EFFECTS OF ENVIRONMENT ON GROWTH AND YIELD PERFORMANCE OF TEN COMMON BEAN (*Phaseolus vulgaris* L.) GENOTYPES

BY

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ABSTRACT

The present study aimed at examining the effect of environment on growth and yield performance of some common bean (*Phaseolus vulgaris* L.) genotypes. The study was conducted during the season of 2007/2008 at SUA Mlali and Mgeta locations in Morogoro region. Ten bean genotypes obtained from SUA Bean Project were used. The beans were SUA90, ROJO, PESA, MSHINDI, ZAWADI, EG10R43, EG21R30, EG10R5, EG10R13 and one local genotype. SUA90, ROJO and one local genotype found in each location were used as a control. A randomized complete block design [RCBD] was used, with three replications at each location. Plot size was 2m x 2m with four rows of 2m, with plant spacing of 20cm x 50cm. Each replication had 10 plots, Net plot having two rows of 2m x 1.5m. Genotypes showed variation on studied variables though there was no significant difference for genotype x environment interaction. The local check performed better for some variables such as yield at the location, Genotypes at Mlali performed better for most of studied variables. From combined analysis, Pesa yielded higher (416kg/ha) while genotypes SUA90 EG10R43, EG21R13 and Zawadi yielded above the average (306 kg/ha) but were unstable and favoured by environment. There was significant positive correlation between yield and days to 50% flowering which implied that later flowering beans results into high yields. Genotype Rojo and EG10R43 were least affected by common bacterial blight at all sites, while genotype EG10R13 was least attacked by angular leaf spot at all locations. For rust, genotypes Zawadi, EG10R5 SUA90 and Pesa were least infected at all locations, these genotypes can be used for crossing programme to have resistant genotype to mentioned diseases. These results on change in relative performance of bean genotypes across studied environments (example seed yield variation) contribute important information about environment effects under Morogoro condition.

DECLARATION

I Elizabeth Peter Mpayo, hereby to declare to the Senate of SOKOINE UNIVERSITY OF AGRICULTURE, that, from the best of my knowledge, this work is original and has never submitted to any University.

…….. ……

Elizabeth Peter Mpayo Date

(MSc. Candidate)

The above declaration is confirmed by

…… ……..

Prof. Susan Nchimbi–Msolla Date

(MSc. Supervisor)

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DEDICATION

To my brother and his wife Mr and Mrs Aaron Mpayo. Nevertheless this study is dedicated to my late daughter Neema Bakari Tindi

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
Ca	Calcium
°C	Degree centigrade
CIAT	Columbia International Agriculture of Tropical of the United Nations
Cu	Copper
cm	Centimetre
DMRT	Duncans multiple range test
FAO	Food and Agriculture Organization
Fe	Iron
g	gram
kg	Kilogram
m	Metre
Mg	Magnesium
Mn	Manganese
%	Percentage
IITA	International Institute of Tropical Agriculture
MT	Metric Tonnes
SUA	Sokoine University of Agriculture
SE	Standard error of the mean
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the most important food legume worldwide, it is highly valued in Latin America where it is part of the traditional diet (Broughton *et al.*, 2003). The crop was discovered in the fifteenth century in America. Its production and consumption extends from its original (South and Middle America) to North America, Africa, Asia, Europe and other parts of the world except Antarctica continent. The estimated annual production including both dry and snap bean exceeds 21 million metric tones which represents more than half of the world's total food legume production (Miklas *et al.*, 2005). According to the FAO statistics, Latin America is the largest producer of dry beans (5 588 564.50 MT) in the world, followed by Sub Sahara Africa (2 676 589.00), and East South Asia (1 629 645 10 MT). America is the largest common bean producing region while Brazil is the largest producer and consumer of bean in the world today (FAO, 2006).

Common bean is the most important grain legume in Tanzania, since it is a basic staple and an important source of protein to rural and urban communities. Almost every region grows some amount of beans (Table 1), but large amount is produced in regions where the soil is well drained and has high organic matter content. The areas of production are divided in the following zones; Eastern zone (Morogoro, Tanga and Pwani); Northern zone (Arusha, Kilimanjaro, Manyara); Western zone- (Kigoma, Tabora, and Shinyanga); Lake zone (Mwanza, Kagera, and Mara); Southern highland zone (Mbeya, Rukwa, Ruvuma and Iringa); Southern zone (Lindi and Mtwara) ,and Central zone (Singida and Dodoma) (MAFSC, 2003).

