSD_{0.05}$(±)0.65				

Table 12: Effects of genotypes X location for days to 50% physiological maturity (days)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±0.69
Seatondale	115	109	102	109
Inyala	109	103	96	103
Uyole	118	109	104	110
Mean(±) 2.46	114	107	101	
CV% 2.3				
$LSD_{0.05}$(±)1.36				

Table 13: Effects of genotypes X location for plant height (cm)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±2.38
Seatondale	252.0	249.2	217.6	239.60
Inyala	161.3	160.8	136.8	153.0
Uyole	258.3	243.8	187.1	229.7
Mean(±) 10.35	223.87	217.9	180.5	
CV% 5				
$LSD_{0.05}$(±) 5.71				

Table 14: Effects of genotypes X location for head diameter (cm)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±0.4
Seatondale	23.40	23.70	26.02	24.37
Inyala	12.34	13.71	14.91	13.65
Uyolo	17.11	19.72	23.71	20.18
Mean (±) 1.55	17.62	19.04	21.55	19.4
CV% 8				
$LSD_{0.05}$ (±) 0.85				

Table 15: Effects of genotypes X location for number of seeds/head (No.)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±91
Seatondale	1053	1134	1324	1170
Inyala	392	647	1024	688
Uyolo	1000	1009	1334	1114
Mean(±)164	815	930	1227	
CV% 16.5				
$LSD_{0.05}$(±) 90.3				

Table 16: Effects of genotypes X location for seed weight/head (g)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±8.7
Seatondale	96.3	100.7	108.0	101.67
Inyala	26.40	44.85	71.73	47.66
Uyole	56.40	60.79	81.20	66.13
Mean (±)10.98	59.7	68.78	86.98	
CV% 15.3				
$LSD_{0.05}$(±) 6.06				

Table 17: Effects of genotypes X location for 100-seed weight (g)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±0.17
Seatondale	7.32	7.05	6.61	6.99
Inyala	5.59	6.09	6.28	5.99
Uyole	5.62	5.72	5.90	5.75
Mean(±) 0.44	6.18	6.29	6.26	
CV% 7.1				

$LSD_{0.05}(\pm)$ within table is 0.24

Table 18: Effects of genotypes X location for seed yield (kg/ha)

Genotype/ Location	Record	K.Fedha	PI 364860	Mean±268.2
Seatondale	3401	3777	4014	3730.67
Inyala	1014	1621	2410	1681.67
Uyole	2635	2663	3666	2988
Mean(±)373.8	2350	2687	3363	2800
CV% 13.3				
$LSD_{0.05}(\pm)$ 206.3				

4.11 Genotype x Spacing Interaction

Genotype x spacing interaction was revealed in most of the studied variables at all locations. The significant genotype x spacing interaction for the studied variables is indicated in Table 19-30 and described per location.

4.11.1 Effects of genotype x spacing interaction at Seatondale site

Genotype x spacing interaction was detected in studied variables at Seatondale. However, most studied variables showed significant interactions. Effects of genotype x spacing interaction at Seatondale site are as shown in Table 19-21.

4.11.1.1 Effects of genotype x spacing interaction for days to 50% flowering

The significant interaction between genotype and spacing was detected for days 50% flowering. The earliest 50% flowering was attained at spacing of 75 x 45 cm (73.67days) with PI 364860 while the latest was at spacing of 75 cm x 15 cm (92.67 days) with Record (Table 19).

4.11.1.2 Effects of genotype x spacing interaction for days to 50% physiological maturity

Genotype x spacing interaction was revealed significantly ($P<0.01$) in attaining 50% physiological maturity at Seatondale site. However, the earliest 50% physiological maturity was achieved at spacing of 75 cm x 45 cm (99.67 days) with PI 364860 whereas the latest at 75 cm x 15 cm (118.33 days) with Record (Table 20).

4.11.1.3 Yield (kg/ha)

The interaction effect was detected in seed yield across spacing regimes. The highest seed yield was obtained at spacing of 75 cm x 15 cm (5410 kg/ha) with PI 364860 while the least at 75 cm x 45 cm (2328 kg/ha) with Record (Table 21).

Table 19: Effects of genotypes X spacing for days to 50%flowering (days)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±1.6
75x45cm	86.00	79.33	73.67	79.67
75x30cm	90.33	83.00	77.33	83.55
75x15cm	92.67	85.00	78.00	85.22
Mean(±)0.9	89.67	82.44	76.33	
CV% 1.1				
$LSD_{0.05}$(±) 3.52				

Table 20: Effects of genotypes X spacing for days to 50% physiological maturity (days)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±1.4
75x45cm	111.33	107.67	99.67	106.22
75x30cm	114.33	109.33	101.67	108.44
75x15cm	118.33	110.67	103.33	110.78
Mean(±)2.2	114.7	109.2	101.6	
CV% 2				
$LSD_{0.05}$(±) 3.98				

Table 21: Effects of genotypes X spacing for seed yield (kg/ha)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±454.2
75x45cm	2328	2680	2750	2586
75x30cm	3593	3480	3881	3651
75x15cm	4283	5172	5410	4955
Mean(±)235.7	3401	3777	4014	
CV% 6.32				
$LSD_{0.05}$(±) 1007.4				

4.11.2 Effects of genotypes X spacing at Inyala site

Genotype x spacing interaction was detected in studied variables at Inyala. However, some studied variables revealed significant interactions across spacing regimes whereas others did not reveal significant interactions. Effects of genotype x spacing interaction at Inyala site are as shown in Table 22-24.

4.11.2.1 Effects of genotype x spacing interaction for days to 50% flowering

The genotype x spacing interaction was significant for days to 50% flowering across spacing regimes. The earliest flowering was experienced at spacing regime 75 cm x 45 cm (71 days) with PI 364860), however the latest was at 75 cm x 15 cm (83.67 days) with Record (Table 22).

4.11.2.2 Effects of genotype x spacing interaction for stem girth

There was a significant interaction for stem girth across spacing regimes. The biggest stems were recorded on spacing 75 cm x 30cm (9.03 cm) with PI 364860, nevertheless the smallest was recorded at 75 cm x15 cm (6.90 cm) with Record (Table 23).

4.11.2.3 Seed yield (kg/ha)

There was a significant interaction for seed yield between spacing regimes. However, the highest seed yield was found at spacing of 75 cm x 15 cm (3190 kg) with PI 364860 whereas the least at 75 cm x 45 cm (1159 kg) with Record (Table 24).

Table 22: Effects of genotypes X spacing for days to 50%flowereing (days) at Inyala

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±0.2
75x45cm	79.67	76.00	71.33	75.67
75x30cm	82.00	76.33	71.00	76.44
75x15cm	83.67	78.67	72.33	78.22
Mean(±)1.2	81.78	77.00	71.78	
CV% 1.6				
$LSD_{0.05}$ (±) 1.78				

Table 23: Effects of genotypes X spacing for stem girth (cm) at Inyala

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±0.2
75x45cm	7.81	8.26	8.33	8.13
75x30cm	7.92	8.69	9.03	8.55
75x15cm	6.90	8.19	8.39	7.83
Mean(±)1.0	7.541	8.379	8.586	
CV% 12.42				
$LSD_{0.05}$ (±) 1.5				

Table 24: Effects of genotypes X spacing seed yield (kg/ha) at Inyala

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±186
75x45cm	830	1048	1598	1158.67
75x30cm	961	1675	2441	1692.33
75x15cm	1250	2141	3190	2193.67
Mean(±)349.2	1014	1621	2410	
CV% 20.76				
$LSD_{0.05}$(±) 589.8				

4.11.3 Effects of genotype X spacing interaction at Uyole site

Genotype x spacing interaction was detected except for 100 seed weight, seed weight per head and number of seeds per head. Nonetheless, most studied variables revealed significant interactions across spacing regimes. Effects of genotype x spacing interaction at Uyole site are as shown in Table 25-30.

4.11.3.1 Effects of genotype x spacing interaction for days to 50% flowering (days)

There was a significant (P<0.01) interaction for days to 50% flowering across spacing regimes. The earliest 50% flowering was attained at spacing of 75 cm x 45 cm (74.67 days) with PI 364860 whereas the latest at 75 cm x 15 cm (92 days) with Record (Table 25).

4.11.3.2 Effects of genotype x spacing interaction for days to 50% physiological maturity

There was a significant interaction among spacing regimes for days to 50% physiological maturity. Genotype PI 364860 showed the earliest physiological maturity at spacing of 75 cm x 45 cm and 75 cm x 30 cm (103 days), while Record showed the latest at 75x15cm (120 days).

4.11.3.3 Effects of genotype x spacing interaction for plant height

There was a significant (P<0.01) interaction for plant height among spacing regimes. The shortest plants were experienced at spacing of 75 cm x 45 cm (177.5 cm) with PI 364860 while the tallest at spacing of 75 cm x 15 cm (275.2 cm) with Record (Table 27).

4.11.3.4 Effects of genotype x spacing interaction for stem girth

There was a significant interaction for stem girth across spacing regimes. Spacing of 75 cm x 45 cm (11.09 cm) experienced plants with the biggest stems were experienced at spacing of 75 cm x 45 cm (13.57) with PI 364860 while the smallest at 75 cm x 15 cm (7.93 cm) with Record (Table 28).

4.11.3.5 Effects of genotype x spacing interaction for head diameter (cm)

There was a significant interaction among spacing regimes for head diameter. Genotype PI 364860 detected the biggest sunflower heads (26.60 cm) at spacing of 75 cm x 45 cm whereas Record the smallest heads (15.30 cm) at spacing of 75 cm x 15 cm (Table 29).

4.11.3.6 Seed yield (kg/ha)

There was a significant interaction for seed yield (kg/ha). The highest seed yield was obtained at 75 cm x 15 cm (5376 kg) with PI 364860 while the least at 75 cm x 45 cm (1163 kg/ha) with Record (Table 30).