Table 1: Common Beans Production in Tanzania Between 2001 – 2005

Regions/Years	**2001/2002**	**2002/2003**	**2003/2004**	**2004/2005**
	"000" Tones	**"000" Tones**	**"000" Tones**	**"000" Tones**
Arusha	82.5	22.2	5.7	9.7
Dodoma	18.8	2.7	26.1	12.1
Iringa	48.6	23.5	51.8	57.0
Kagera	68.4	80.8	71.9	88.9
Kigoma	63.0	40.3	42.3	57.2
Kilimanjaro	29.0	17.6	16.7	26.7
Manyara	-	16.4	27.1	17.2
Mara	8.6	7.6	9.2	8.8
Mbeya	42.4	29.6	51.2	50.1
Morogoro	13.6	8.6	19.0	11.1
Mwanza	2.1	13.2	43.0	53.0
Rukwa	55.5	17.3	0.0	50.8
Ruvuma	11.3	15.1	10.22	17.9
Shinyanga	50.4	5.4	23.6	50.0
Singida	12.9	1.7	3.3	13.2
Tabora	-	7.1	-	21.2
Tanga	53.35	24.0	46.5	81.7
Total	**560.4**	**309.6**	**447.7**	**626.3**

Source: Statistics Unit Ministry of Agriculture, Food Security and Cooperative (2005)

Common bean is cultivated for its green pods, green shelled seeds and dry; seeds in some Eastern Africa, Central and Latin AmericaN countries. Young tender leaves or flowers are harvested as fresh vegetable. However, the largest production and consumption is of dry bean, followed by a much lower level of production for snap bean cultivars. In addition green leaves, stem, and shelled pods are fed to cattle; while dry plant stubble is used to feed cattle, also can be ploughed under the soil in order to increase its organic matter content (Singh, 1999). Commercially, there are two major classes of common bean namely snap and dry beans (Singh, 2001). Snap bean cultivars posses a thick succulent mesocarp with either reduced or no fibre in green pod wall and sutures (Myers, 2000).

Common beans have a high nutritive value for people of all ages. Dry weight of bean comprise 60 percent of Carbohydrates, which provides calories. Nutritional analysis shows that 100 g dry weight of beans gives 120 kilocalories (Kca), while varying percentage of 18%-30% dry weight of beans provide protein. Common bean also contains vitamin B and minerals namely calcium, zinc, copper, manganese and magnesium (Ca, Cu, Fe, Mg, Mn, Zn), that is why it is sometimes referred to as near perfect food (Broughton *et al*., 2003).

The consumption of common bean without removing coat retains its mineral content (Welch *et al.*, 2000). Therefore common is highly recommended in regions where there is a high prevalence of micronutrients deficiencies such as iron deficiency disease (anaemia) (WHO, 2002). Its intake also protects people against diseases like cancer, diabetes and heart problems (Hangen and Bennink, 2003). A great deal of the bean production is done under low input agriculture on small-scale farms in developing countries. The beans produced by these resource-poor farmers are more vulnerable to biotic and to abiotic stresses.

When cultivars are grown in different locations (environments) their performance would vary according to environmental variations of these locations. One cultivar may have the highest yield in one location while a second cultivar may excel in another location. Therefore, G x E interaction shows that the performance of genotypes depends on the conditions of a particular environment in which they are grown. Inconsistent genotypic responses to environmental factors such as temperature, soil moisture, and soil type or fertility level from location to location, is a function of G x E interaction and yield stability hence resulting in alteration to the ordering of genotypes from one environment

to another. The factors are important for breeding new cultivars with improved adaptation to environment constraints prevailing in the target environments.

Various improved bean genotypes have been developed at Sokoine University of Agriculture (SUA) under the bean project. However, the performance evaluations of these genotypes were done in limited agro ecological environments (Nchimbi-Msolla 2007, person communication). This study is therefore aimed at investigating the effect of genotype x environmental interaction on the growth and yield performance of these genotypes under low, medium, and high altitude locations.

1.1 Overall objective

Generally the study intended

To evaluate growth and yield performance of ten common bean genotypes in low, medium and high altitudes in Morogoro Region.

1.1.1 Specific objective

Specifically the study aimed at

(i) Assessing the effect of environment on agronomic and yield performance of ten common bean genotypes.

(ii) Determining the relationship between yield components and total yield and among yield components

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Taxonomy of common bean

Common beans (*Phaseolus vulgaris L.*) belong to the legume tribe *Phaseoleae* within the *Papilionoideae-Leguminosae*. The *Phaseoleae* tribe include approximately 55 species of which five are cultivated viz. the common bean (*Phaseolus vulgaris* L.), Lima bean (*Phaseolus lunatus* L.), Scarlet runner bean (*Phaseolus coccineus* L.), Gray Tepary bean (*Phaseolus acultifolius* L) and *Phaseolus polyanthus* L. which is a Greenman and year-bean. All these types are diploids (2n = 2x =22) (Debouck, 1991).

The cultivated common bean genotype was domesticated from wild *P. vulgaris*, a viny plant with indeterminate growth from the mid-altitude Neo-tropics and subtropics that has a wide distribution range from northern Argentina to northern Mexico (Gepts and Debouck, 1991; Debouck and Smartt, 1995). Over 30 different Phaseolus species of American original were domesticated in this region (Gepts and Debouck, 1991).

The plant is a short day crop (White and Laing, 1989). This crop is adapted to temperate and cools tropical climates under diverse climatic conditions. It sustains the optimum temperature ranges from 16ºC to 18°C of about 12hrs day length, and free from abiotic and biotic stresses. It is also grown in a wide range of soil types, light loamy soils which is rich in organic matter and have pH ranging from 5.5 to 7.0. Most cultivars complete their growing cycle from germination to seed maturity in between 100 to 130 days in temperate climate, having a variation in growth habit from determinate to indeterminate extreme climbing types (Singh, 1999).

2.2 Genotype x Environmental Interaction

Baker (1988) defines genotype x environment (G x E) interaction as the failure of genotype to achieve the same relative performance in different environments. Fehr (1987) on the other hand defines the G x E interaction as changes in the relative performance of genotypes across different environments. The term environment relates to the set of climatic, abiotic, biotic (pest and diseases) and management conditions in an individual trial carried out at a given location in one year (in the case of annual crops) or over several years (in the case of perennials).

When genotypes are compared in different environments, their performance relative to each other may not be the same, as one genotype may have the highest yield in some environments while another cultivar may excel in another environment. Therefore, there is no G x E interaction when the relative performance among genotypes remains constant across environments.

The most important G x E interaction for the plant breeder is the one caused by changes in the rank among genotypes (Fehr, 1987). The change in the rank between cultivars resulting from the G x E interactions can occur in two ways, the first is when the difference among genotypes varies without any alteration in their rank while another is when the rank among cultivars changes across environments. Breeders are mostly interested on the change in the rank between cultivars which results from a G x E interaction and this is the most important interaction (Mushi, 1994).

Genotype main effects (differences in mean yield between genotype) provide the only relevant information when G x E interaction effects are absent or ignored. Thus development of new cultivars involves breeding of cultivars with desired characteristics

such as economic yield, tolerance or resistance to biotic and abiotic stresses, traits that add value to the product, and stability of the traits in the target environments,

2.3 Reasons for Inconsistence of G x E Interaction

The relative performance of genotypes across the environments determines the importance of an interaction, since gene expression is subject to environment modification; therefore, genotypic expression of the phenotype is environmentally dependant (Baker, 1988). A major interaction can be expected when there is a wide variation between genotype for morpho-physiological characters to give one or more stresses, and a wide variation between environments for incidence of some stresses as determined by climatic, soil, biotic and management factors. Other examples may concern the differential response of genotypes to variable levels of stress, such as low temperature, soil salinity, nutrient deficiency, insect pest, diseases, lodging, grazing, or inter specific competition (Annicchiaerico, 2002).

The genetic structure of plant materials may also have a bearing on the extent of G x E interaction. A variety of the types characterized by low levels of heterogeneity such as pure lines, clones tend to interact with the environment more than the types with opposite features such as open-pollinated populations and mixtures of pure lines, because of the lower richness in adaptive genes implied by their genetic structure. This makes them more susceptible to variation in environmental conditions (Brancourt-Hulmel *et al*., 1997 and Becker and Leon, 1988).

2.4 Types of Environmental Interactions

Environmental variables according to Allard and Bradshaw (1964) are classified into predictable and unpredictable. Predictable (systematically fluctuating) those which are

under human control, such as soil type, planting date, row spacing, plant population and rates of nutrient application; while the unpredictable ones (inconsistently fluctuating) include rainfall, temperature, and relative humidity.

2.5 Analysis of Genotype x Environmental interaction

Analysis of variance and linear regression are the common method for G x E interaction analysis. In order to identify superior genotype with stable performance, breeders have to evaluate material over several locations and seasons and then use the components of variance to compare G x E interaction. Linear regression of individual genotype performance in each environment on the performance of all genotypes in each environment is used to indicate relative stability. Genotypes with small b values (regression coefficient) that is less than a unit are to be regarded as stable while those with a value greater than a unit are unstable.