Table 25: Effects of genotypes X spacing for days to 50% flowering (days) at Uyole

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±1.5
75x45cm	87.33	79.00	74.67	80.33
75x30cm	89.67	83.67	75.67	83
75x15cm	92.00	84.00	78.00	84.67
Mean±1.4	89.67	82.22	76.11	
CV% 1.7				
$LSD_{0.05}$± 3.4				

Table 26: Effects of genotypes X spacing for days to 50% physiological maturity (days)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±3.2
75x45cm	115.67	108.67	103.00	109.11
75x30cm	117.33	106.33	103.00	108.89
75x15cm	120.00	112.67	105.33	112.67
Mean(±)3.2	117.7	109.2	103.8	
CV% 2.91				
$LSD_{0.05}$(±) 7.48				

Table 27: Effects of genotypes X spacing for plant height (cm)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±7.0
75x45cm	240.7	228.2	177.5	215.47
75x30cm	259.0	245.3	189.0	231.1
75x15cm	275.2	258.0	194.8	242.67
Mean(±)10.5	258.3	243.8	187.1	
CV% 4.6				
$LSD_{0.05}$(±) 19.4				

Table 28: Effects of genotypes X spacing for stem girth (cm)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±0.3
75x45cm	9.27	10.43	13.57	11.09
75x30cm	8.90	9.70	12.13	10.24
75x15cm	7.93	8.77	9.97	8.89
Mean(±)0.3	8.70	9.63	11.89	
CV% 2.87				
$LSD_{0.05}$(±) 0.74				

Table 29: Effects of genotypes X spacing for head diameter (cm)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±0.6
75x45cm	18.07	22.10	26.60	22.26
75x30cm	17.97	20.30	23.73	20.67
75x15cm	15.30	16.77	20.80	17.62
Mean(±)1.0	17.11	19.72	23.71	
CV% 4.97				
$LSD_{0.05}$(±) 1.75				

Table 30: Effects of genotypes X spacing for seed yield (kg/ha)

Genotype/ Spacing	Record	K.Fedha	PI 364860	Mean±853
75x45cm	1163	1657	2099.	1639.67
75x30cm	2555	2658	3523	2912
75x15cm	4186	3674	5376	3505
Mean(±)491.7	2635	2663	3666	
CV% 16.5				
$LSD_{0.05}$(±) 1892.8				

4.12 Genotype x Location x Spacing Interaction

Genotype x location x spacing interaction for the seed yield (kg/ha) is indicated in Appendix 5. The highest yields (5410 kg/ha and 5376 kg/ha) were obtained with PI 364860 at Seatondale and Uyole respectively at a spacing of 75 cm x 15 cm. On the other hand the lowest yields (830 kg/ha and 961 kg/ha) were registered with Record at Inyala at spacing of 75 cm x 45 cm and 75 cm x 30 cm respectively.

4.13 Stability Analysis

Stability analysis revealed significant differences ($P \leq 0.001$) among genotypes across environments. The results for mean, regression coefficient (b) and variances of deviation from regression (S^2d) are presented in Table 31-37 for the selected variables. However, their relationships are presented in form of scatter diagrams beginning from Fig. 1-21.

4.13.1 Estimates of stability parameters for seed yield (kg/ha) combined in all locations and spacing regimes

With respect to yield (kg/ha): results on stability parameters for yield are indicated in Table 31 and Figures 1, 2 and 3. Statistical analyses indicated that Record (1) and K.Fedha

(2) deviated significantly from unit value regression. However, genotype PI 364860 had the highest yield and regression coefficient (b) approximately to 1 (Fig.1). Not only that but also PI 364860 had the lowest variance of deviation (Fig. 3), indicating that it is relatively stable for seed yield across environments.

4.13.2 Estimates of stability parameters for seed weight per head combined in all locations and spacing regimes

In regard to seed weight per head, K.Fedha (2) detected the regression coefficient to approximately unit value (Fig. 4) and the least variance of deviation (Fig.6), indicating that it is relatively stable for seed weight per head. However, Record (1) and PI 364860 (3) deviated significantly from unit regression coefficient (Table 32). The genotype PI 364860 (3) did not detect stability, nonetheless had the highest mean for seed weight per head (Fig.6).

4.13.3 Estimates of stability parameters for 100seed weight combined in all locations and spacing regimes

Upon estimating stability parameters for 100seed weight across environments, K.Fedha (2) detected the regression coefficient around unit (Fig.7 and 8) with the highest mean (Table 33). However, PI 364860 (3) showed minimal variance of deviation (Fig.9) than other genotypes.

4.13.4 Estimates of stability parameters for number of seeds per head combined in all locations and spacing regimes

Results on stability parameters for number of seeds per head are indicated in Table 35 and Figures 10, 11 and 12. Statistically, Record (1) and PI 364860 (3) deviated significantly from unit value regression. However, K.Fedha (2) had regression coefficient value close to unit than the other genotypes (Table 34 and Fig. 10 and 11). Nevertheless, PI 364860 (3) had minimal variance of deviation (Fig.12) indicating that it is relatively stable.

4.13.5 Estimates of stability parameters for head diameter combined in all locations and spacing regimes

The genotype PI 364860 (3) detected the widest heads (Fig.13 and 15) with relatively low variance of deviation (Fig.14), indicating that it can be recommended as best in all studied environments. However, Record (1) did not deviate significantly from unit regression value (Table 35), indicating that it has average stability in head diameter over all studied environments.

4.13.6 Estimates of stability parameters for days to 50% flowering combined in all locations and spacing regimes

The genotype PI 364860 (3) attained 50% flowering earliest (Fig. 16 and 18) on the other hand it had relatively low variance of deviation (Fig.17), hence relatively stable. However, K.Fedha (2) showed regression coefficient value close to unit value (Table 36 and Fig.17) indicating that its response is average.

4.13.7 Estimates of stability parameters for plant height combined in all locations and spacing regimes

Results showed that Record had the tallest plants whereas PI 364860 had the shortest plants (Table 37). Record (1) and PI 364860 (3) deviated significantly from unit regression value, nevertheless K.Fedha (2) had the value of regression coefficient close to unit value (Fig.19 and 20) with minimal variance of deviation (Fig.21), hence it is relatively stable.

Table 31: Estimates of stability parameters for yield (kg/ha) combined in all locations and spacing regimes

Parameter/ Genotype	μ	b ±0.1	b-1	δ^2_{di}
Record	2349.915±402	1.05	0.05**	0.53262
K.Fedha	2687.229±65	0.95	0.05**	0.60138
PI 364860	3363.158±611	1.01	0.01	0.41006

$r_{\mu b}$= -0.22

$r_{\mu b}$ = correlation between means and regression coefficients.

Table 32: Estimates of stability parameters for seed weight/head combined in all locations and spacing regimes

Parameter/ Genotype	μ	b ±0.13	b-1	δ^2_{di}
Record	66.621±14	1.40	0.4**	-62.69
K.Fedha	75.558±5.1	1.08	0.08	-109.01
PI 364860	99.724±19	0.52	-0.48**	-84.11

$r_{\mu b}$= -0.99

Table 33: Estimates of stability parameters for 100 seed weight combined in all locations and spacing regimes

Parameter/ Genotype	μ	b ±0.45	b-1	δ^2_{di}
Record	6.339±0.15	1.50	0.5**	0.10
K.Fedha	6.644±0.16	1.11	0.11	0.02
PI 364860	6.472±0.01	0.39	-0.61**	-0.07

$r_{\mu b}$= -0.28

Table 34: Estimates of stability parameters for number of seeds/head combined in all locations and spacing regimes

Parameter/ Genotype	μ	b±0.2	b-1	δ^2_{di}
Record	857.778±192	1.5	0.5**	507.58
K.Fedha	967.444±82	1.05	0.05	554.61
PI 364860	1323.000±274	0.43	-0.57**	-336

$r_{\mu b}$=-0.98

Table 35: Estimates of stability parameters for head diameter combined in all locations and spacing regimes

Parameter/ Genotype	μ	b±0.13	b-1	δ^2_{di}
Record	17.892±1.79	1.09	0.09	0.50
K.Fedha	19.324±0.36	0.72	-0.28**	-0.94
PI 364860	21.822±2.14	1.19	0.19**	-0.20

$r_{\mu b}$= 0.35

Table 36: Estimates of stability parameters for days to 50% flowering combined in all locations and spacing regimes

Parameter/ Genotype	μ	b±0.13	b-1	δ^2_{di}
Record	87.333±6.37	1.15	0.15**	-0.69
K.Fedha	80.889±0.07	1.05	0.05	0.09
PI 364860	74.667±6.3	0.80	-0.20**	0.06

$r_{\mu b}$= 0.97

Table 37: Estimates of stability parameters for plant height combined in all locations and spacing regimes

Parameter/ Genotype	μ	b±0.1	b-1	δ^2_{di}
Record	226.889±19.19	1.15	0.15**	-15.78
K.Fedha	217.878±10.18	1.04	0.04	-48.06
PI 364860	178.250±29.45	0.81	-0.19**	61.07

$r_{\mu b}$=0.99

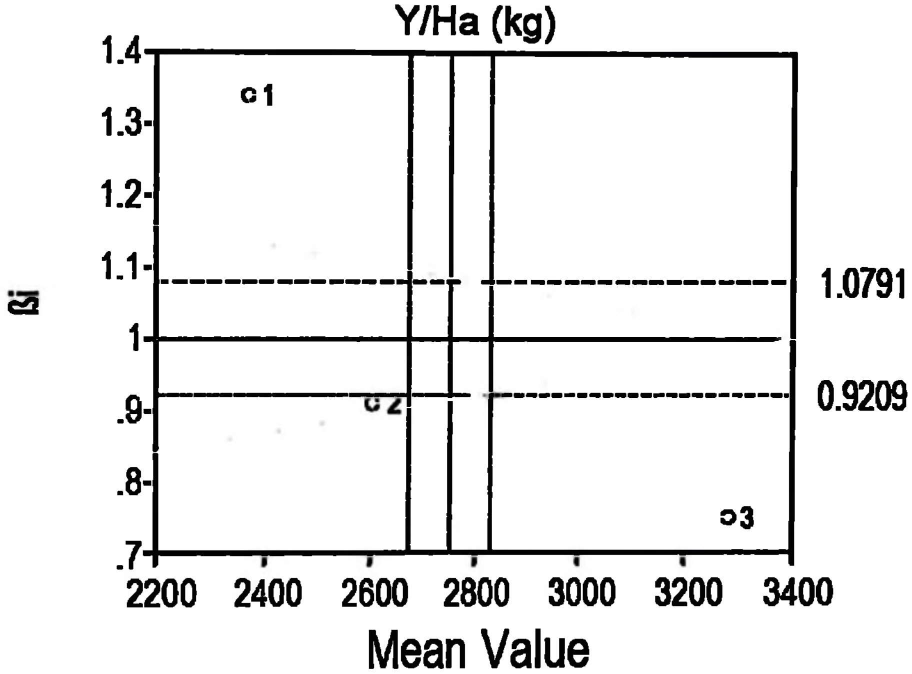


Figure 1: Scatter diagram indicating the relationship between regression coefficient and mean value of seed yield kg/ha

Where;

1= Record

2= K.Fedha

3= PI 364860 genotype

- - — - is region of the average mean and acceptable level of regression coefficient respectively.

- is the exact mean of three genotypes obtained and a unit regression coefficient respectively.

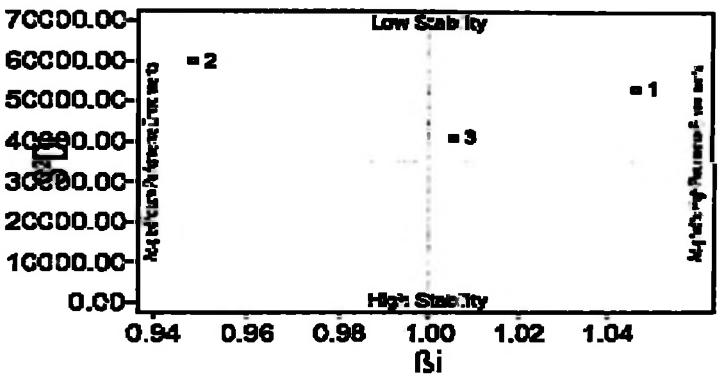


Figure 2: Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient (βi)

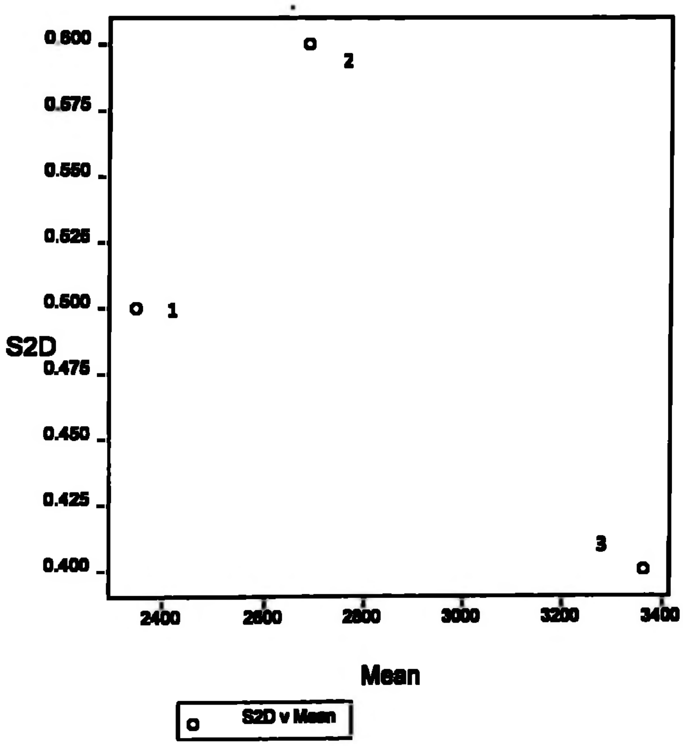


Figure 3; Scatter diagram indicating the relationship between variance of deviation (S2D) and mean seed yield.

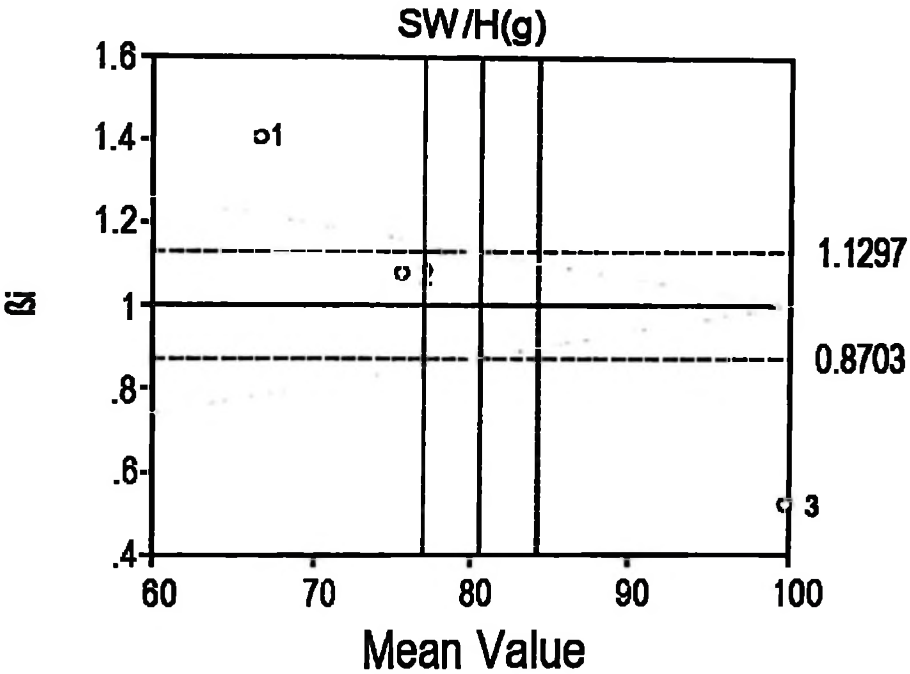


Figure 4; Scatter diagram indicating the relationship between regression coefficient and mean value of seed weight per head

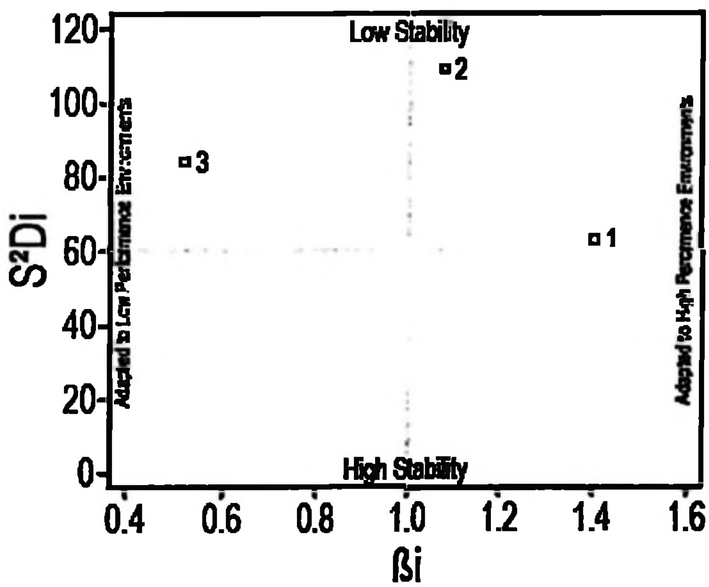


Figure 5; Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient for seed weight per head.

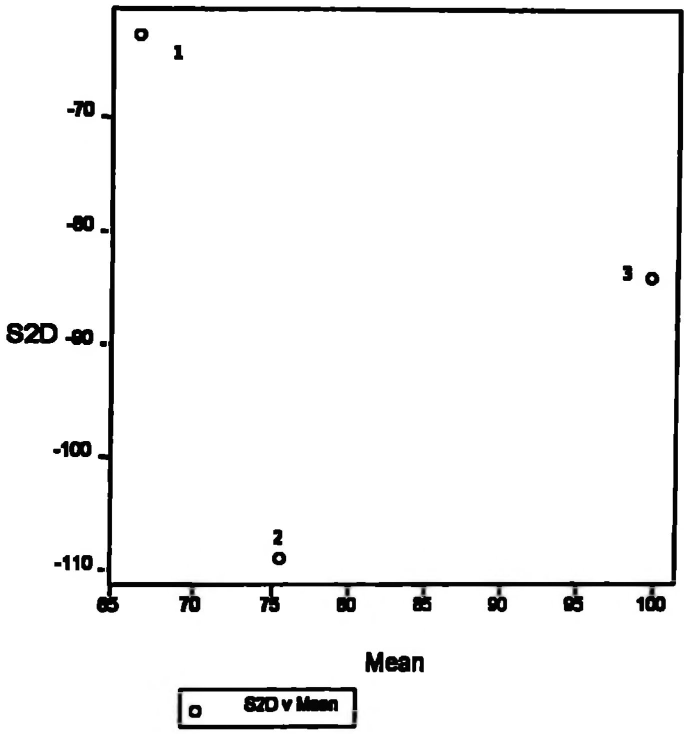


Figure 6; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of seed weight per head

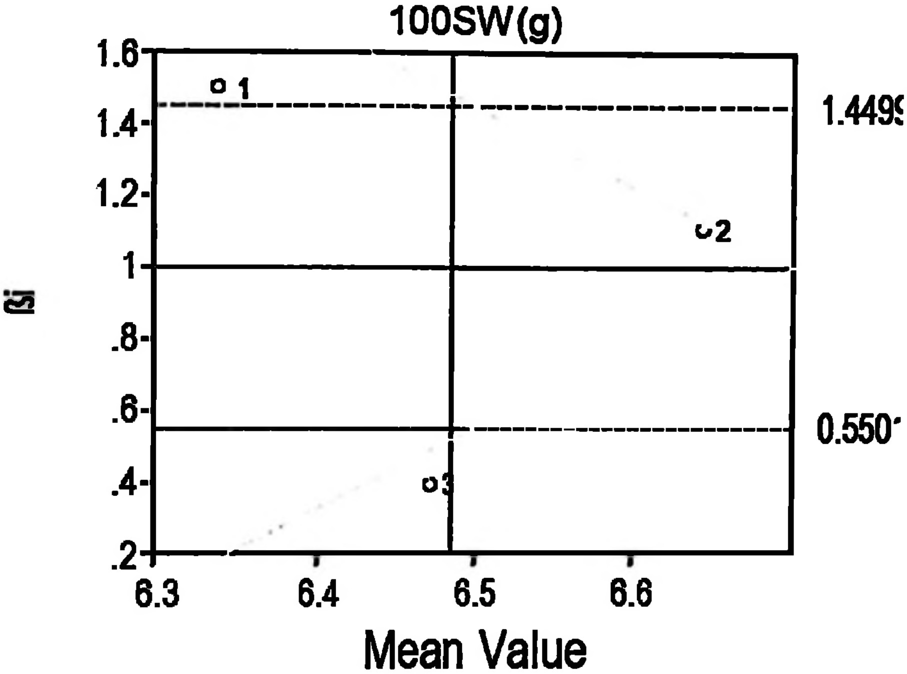


Figure 7; Scatter diagram indicating the relationship between regression coefficient and mean value of 100seed weight

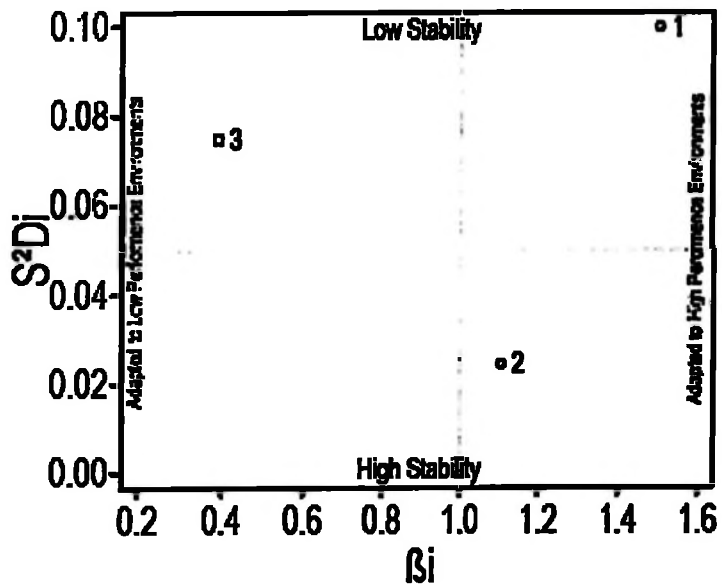


Figure 8; Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient for mean value of 100seed Weight