In 1966, Eberhart and Russell, advocated the importance of deviation from regression when deciding the suitability of genotype for different environmental conditions. In this case, the genotype with the deviation from regression approaching zero and regression coefficient equal to unity will be suitable for a given environment. According to Annichiarico (2002) a genotype that performs consistently (high yielding) across many environments would have a possibility to posses broad-based, durable resistance-tolerances to the biotic and abiotic environmental factors that it would encounter during development.

The analysis of genotype x environmental was also illustrated by Wallace *et al*., (1993) using principle component analysis, he divided G x E interaction into plus (positive) and

minus (negative) effects for days to flowering and maturity; the negative G x E interaction represents the decrease in days to flowering (or consequent effect on days to maturity or yield) caused when a higher mean temperature decreases the time the cultivar needs to develop a node. The positive G x E interaction represents the increase in days to flowering (or consequent effect on days to maturity) when the same higher temperature and/or longer day length amplifies the photoperiod gene activity to thereby increase and delay the node to flower. The photoperiod gene activity contests the rate of partitioning to the reproductive growth, which is a control over the rate of accumulation of yield.

Mekbib (2001) conducted a study aimed at evaluating common bean (*Phaseolus vulgaris* L.) genotypes for yield performance in Ethiopia for three years. The results show that the relative performance of the varieties varied in different environments indicating the significance G x E interaction. In 2003, Gebeyehu and Assefa, studied G x E interaction and stability analysis of seed yield in 16 navy bean genotypes grown in Ethiopia, they found that there is considerable variation in seed yield within and across environments. The experiment of Muhammad (2002) which assessed the correlation and path analysis in yard long bean, found that genotypic correlation of pods per plant with yield was highly significant.

According to Corte *et al.,* (2002), conducted a study aimed at estimating the genetic variability for earliness, adaptability and phenotypic stability for grain yield in five common bean cultivar and nine lines. The results show the presence of genetic variability among the cultivars and lines assessed for days to flowering and maturity; there was also wide adaptability and stable performance of the cultivars and lines in different environments.

In Tanzania, Mushi (1994) determined the estimate of G x E interaction and their significance on breeding for the yield of common bean in the medium altitude zone and found that the G x E interaction effects were high. In contrast, Mduruma (1996) evaluated maturity characteristics and yield components of high protein bean (*Phaseolus vulgaris* L.) varieties got a negative correlation between yield and days to 80% maturity. Gridley (1991) also determined G x E interaction in breeding for improved bean seed yield in Uganda. The author reported that, significant lines x site interaction were detected in 73% of the trials

2.6 Seed Yield

Beans are generally characterized by their unstable yields resulting from biological, climatic, and edaphic factors which affect plant growth and productivity (Mduruma, 1996). The common bean varieties and their crosses have been found to vary significantly for each yield component. Heritable influences were observed in the genetic segregation of F_2 generation crosses (Adams, 1967; Chung and Goulden, 1971; Denis and Adams, 1978; Coyne, 1978).

Seed yield in common bean is a complex trait expressed as the product of pods per plant, seed per pod and mean seed weight. Pod per plant has often been used as an indirect selection mechanism for increasing bean seed yield, because of its high and consistent correlation with yields (Benned *et al.*, 1977; Chung and Goulden, 1971; Sarafi, 1978). In a set of eight dry bean cultivars, Chung and Goulden (1971) showed that the number of pods per plant is the main morphological component determining seed yield. Other components of yield could not be used as indirect selection criteria for yield because of

their low heritability and large G x E interaction (Chung and Stevenson, 1973; Nienhuis and Singh, 1985; Slump *et al.*, 1973).

Seed size, together with the number of pods per plant and seeds per pod, constitute three major components which determine the seed yield in common beans. Seed yield in grain crops depends upon the accumulation of the dry matter in the seed itself. The amount of seed yield produced is thus a product of the number of seeds and their sizes determined by the rate and duration of the dry matter accumulation into them (Wien and Ackah, 1978; Al-mukhtar and Coyne, 1981).

2.7 Temperature Effect on Growth and Flowering

The common bean is a quantitative short day plant, which is affected by temperature in all stages of the plant growth (that is increase in size and dry matter accumulation) and development.(that is progress of the plant from germination to maturity) (Monteith, 1977).

In pigeon pea for example, temperature has been found to determine the respective rates of growth, development and dry matter accumulation as well as the number of flowers, which develop into pods, and the number of pods retained (Sharma *et al*., 1981). Temperature also influences seed filling rate and the total crop growth circle (Sheldrake and Narayanan, 1979; Hughes *et al*., 1981).

For most temperate crops, progress towards flowering begins when temperature is raised above the base temperature, a value often between 0º and 5ºC; whereas for tropical crops it is between 10º and 15ºC. In legumes including beans, the time from sowing to the emergence of the first flower is markedly affected by genotype (G), day length (DL),

temperature (T) and the interaction between these factors. Day length and temperature interact to exert major control of continued vs arrested development of initiated flower buds and the major effect of temperature and day length cannot be separated. Day length x temperature interaction also controls the number of branches and leaves per plant, leaf orientation, plant size and height, Stem diameter, harvest index, and numerous other growth characteristics (Monteith, 1977).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. Materials

Ten bean genotypes obtained from SUA Bean Project were used. The beans were SUA 90, ROJO, PESA, MSHINDI, ZAWADI, EG10R43, EG21R30, EG10R5, EG10R13 and one local genotype. The SUA90, ROJO and one local genotype found in each location were used as control. The bean genotypes were evaluated at three locations; Mgeta which is in high altitude (1640m.a.s.l S07°05´02.9¨ E037°34 45.0¨), Mlali which is in medium altitude (563m.a.s.l. S06º57´ 19.9¨E037° 32´04.8¨), and SUA which is a lowland, (531m.a.s.l S06°50´48.7¨ E037º39´48.5¨). The study was conducted in Morogoro region during the of 2007/2008 season.

3.2: Experimental Design

A randomized complete block design [RCBD] was used, with three replications at each location. The plot size was 2m x 2m with four rows of 2m, in which the spacing between one plant and another was 20cm and the spacing between row and another was 50cm. Each replication had 10 plots: Net plot having two rows had 2m x 1.5m, two rows from each side of the plot were used as guard rows. The altitude was the factor and ten common bean genotypes used as the treatment.

3.3 Cultural Practices

Sowing was done on 7 April, 5 May and 7 June 2008 at Mlali, SUA and Mgeta respectively. Replanting was done at Mgeta and SUA sites because of high amount of rainfall which made the area become waterlogged, causing poor growth and death of the plants. Dibbling method was used during planting, where one seed per hill was planted

and a gap filling done seven days later. Urea fertilizer was top dressed during the third week after planting at the rate of 20kg per hectare. Weeds were controlled manually by hand hoe, and insect pests were controlled by spraying with karate insecticide.

Table 2: Bean Genotypes Description

Bean genotypes	Plant type	Seed colour	Seed size
SUA 90	Determinate	Tan	Small
ROJO	Determinate	Brownish red	medium
PESA	Determinate	Red	medium
MSHINDI	Determinate	Purple mottled	Small
ZAWADI	Determinate	Purple mottled	medium
EG10R43	Determinate	Tan	medium
EG21R30	Determinate	Red	medium
EG10R5	Determinate	Dark red	medium
EG10R13	Determinate	Red	medium
KBT	Indeterminate	Grey mottled	Large
LYAMUNGU	Determinate	Red mottle	Large

3.4 Data Collected

Plant height was taken during harvesting. It was done by measuring the distance from the base to the tip of the main shoot.

A number of internodes per plant was taken at harvesting time, internodes of five plants taken at random from each plot were counted and the average was taken as the number of branches per plant.

Number of days to 50% flowering was measured as days after planting to the time coinciding with the initiation of developmental stage R6 when 50% of the plants had one or more flowers.

Days to 80% maturity were measured as days after planting to the time coinciding with the initiation of developmental stage R9 when 80% of the plants had reached maturity.

Pods per plant were recorded as an average from five plants picked at random, and the mean counted as pods per plant.

The pod length was measured by using ruler from one end to another end, from five pods per plant then the average represented the pod length of the plot.

For pod width, five pods selected randomly from five plants were used, the measurement was done by using a tape in centimetres by wrapping the central part of the pod and the average was recorded as the pod width.

Seeds per pod were recorded at harvesting and twenty pods were sampled randomly then threshed separately, the total number of seeds obtained from them was divided by twenty to get the average which represented the number of seeds per pod for that plot.

A sample of 100 seeds was taken randomly from each genotype then weighed to give 100 seed weight.

For weight of seeds per plot, all seeds per plot were weighed separately after sun drying at 12% moisture content and recorded then computed into kilograms per hectare.
The data on rainfall and daily maximum and minimum temperatures during the growing season were collected from a nearby weather station.

Disease severity was determined by scoring using a 1 to 9 CIAT scale, whereas 1 to 3 means resistance (no symptoms or very light symptoms), 4 to 6 intermediate visible and conspicuous symptoms, 7 to 9 susceptible that is severe to very severe symptoms (CIAT 1987).