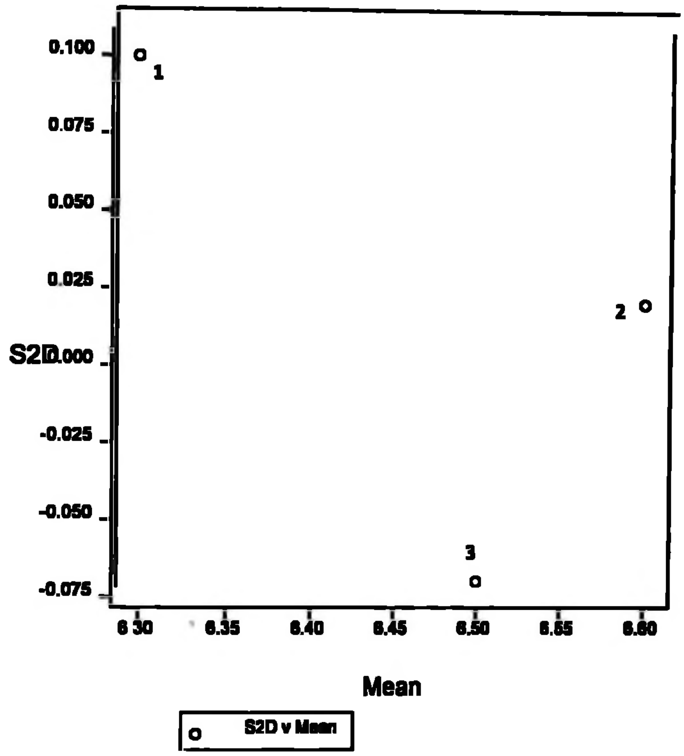


Figure 9; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of 100seed weight

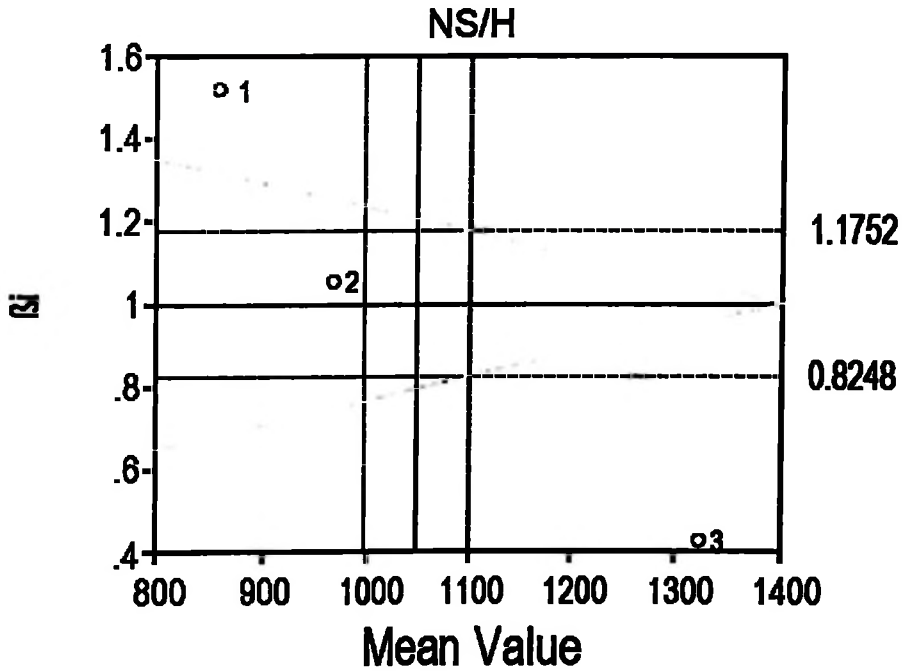


Figure 10; Scatter diagram indicating the relationship between regression coefficient and mean value of number seed per head

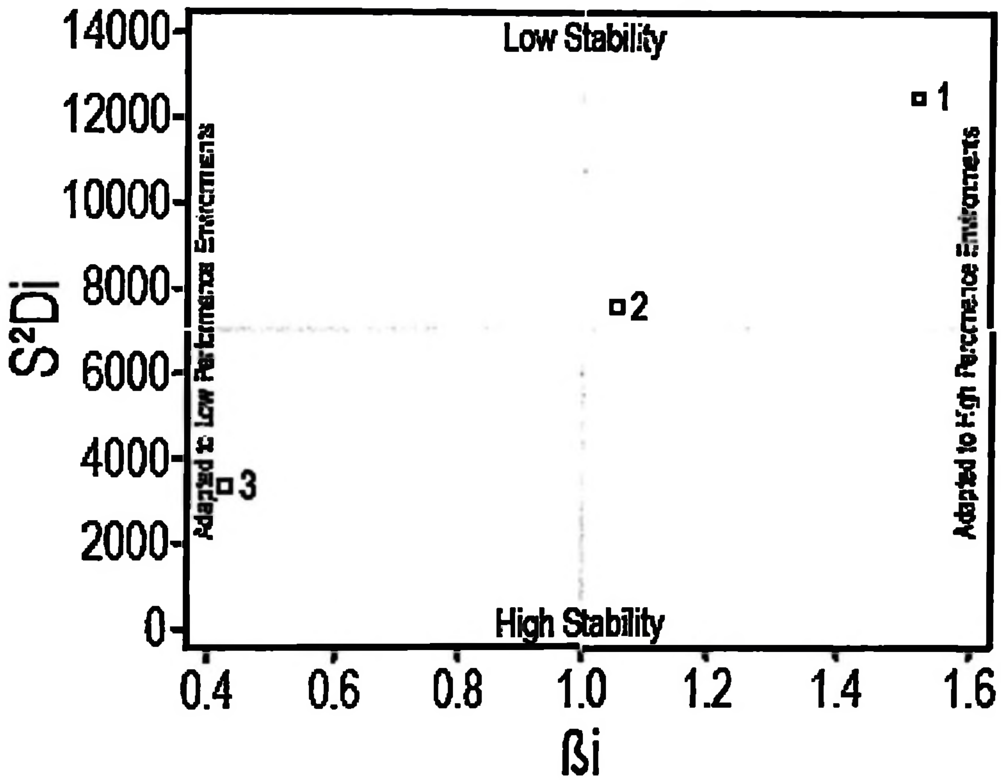


Figure 11; Scatter diagram indicating the relationship between variance of deviation (S2D) and regression coefficient for number of seed per head

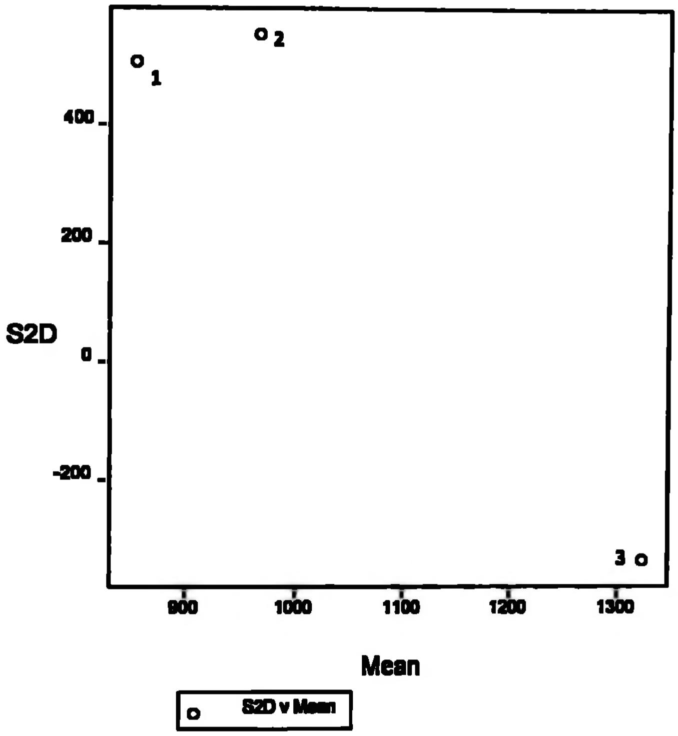


Figure 12; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of number of seed per head

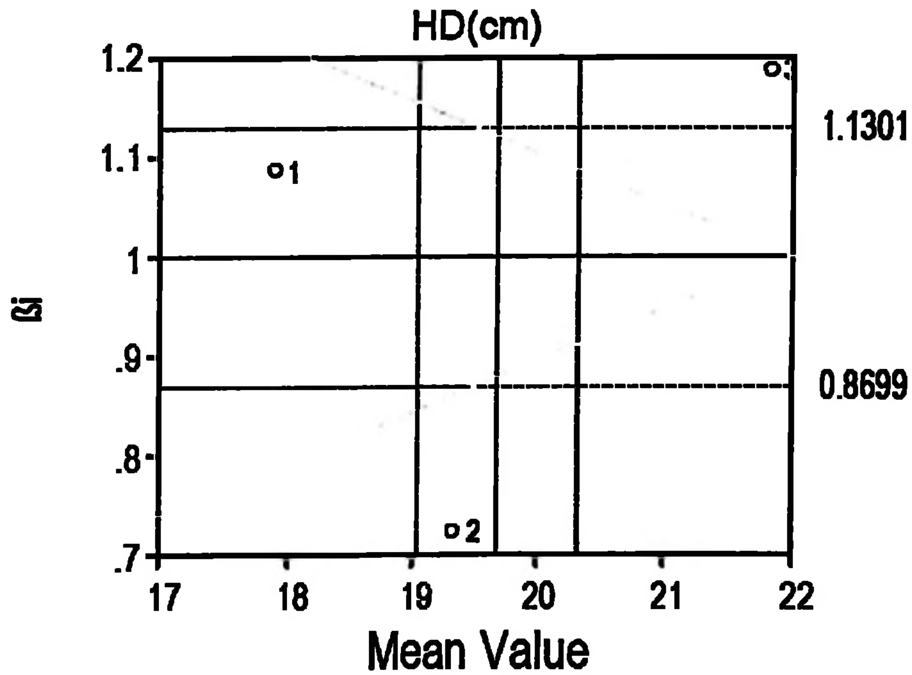


Figure 13; Scatter diagram indicating the relationship between regression coefficient and mean value of head diameter