3.5: Data analysis

3.5.1: Analysis of Variance

The data collected were analyzed using CoSTAT (2004) computer program package. The data were first subjected to analysis of variance for each location using the procedure illustrated by Gomez and Gomez (1984) for a complete randomized block design (CRBD). A combined analysis of variance was computed using the same software as for the single site analysis (CoSTAT). The statistical model was given by

$Y_{ijk} = \mu + g_i + \varepsilon_j + g\varepsilon_{ij} + eijk$

Whereas;

Y_{ijk} = measurement obtained for the unit in of i^{th} genotype of k^{th} replication of the j^{th} altitude,

μ = overall mean,

g_i = mean of the i^{th} genotype,

ε_j = mean of j^{th} altitude,

$g\varepsilon_{ij}$ the interaction effect of the j^{th} genotype of j^{th} altitude,

e_{ijk} = random experimental error.

A combined analysis of variance as shown in Table 3 below, the error mean squares (EMS) were used to calculate the variance due to genotype, environment, and genotype x environment interaction.

3.5.2 Estimate of Variance Components for various common bean traits.

The analysis of variance table from which the estimated components of variance were calculated is shown in Table 3.

Table: 3 Analysis of Variance

Source of variation	d f	Mean of squares	EMS
Environment (E)	2	M1	$\sigma^2e + r\sigma^2ge + g\sigma^2r/e + rg\sigma^2e$
Replication within			
Environment (R/E)	6	M2	$\sigma^2e + g\sigma^2r/e$
Genotypes (g)	9	M3	$\sigma^2e + r\sigma^2ge + re\sigma^2g$
E x G	18	M4	$\sigma^2e + r\sigma^2ge$
Error {Pooled}	54	M5	σ^2e
Total	26		

Where:

σ^2e = plot error variance

σ^2g = genotypic variance among genotypes.

σ^21/e = environmental (location) variance.

r = number of replications.

n = number of environment.

g = number of genotypes.

3.5.3 Simple correlation, Regression and Stability analysis

Simple correlation coefficients among yield and yield components were done by using CoSTAT software Eberhart and Russel (1966) method of linear regression which advocates that a genotype with deviation from regression (S^2di) approaching zero and regression coefficient equal to unity will be suitable for a given environment, and hence being the measure of cultivar stability and reliability across environments. Therefore, it is an indicator for genotype performance for different environmental conditions.

The regression model is as follows

$Yij = \mu i + ßiIj + \delta ij$

Where as;

Yij =mean of the i^{th} variety at j^{th} environment

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

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

Ij = the environmental index

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

According to Finlay and Wilkison (1963), varieties with b value around 1 have an average response. When the average response is associated with high yield, the varieties are said to be specifically adapted to high yielding environments and are optimally responding to inputs. If associated with low yield, varieties are said to be specifically adapted to low yielding environments. b>1 which implies high sensitivity to environmental change

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Performance of genotypes

4.1.2 Performance of genotypes at SUA location

The results for genotypes performance for different variables were as indicated in Table 4. The results for plant height show that there were highly significant differences ($p< 0.001$) among genotypes at SUA location. Genotype Kablanketi was the tallest with a height of 109.7cm followed by Rojo (42.3), EG10R43 (30.9cm) and Zawadi (38.3cm), while genotype EG10R13 was the shortest with height of 29.2cm. The rest genotypes

ranged from 33.7cm to 35.9m. The number of internodes per plant was not significantly different among the genotypes, internodes number ranged from 21 to 30, the lowest internodes number of 21was for EG10R5 and Kablanketi while the highest number was for Rojo and EG10R43 (30).

The number of days to 50% flowering of different genotypes studied at SUA, did not differ significantly. Genotype EG21R30 flowered significantly late (34 days) followed by genotypes Kablanketi, Mshindi and EG10R13 which flowered at 33, 33 and 32 days respectively. The rest of the genotypes flowered significantly earlier at the range of 30 to 31 days.

The days to 80% maturity among bean genotypes planted at SUA location were significantly different. Genotypes EG10R5 and Zawadi attained the earliest maturity at 72days, genotypes EG10R43, Pesa and Kablanketi had 74, 75 and 76 days respectively; while genotype EG21R30 attained maturity latest (81 days) (Table 4).

The number of pods per plant and the number of seeds per pod at SUA location indicate non-significant differences among genotypes, where the number of pods per plant varied from 8 to 12 pods per plant and a mean of 4 seeds per pod with a narrow ranged from 3 to 4 (Table 4).

The genotype which had the longest pod was SUA90 (16.7cm), while the genotype with the shortest pods (11cm) was Kablanketi. The pod width as depicted in Table 4 had a range of 2.7cm to 3.1cm, showing a significant difference where genotype EG10R13 and EG21R30 had a wider (3.1cm) and a narrow (2.7cm) pods respectively. Genotypes varied in 100 seed weight, and ranged from 24.6g to 42.5g, Kablanketi had the highest

100 seed weight with 42.5g, and EG10R13 had the lowest 100 seed weight indicating small seed size.

Seed yield differed significantly ($p \leq 0.05$) among genotypes at SUA location with a mean of 330.1kg/ha. The yield varied from 95.2kg/ha to 441kg/ha where genotypes Rojo (441kg/ha) which had the highest seed yield followed by Pesa (409.6 kg/ha), Kablanketi (400.2kg/ha), EG21R30 (382.3kg/ha) and Mshindi (353.3kg/ha) all had high yield above the mean; and genotype EG10R13 had the lowest seed yield of 95.2kg/ha (Fig 1).

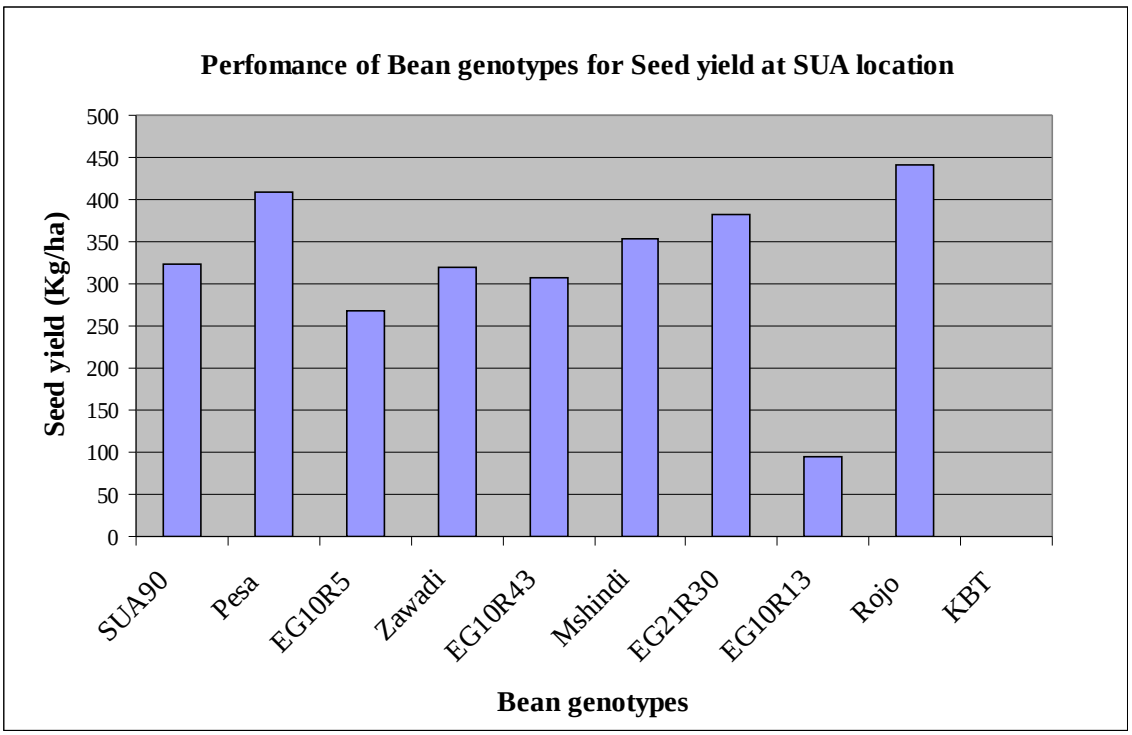

Figure 1: Performance of 10 Bean genotypes for Seed yield at SUA location

Table 4: Performance of 10 common bean genotypes grown at SUA

Genotype	Variable									
	Plant height (cm)	No. of internodes	Days to 50% flowering	Days to 80% maturity	Pods per plant	Seeds per pod	Pod length (cm)	Pod width (cm)	100 seed Wt (g)	Seed yield kg/ha
Rojo	42.0^{b}	30^{a}	31^{b}	77^{ab}	11^{ab}	4^{a}	12.2^{b}	3.0ab	34.1^{bc}	441.4^{a}
SUA 90	35.3^{bcd}	28^{ab}	31^{b}	78^{ab}	10^{ab}	5a	16.7^{a}	2.8^{b}	26.3^{de}	324.0^{a}
Pesa	36.0^{bcd}	23^{abc}	30^{b}	75^{bc}	11^{ab}	4^{a}	10.6^{b}	3.1^{ab}	36.7^{b}	409.6^{a}
EG10R5	33.7^{cd}	21^{c}	31^{b}	72^{c}	9^{ab}	5^{a}	12.2^{b}	2.8^{b}	30.4^{cd}	268.3^{ab}
Zawadi	38.3^{bc}	23^{abc}	31^{b}	75^{bc}	8^{b}	5^{a}	13.9^{ab}	2.9^{b}	30.2^{cd}	319.1^{a}
EG10R4										
3	39.9^{b}	27^{abc}	30^{b}	74^{bc}	8^{b}	5^{a}	13.2^{ab}	3.1^{ab}	35.5^{bc}	307.0^{a}
Mshindi	35.9^{bcd}	24^{abc}	33^{ab}	78^{ab}	11^{ab}	5^{a}	10.6^{b}	2.8^{b}	30.1^{cd}	353.3^{a}
EG21R3										
0	35.4^{bcd}	26^{abc}	34^{a}	80^{a}	12^{a}	4^{a}	12.0^{b}	2.7^{b}	36.8^{b}	382.3^{a}
KBT	109.7^{a}	21^{bc}	33^{ab}	75^{bc}	9^{ab}	4^{a}	11.0^{b}	3.1^{ab}	42.5^{a}	400.2^{a}
EG10R1										
3	29.2^{d}	30^{a}	32^{ab}	76^{abc}	9^{ab}	4^{a}	10.4^{b}	3.1^{a}	24.6^{e}	95.2^{b}
Mean	43.6	25	32	76.5	10	5	12.3	3.3	32.7	330.1
SE ±	20.3	18.2	3.3	8.2	5.1	0.2	5.1	5.1	10.3	10564.6
CV	10.3	17	5.8	3.7	23.3	10.7	18.3	68.6	9.8	31.1

Mean followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 0.05$)