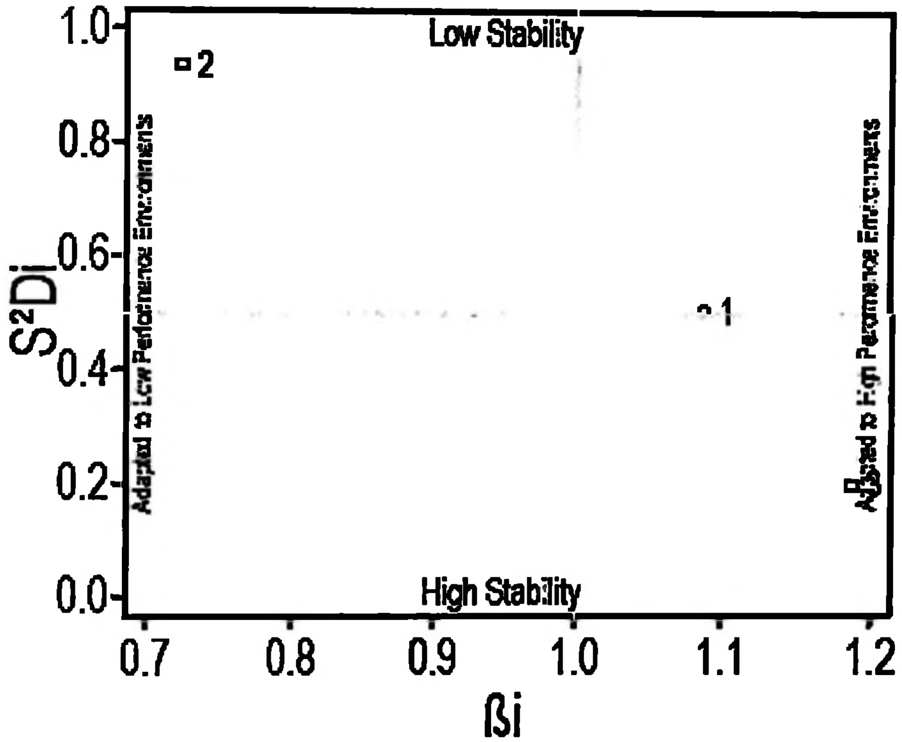


Figure 14; Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient for head diameter

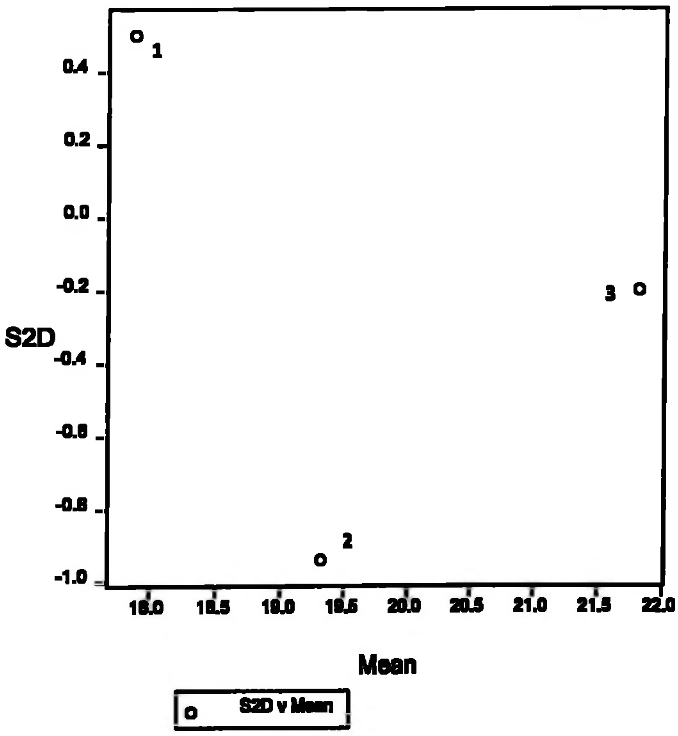


Figure 15; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of head diameter

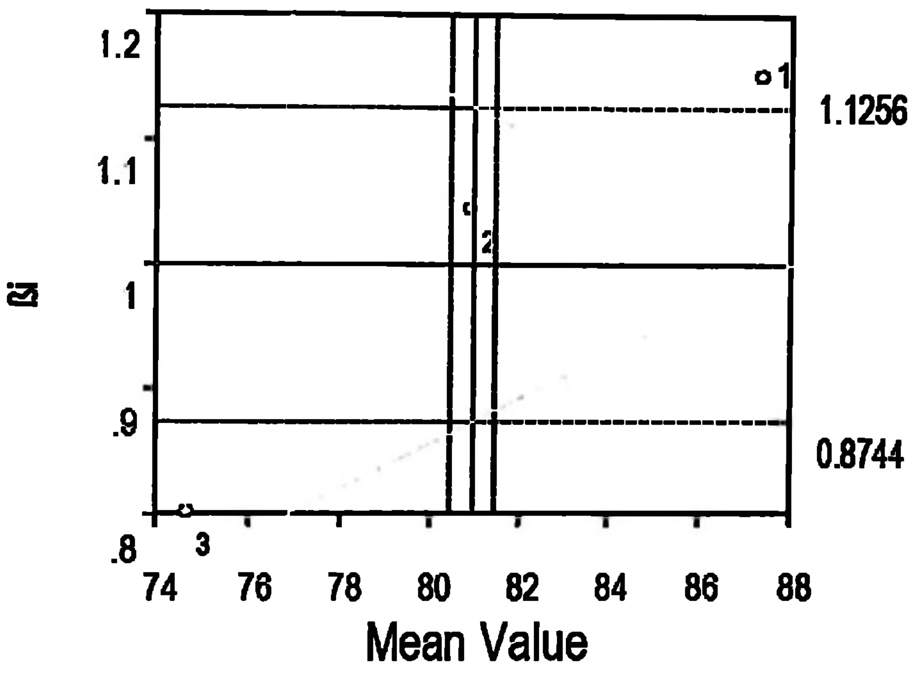


Figure 16; Scatter diagram indicating the relationship between regression coefficient and mean value of days to 50% flowering

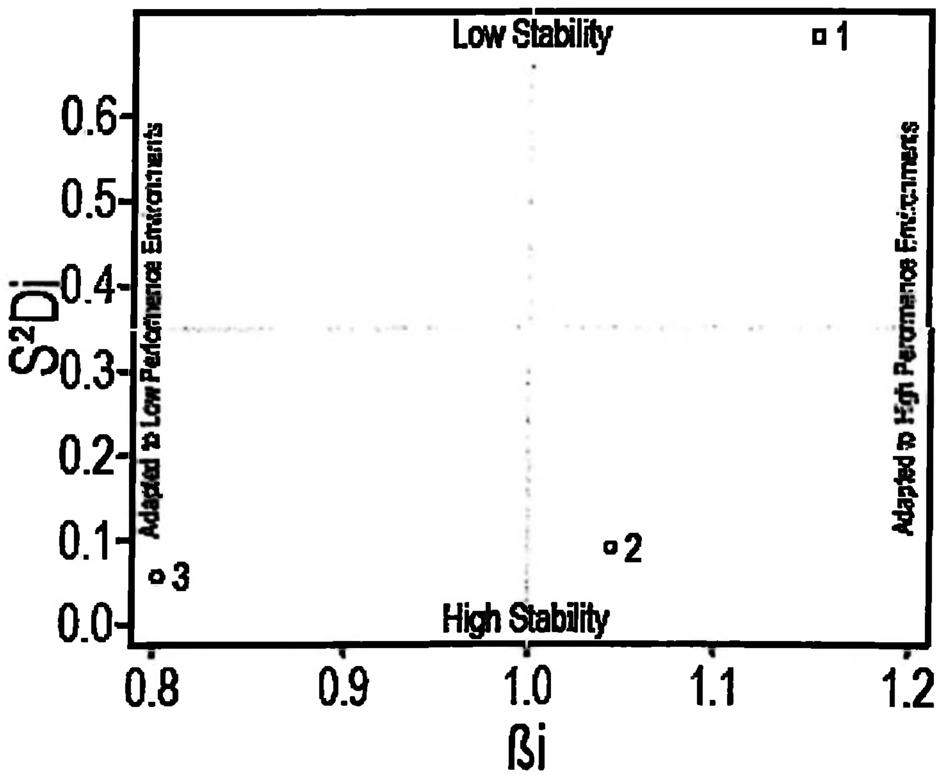


Figure 17; Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient for days to 50% flowering

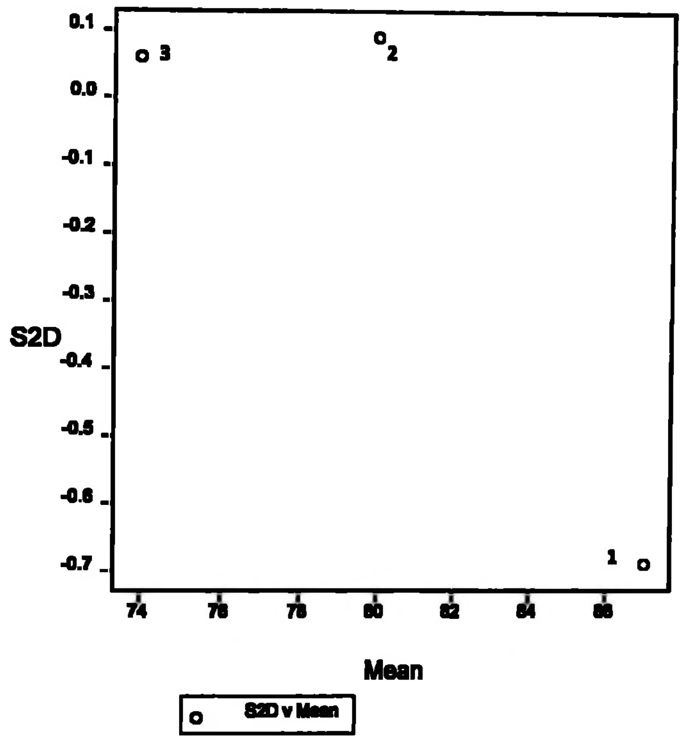


Figure 18; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of days to 50% flowering

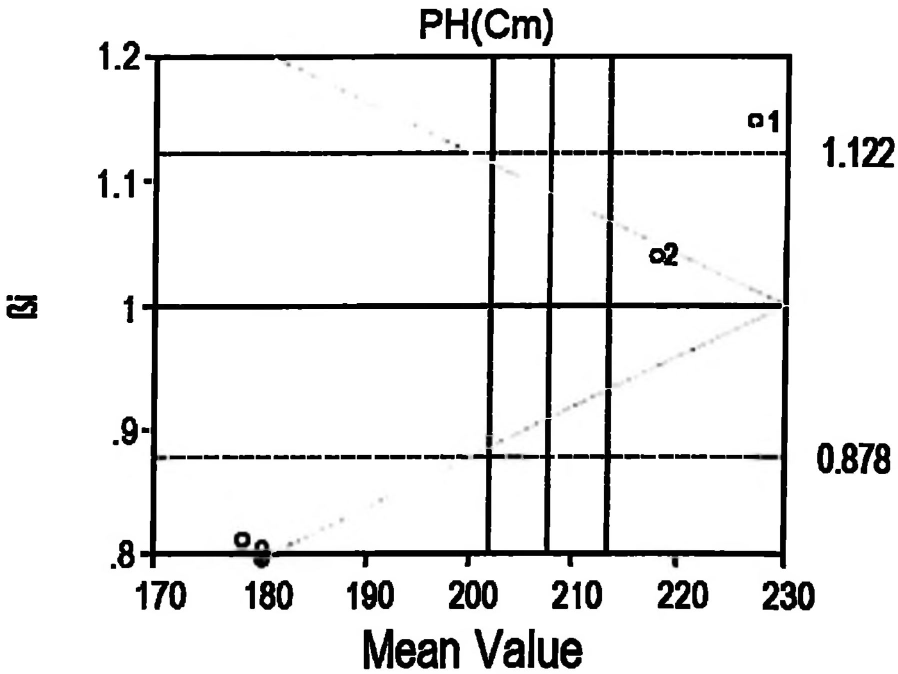


Figure 19; Scatter diagram indicating the relationship between regression coefficient and mean value of plant height

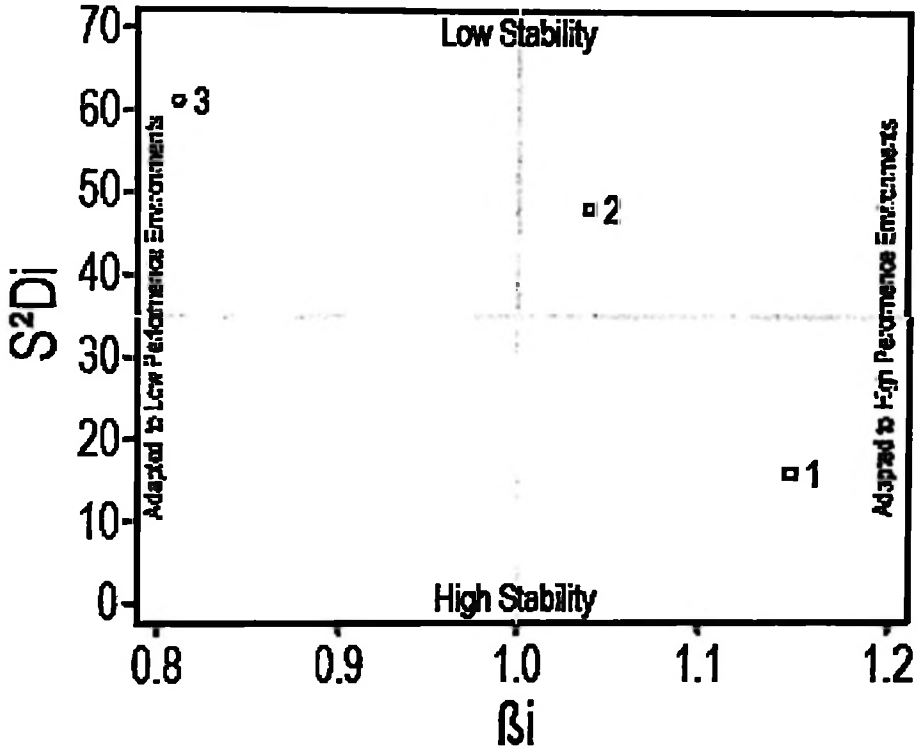


Figure 20; Scatter diagram indicating the relationship between variance of deviation (S^2D) and regression coefficient for plant height

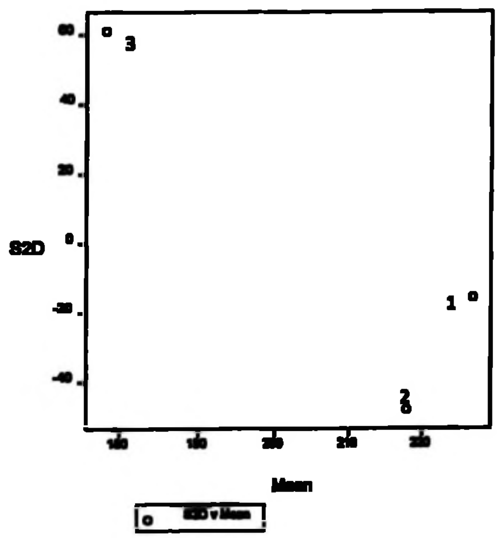


Figure 21; Scatter diagram indicating the relationship between variance of deviation (S^2D) and mean value of plant height

4.14 Phenotypic and genotypic correlations

Phenotypic and genotypic correlation coefficients for all possible comparisons are presented in Table 38. The significant phenotypic and genotypic correlations with seed yield/ha were observed with seed weight/head (rp=0.894**,rg=0.898**), number of seeds/head (rp=0.811**,rg=0.821**), head diameter (rp=0.814**,rg = 0.78**) ,100seed weight (rp=0.608**,rg=0.621**). The phenotypic and genotypic correlation coefficients between plant height with days to 50% flowering and head diameter were positive and significant. Similarly, the correlation coefficients were positive and significant between head diameter with number of seeds per head and seed weight per head. Also correlation coefficients were positive and significant between seed weight per head with number of seeds per head and 100seed weight with seed weight per head.

Table 38: Phenotypic (top) and Genotypic(bottom) correlations on combined analysis

	Plant height	50% Flowering	Head diameter	No.of seeds/head	Seed weight/head	100seed weight	Seed yield/ha
Plant height		0.825**	0.554**	0.323	0.33	0.197	0.42
		0.824**	0.560**	0.318	0.321	0.198	0.409
50%Flowering			0.157	-0.065	-0.022	0.058	0.081
			0156	-0.072	-0.056	0.036	0.068
Head diameter				0.712**	0.778**	0.340	0.814**
				0.716**	0.684**	0.196	0.78**
No.of seeds/head					0.844**	0.295	0.811**
					0.967***	0.428*	0.821**
Seed weight/head						0.645**	0.894**
						0.549**	0.898**
100seed weight							0.608**
							0.621**
Seed yield							-

* = Significant at 0.01,

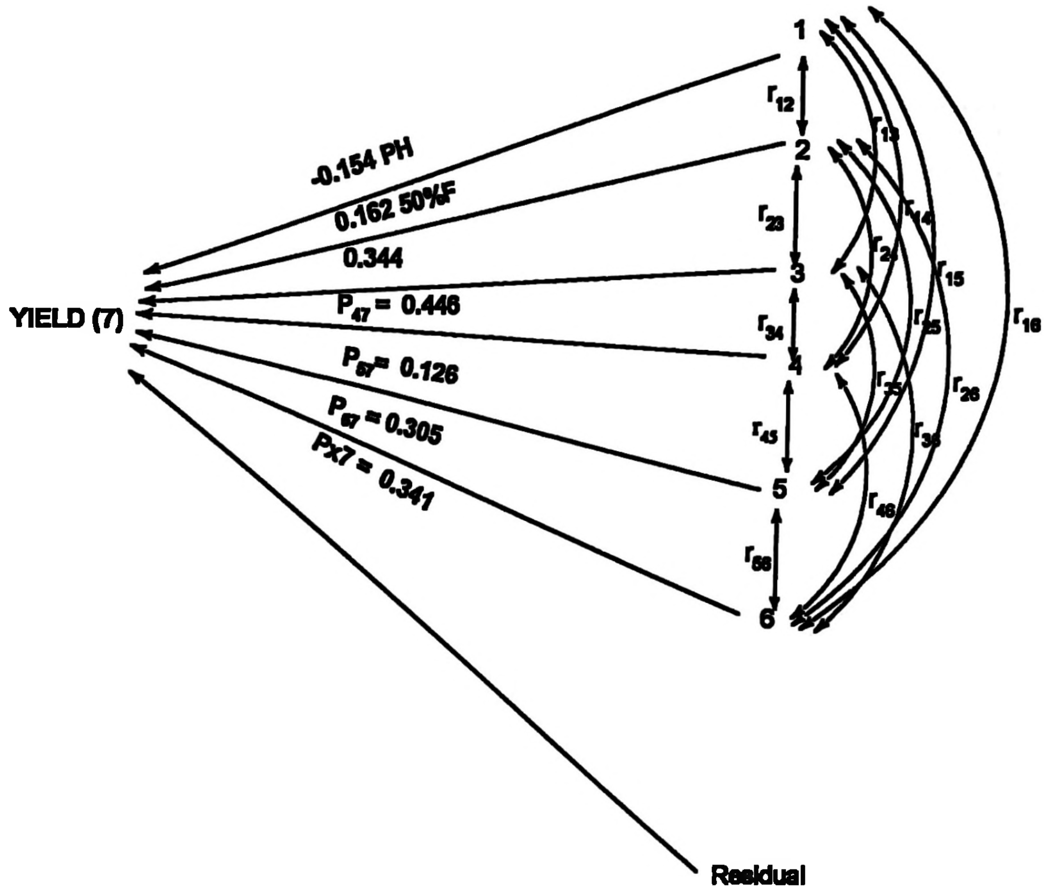
** = Significant at 0.05 and

*** = Significant at 0.001

4.15 Path coefficient analysis

The genotypic and phenotypic correlation coefficients of yield with its contributing components were portioned into direct and indirect effects through path coefficient analysis (Fig.22 and Tables 39 and 40) in order to formulate a sound basis for selection of the important contributing characters to yield in sunflower.

Results obtained in path coefficient analysis revealed that number of seeds per head had both high direct effect (0.446) and positive correlation (r=0.822**) on seed yield. Head diameter showed both high direct effect (0.344) and positive correlation(r=0.78**) on seed yield. The total correlation (r=0.78**) for head diameter was predominantly due to the direct effect (0.344) and indirect effect through number of seeds per head (0.3). Thus, number of seeds per head interacts favourably with head diameter in the relationship between head diameter with seed yield. 100 seed weight had both high direct effect (0.305) and high positive correlation (r=0.621**) with yield. This total correlation was mainly due to the direct effect of 100 seed weight and the cumulative indirect effects through head diameter and number of seeds per head. Number of seeds per head was significantly and positively correlated (r= 0.821**) with yield. This correlation was mainly due to the direct effect (independent contribution) (0.446) of this variable on yield and indirect effect through head diameter. Thus, head diameter interacted positively with number of seeds per head in the relationship between numbers of seeds per head with yield. Seed weight per head had significant and positive correlation (r=898**) with seed yield. This correlation was highly due to indirect effect through number of seeds per head and head diameter. Hence, number of seeds per head and head diameter interacted favourably with seed weight per head in the relationship between seed weight per head with yield. The other relationships namely; Plant height, days to 50% flowering with yield were too low to be of any predictive value. The residual effect was 0.341 which indicated the contribution of remaining factors other than those studied.



Significant at (P<0.05) if r =>0.3809

Figure 22: Path diagram indicating the direct and indirect effects on seed yield

Key

R12= 0.824	1= Plant height (cm)
R23= 0.159	2= Days to 50% flowering
R34=0.671	3= Head diameter (cm)
R45= 0.855	4= Number of seeds/head
R56=0.654	5= Seed weight/head (g)
R13= 0.552	6= 100-seed weight (g)
R14= 0.315	7= Seed yield (kg/ha)
R15=0.316	
R16=0.196	
R24=-0.074	
R25=-0.035	
R26= 0.05	
R35= 0.717	
R36=0.326	
R46=0.322	

Table 39: Showing the genotypic relations between Plant height, Days to 50% flowering and Head diameter yield components with seed yield

1. Plant height vs. seed yield r_{17}	**0.409**
Direct effect P_{17}	**-0.154**
Indirect effect, via 50% flowering $r_{12}P_{27}$	**0.133**
Indirect effect, via head diameter $r_{13}P_{37}$	**0.19**
Indirect effect, via number of seeds/head $r_{14}P_{47}$	**0.14**
Indirect effect, via seed weight/head $r_{15}P_{57}$	**0.04**
Indirect effect, via 100seed weight $r_{16}P_{67}$	**0.06**
Total	**0.409**
2. Days to 50% flowering vs. seed yield r_{27}	**0.068**
Direct effect P_{27}	**0.162**
Indirect effect, via plant height $r_{12}P_{17}$	**-0.127**
Indirect effect, via head diameter $r_{23}P_{37}$	**0.055**
Indirect effect, via number of seeds/head $r_{24}P_{47}$	**-0.033**
Indirect effect, via seed weight/head $r_{25}P_{57}$	**-0.004**
Indirect effect, via 100seed weight $r_{26}P_{67}$	**0.015**
Total	**0.068**
3. Head diameter vs. yield r_{37}	**0.78****
Direct effect P_{37}	**0.344**
Indirect effect, via plant height $r_{13}P_{17}$	**-0.08**
Indirect effect, via 50% flowering $r_{23}P_{27}$	**0.026**
Indirect effect, via number of seeds/head $r_{34}P_{47}$	**0.3**
Indirect effect, via seed weight/head $r_{35}P_{57}$	**0.09**
Indirect effect, via 100seed weight $r_{36}P_{67}$	**0.1**
Total	**0.78**

Table 40: Showing the genotypic relations between Number of seeds/head, Seed weight/head and 100seed weight yield components with seed yield

4. Number of seeds/head vs. Seed yield r_{47}	**0.821****
Direct effect P_{47}	0.446
Indirect effect, via plant height $r_{14}P_{17}$	-0.05
Indirect effect, via 50% flowering $r_{24}P_{27}$	-0.012
Indirect effect, via head diameter $r_{34}P_{37}$	0.231
Indirect effect, via seed weight/head $r_{45}P_{57}$	0.108
Indirect effect, via 100seed weight $r_{46}P_{67}$	0.098
Total	0.821
5. Seed weight/head vs. Seed yield r_{57}	**0.898****
Direct effect P_{57}	0.126
Indirect effect, via plant height $r_{15}P_{17}$	-0.049
Indirect effect, via 50% flowering $r_{25}P_{27}$	-0.006
Indirect effect, via head diameter $r_{35}P_{37}$	0.247
Indirect effect, via number of seeds/head $r_{45}P_{47}$	0.381
Indirect effect, via 100seed weight $r_{56}P_{67}$	0.199
Total	0.898
6. 100seed weight vs. Seed yield r_{67}	**0.621****
Direct effect P_{67}	0.305
Indirect effect, via plant height $r_{16}P_{17}$	-0.03
Indirect effect, via 50% flowering $r_{26}P_{27}$	0.008
Indirect effect, via head diameter $r_{36}P_{37}$	0.112
Indirect effect, via number of seeds/head $r_{46}P_{47}$	0.144
Indirect effect, via seed weight/head $r_{56}P_{57}$	0.082
Total	0.621

CHAPTER FIVE

5.0 DISCUSSION

5.1 Genotype x Location Interaction

Results of this study showed significant differences among genotypes for all the studied variables across locations as indicated in Table 2. The differences between genotypes, environments and G x E interaction were highly significant. This revealed that the agro-climatic conditions of the environments were different, and that there was a differential response of the locations on the studied variables. This is in agreement with the findings by Abdulahi *et al.* (2009) who also observed differential response of locations on sunflower crop. Arshad *et al.* (2010) reported also the difference in sunflower variables performance across locations. The differences in rainfall amount and distribution, temperatures and altitudes that existed in the three locations affected greatly these traits. For example when the crop was about three months in the field the mean rainfall recorded was 100.7 mm at Seatondale, 90.7 mm at Uyole and 68.8 mm at Inyala. This indicates that there was more rainfall at Seatondale and low at Inyala which may have contributed to the highest performance at Seatondale. The earliest flowering and physiological maturity were attained at Inyala whose temperature was relatively high, whereas the latest at Uyole whose temperature was relatively low compared to other sites. The mean temperature for four consecutive months since planting was 26.7^{0}C at Inyala and 23.33^{0}C at Uyole. Monteith and Scott (1982) denoted that increasing temperature above the coolest limit up to 25 - 37^{o}C accelerates plant development. Therefore, the earliest attainment to flowering and physiological maturity at Inyala was due to the highest temperature that accelerated plant development than the other sites. This is in close agreement with that reported by Kaleem *et al.* (2009) who observed that environmental variables especially temperature, are the key factors which affect plant growth, development and productivity.

The general performance of all genotypes at Inyala was poor compared to other sites, this resulted to a significant reduction of growth traits which is reflected by reduced head diameter, number of seeds/head, seed weight/head and total seed yield (Table 2). This occurred because at Inyala when the plants were about two months in the field leaf spot disease was identified in all three genotypes, although Record and K.Fedha were highly affected compared to the rest, this was due the genetic differences among genotypes. Lagopodi and Thanassoulopoulos (1998) reported that the leaf spot disease caused by *A. alternate* significantly reduced the number of seeds produced per head from 16% - 65% and seed weight from 15% - 79%. Disease intensity is known to be negatively correlated with number of seeds produced per head, and also with seed weight. During this time the temperature at Inyala was about 25^{0}C which is known to favour *A. alternate* to develop. As the name of the disease suggests, it is a disease that destroys active leaf area thus reducing photosynthetic capacity consequently affecting the plant's productivity. All genotypes at Seatondale site yielded higher than other sites, probably due to the fact that the overall performance of genotypes for the various traits was better at Seatondale than other sites: Such traits included head diameter, number of seeds/head, seed weight/head and 100 seed weight (Table 2) which in turn upon path coefficient analysis these traits showed positive and significant direct effects on seed yield (Figure 22). Genotype PI 364860 performed better than other genotypes at all locations for all variables except for 100 seed weight and it yielded higher than the rest of the genotypes as indicated in Table 11-18. Thus, it can be recommended to be grown at all locations studied following variety release procedures. Nevertheless, if the improvement is based on 100seed weight, Record can be recommended to be used since it attained the highest value for this variable. However, in this study Seatondale and Uyole were identified to be the best locations for sunflower production. The significant genotype x environment interactions for the studied variables indicates the importance of evaluating genotypes at different environments. The performance of genotypes was different due to genetic differences, thus increases efficiency of breeding program and selection of best sunflower genotypes. Becker and Leon (1988) noted that the genetic structure of plant materials may also have a bearing on the extent of genotype x environment interaction.

5.2 Genotype x Spacing Interaction

Yield attributes showed significant differences at three spacing regimes as indicated in Table 6. These differences occurred because there was less below and aboveground competition between the plants at wider spacing of 75 cm x 45 cm. This led to greater light interception by the actively spreading, horizontally developing plants, which could thus reduce more atmospheric CO_2 into food materials because of greater initial light use efficiency. The reduction in the values of yield variables at closer spacing may be attributed to severe competition between the sunflower plants. Vijayalakshmi *et al.* (1975) reported that at closer spacing yield variables are reduced due to severe competition between sunflower plants especially under rain fed conditions where moisture is a limiting factor throughout the crop growth period. Results obtained in this study are in agreement with the findings by Vijayakumar *et al.* (2003) who also observed the differences in performance based on spacing regimes.

Higher plant population levels decreased seed number and seed weight per head, however it was not significant between wider spacing of 75 cm x 45 cm and the intermediate spacing of 75 cm x 30 cm. This was due to competition at higher density which could have caused the abortion of the initiated florets and reduced head diameter. Mohammad and Foroud (2009) reported on sunflower crop that the larger the head, the higher the seed numbers. Although, the number of seeds/head, seed weight/head and 100 seed weight did not show significant ($P<0.05$) difference between spacing regimes of 75 cm x 45 cm and 75 cm x 30 cm they differed significantly ($P<0.05$) from closer spacing of 75 cm x 15 cm. However, spacing of 75 cm x 30 cm attained the highest values for number of seeds/head, seed weight per head and 100 seed weight. This may be attributed to low competition at wider spacing for resources like moisture, light and nutrients which led to best utilization especially when resources become limiting. Therefore, in the widest spacing the genotypes had better grain filling as opposed to closer spacing.

Seed yield: The sunflower seed yield was significantly influenced by the various spacing regimes tested at both locations. A closer spacing of 75 cm x 15 cm gave a significantly higher seed yield than wider spacing of 75 cm x 45 cm and 75 cm x 30 cm .Though the yield attributes had higher values per plant basis under the widest plant spacing of 75 cm x 45 cm, the yield per unit area was higher under closer spacing due to the greater number of plants per hectare. The percentage yield loss due to competition at higher density was compensated by the increased plant population per unit area. These results are in agreement with the findings indicated by other researchers (Beg *et al.* 2003; Aein *et al.* 1998; Reddy and Giri, 1997; Karami, 1980; Robinson *et al.*, 1980; Radford, 1978).

5.3 Stability Parameters

The stability parameters were estimated by regressing the genotype means. The regression coefficient (*bi*) and deviation from regression (S^2di) were the parameters used to compare the environmental responses of the genotypes. According to Eberhart and Russell (1966) model, regression coefficients approximating unity coupled with a (S^2di) value of zero indicate average stability. Genotype PI 364860 had the highest yield and regression coefficient (b) approximately to 1 and the lowest variance of deviation, thus it was regarded to be relatively stable for seed yield across environments in this study. Not only that but also when this is associated with high mean yield, the genotypes have general adaptability. Hence, genotype PI 364860 has general adaptability for seed yield. Regression values above unity describe genotypes with higher sensitivity to environmental change and greater specificity of adaptability to high-yielding environments. However, Record had regression above unit whose b-1 was significant, hence it has higher sensitivity to environmental changes regression coefficients below unity indicate greater resistance to environmental change, and therefore more specific adaptability to low-yielding environments. Nevertheless, K.Fedha had regression coefficient below unit and its b-1 was significant, therefore it is more specific to low yielding environments.

In respect to variables other than yield, the stability parameters were differently observed. K.Fedha was regarded to be relatively stable for seed weight per head, 100 seed weight, number of seeds per head, and 50% flowering and plant height. However, PI 364860 was regarded as relatively stable for number of seeds per head, 100 seed weight, head diameter and 50% flowering whereas Record was only for head diameter. Results showed that, some genotypes had good attributes stability parameters but lack in other variables. Thus, crosses that could possibly combine all the stability and performance attributes are suggested. The genotype PI364860 could have optimum combination of stability parameters with K.Fedha for seed weight per head. The genotype PI364860 had high mean seed weight per head and high variance of deviation from regression (less stable), whereas K.Fedha had low mean seed weight per head and low variance of deviation. Hence, crossing of two genotypes will likely result to segregates with high mean seed weight per head and stable.

5.4 Correlation Coefficients

Correlation analysis showed that most of the yield related characters had a significant association among themselves and with yield. Excluding days to 50% flowering, all characters showed significant associations among themselves, implying that either gene(s) involved in controlling the traits are closely linked or it might be explained by the pleiotropical effect of given genes. Pleiotropic effects are the main causes for correlations among traits (Falconer and Mackay, 1997;Aastveit and Aastveit, 1993). According to the correlation results of test genotypes, the strongest significant positive correlations with seed yield were observed for seed weight/head, number of seeds/head, head diameter and 100 seed weight while the least significant was observed for plant height. These findings are in close agreement with those of Abrar and Shubhra, (2010); Göksoy andTuran, (2007); Dagustu, (2002);Teklewold *et al.*, (2000); Razi and Assad, (1999); Patil *et al.*, (1996); Vanishree *et al.*, (1988) who reported that head diameter is the most important yield component in sunflower. Phenotypic correlations were higher than genotypic correlations for days to 50% flowering, number of seeds/head and seed yield, indicating the influence of environment on these variables. On the other hand, 100 seed weight genotypic correlation was higher than phenotypic correlation due to relative stability of the genotypes on this variable and that the association is mainly due to genetic facts. One of the interesting features in sunflower reflected in the present study is that the associations among all yield components except days to 50%flowering were positive and significant which would be encouraging for rapid improvement of seed yield. Based on correlation coefficient analysis (Table 38), screening for high seed weight/head, number of seeds/head, wider diameter and high 100 seed weight would be useful in selection of best parents for making crosses to achieving high seed yield.

Although, a negative relationship existed between days to 50% flowering and number of seeds per head, the number of seeds per head was positively correlated with seed yield, Head diameter and number of seeds per head had a positive correlation. Bigger heads on the average produced many seeds per head than small heads. The reason for this association may be that plants with bigger heads were capable of filling more seeds during seed formation. Head diameter and seed weight per head had a significant positive correlation. Bigger heads on the average produced much seed weight per head; this was contributed by many seeds per head. This, combined with the fact that larger heads produced many seeds per head, should give more seed weight per head and eventually more seed yield per unit area. Also, seed weight per head showed a significant positive correlation with 100 seed weight. This implies that the heaviest seeds were obtained in heads whose seed weights were heavier. Generally, all these four variables (head diameter, number of seeds/head, seed weight/head and 100 seed weight) were positively correlated among themselves. Hence, selection for all the above traits would be more effective to bring about simultaneous improvement for yield and other yield components in sunflower. This is in close agreement with the findings by (Kaya *et al.*, 2007; Hladni *et al.*, 2006; Srimuenwai, 2006; Satjawattana, 2005; Chikkadevaiah *et al.*, 2002; Marinkovic, 1992; Ahmad *et al.*, 1991).

5.5 Path Coefficients

Path coefficient analysis for this study shows that seed yield is mainly a result of head diameter, number of seeds/head, seed weight/head and 100 seed weight and a composite variable that includes all other factors affecting seed yield in this study. The last four variables are themselves interrelated; consequently, each variable influences seed yield by a direct contribution and by acting in combination with the three other variables with which it is correlated.

The direct effects point out the already obvious fact that sunflower yield is highly influenced by head diameter, number of seeds per head and 100 seed weight (Abrar and Shubhra, 2010). For example, increasing head diameter will increase seed yield per unit area. Thus, if all other variables are held constant, head diameter will increase yield independently. However, the more understated indirect effects play a more important part and mask the direct influence. Considering head diameter (Table 39); the highest positive influences were registered by head diameter through number of seeds per head, 100seed weight and seed weight per head which in turn had a large direct effect upon seed yield. A strong positive influence, 0.381, was registered indirectly by seed weight per head upon seed yield through number of seeds per head, which in turn had a large direct effect of 0.446 upon seed yield. However, the direct effect showed that seed weight per head has little to do with seed yield per unit area, nevertheless the indirect effect through head diameter and number of seeds per head indicated that seed weight interacts well with these variables in influencing seed yield. Therefore, head diameter, number of seeds per head, seed weight per head and 100seed weight are the best selection criteria in sunflower breeding programme in making crosses.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

It is concluded from the present study that, there was a genotype x environmental interaction on all studied variables except stem girth. The significant genotype x environment interactions for seed yield and other variables indicates the importance of evaluating genotypes at different environments. Genotypes used in this study showed genetic variation, which simplifies selection of the best genotype(s). However, genotype PI364860 was identified to be the most adaptable and stable for most of variables including seed yield. Environments (locations and spacing regimes) also showed variations and simplifies selection of the best location(s) and spacing regime(s). Therefore, Seatondale and Uyole were considered to be the best sites for sunflower production based on results of this study. With respect to spacing regimes looking at the most important variable in this study (seed yield) to consider in marketing and processing, the spacing of 75 cm x 15 cm is the best since it gave the highest yield. Even though the narrow spacing gave the highest seed yield and seemed to be the best it needs to be quantified economically in terms of resources used by relating with the outputs in order to avoid misleading of the concept.

Correlation coefficient analysis revealed that seed yield had positive and significant association with number of seeds per head, head diameter, seed weight/head and 100-seed weight at both genotypic and phenotypic levels. All these four variables are positively interrelated, hence considered to be the best selection criteria to be used in sunflower breeding upon seed yield improvement

Path coefficient analysis indicated that number of seeds per head; 100-seed weight, head diameter and seed weight per head have relatively high positive direct effects on yield. Also they showed positive indirect effects through each other. The selection of these traits would be more effective to bring about simultaneous improvement for yield in sunflower. Therefore, selection for seed yield of sunflower should be made through number of seeds per head, 100 seed weight, head diameter and seed weight per head.

6.2 Recommendations

This study was conducted for one year/season (2011/12), therefore it requires also more years to verify the most interesting findings that were obtained during the study. Therefore this study recommends;

(a) From the above results it would be reasonable to suggest that a breeder engaged in the improvement of sunflower yield should pay great emphasis also on the studies of genotype x environment interaction, stability, and correlation and path coefficient analyses in order to meet farmers' demand. This is because farmers always need a variety that is adaptable, stable with good desirable characteristics.

(b) A plant breeder should also, pay great emphasis on variables namely; head diameter, number of seeds/head, 100 seed weight and seed weight per head as the best selection criteria for increased yield. Therefore, plant breeders engaged in sunflower crop should also make considerations of these four variables for making crosses.

(c) The genotype PI364860 to be the best adaptable and stable for yield that is to be grown in the studied locations and appropriate spacing of 75 cm x 15 cm

(d) Seatondale and Uyole recommended to be the best locations for sunflower production among the studied locations.

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APPENDICES

Appendix 1: Experimental sites

Location	District	Latitude	Longitude	Altitude (m)
Uyole	Mbeya urban	S 08° 56'	E 033° 06'	1795
Seatondale	Iringa urban	S 7° 45'	E 035° 39'	1693
Inyala	Mbeya rural	S 08° 51'	E 033° 38'	1505

Seatondale 07° 45' S and 35° 39' E at an elevation of 1 693 meters above sea level (Iringa region).

Appendix 2: Weather conditions during the 2011/12 rain season at Seatondale

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
December	25.4	13.2	115
January	24.9	12.5	239.7
February	24.3	11.1	90.5
March	24.7	12.8	100.7
April	25.3	13.4	90.7
May	24.6	11.1	185.2
June	-	-	-

Source; Iringa Agro-meteorological Station

Appendix 3: Weather conditions during the 2011/12 rain season at Inyala

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
December	28.4	14.5	162.9
January	26.9	14.1	273
February	26.9	14.1	104.4
March	26.8	14	68.8
April	26.2	13.8	80.3
May	25.6	12.2	175.5
June	25.2	11.8	-

Source: Inyala Agro-meteorological Station

Appendix 4: Weather conditions during the 2011/12 rain season at Uyole

Month	Max Temperature (°C)	Min Temperature (°C)	Rainfall (mm)
December	24.4	13.8	114
January	23.7	13.5	237.8
February	23.9	13.6	78.5
March	23.5	12.8	80.7
April	23.3	11.6	90.7
May	22.6	10.1	180.4
June	-	-	-

Source: Uyole Agro-meteorological Station

Appendix 5: Effects of genotype x location x spacing interaction on seed yield (kg/ha)

		Genotypes			
Location	Spacing	Record	K.Fedha	PI364860	Mean
	75x45cm	2328	2680	2750	2586
Scatondale	75x30cm	3593	3480	3881	3651
	75x15cm	4283	5172	5410	4955
Mean		3401	3777	4014	3731
	75x45cm	830	1048	1598	1159
Inyala	75x30cm	961	1675	2441	1692
	75x15cm	1250	2141	3190	2194
Mean		1014	1621	2410	1682
	75x45cm	1163	1657	2099	1640
Uyole	75x30cm	2555	2658	3523	2912
	75x15cm	4186	3674	5376	4412
Mean		2635	2663	3666	2988