4.1.3 Performance of genotypes at Mlali location

Table 5 shows performance of genotypes under Mlali conditions.

The result for plant height show that there were highly significant differences ($p \leq 0.001$) among genotypes. Genotype Kablanketi was the tallest with a plant height of 129.9cm while genotype EG10R13 was the shortest with 24.4cm plant height; the rest of the genotypes ranged from 31cm to 34cm. The number of internodes per plant was significantly different among genotypes ($p \leq 0.05$). Internodes number varied from 18 to 31, genotype EG10R13 had the highest number of internodes while Kablanketi had the lowest number (18) of internodes (Table 5).

The number of days to 50% flowering of different genotypes studied differed significantly ($p \leq 0.05$). Genotypes EG21R30 and EG10R13 attained 50% flowering at 33 days followed by genotypes SUA 90, PESA, Zawadi, Mshindi and EG10R43; the rest of the genotypes flowered earlier (30 days).

For days to 80% maturity, genotypes differed significantly ($p \leq 0.05$) where Zawadi matured earlier (71 days) than the rest of the genotypes. Genotypes Mshindi and EG21R30 attained maturity very late at 85 days.

Genotypes differed significantly ($p \leq 0.05$) for the number of pods which varied from 7 to 16 where Mshindi and Kablanketi had the highest number of 16 pods per plant while EG10R43 had the lowest of 7 pods per plant, also had 4 to 5 seeds per pod.

For pod length variable, genotypes differed significantly ($p \leq 0.05$), genotype Zawadi with a pod length of 13.4cm had the longest pods followed by SUA 90 (12.7cm) and EG10R5 (12.2cm), the shortest pods were recorded in Mshindi genotype (10cm). For

pod width variable, there was no significant differences among the genotype recorded, but local check Kablanketi had wider pods (3.2cm) and a narrow pod was found on Mshindi genotype (2.9cm).

At Mlali the genotypes differed significantly ($p \leq 0.001$) in 100 seed weight, Kablanketi had a high 100 seed weight of 47.7g/100 seeds and a medium 100 seed weight were from SUA90 (31.3g), Zawadi (35.3g), Mshindi (38.5g) and EG10R5 (39.1g); while the rest had a high 100 seed weight seeds.

At Mlali location there was a significant different in seed yield among the genotypes. Local genotype Kablanketi and SUA90 recorded the highest yields of 663.3 kg/ha, also genotypes Zawadi and, EG10R5 had seed yields above the mean (551.8 kg/ha). Genotype EG10R13 had the lowest yield of 223.3kg/ha (Fig 2).

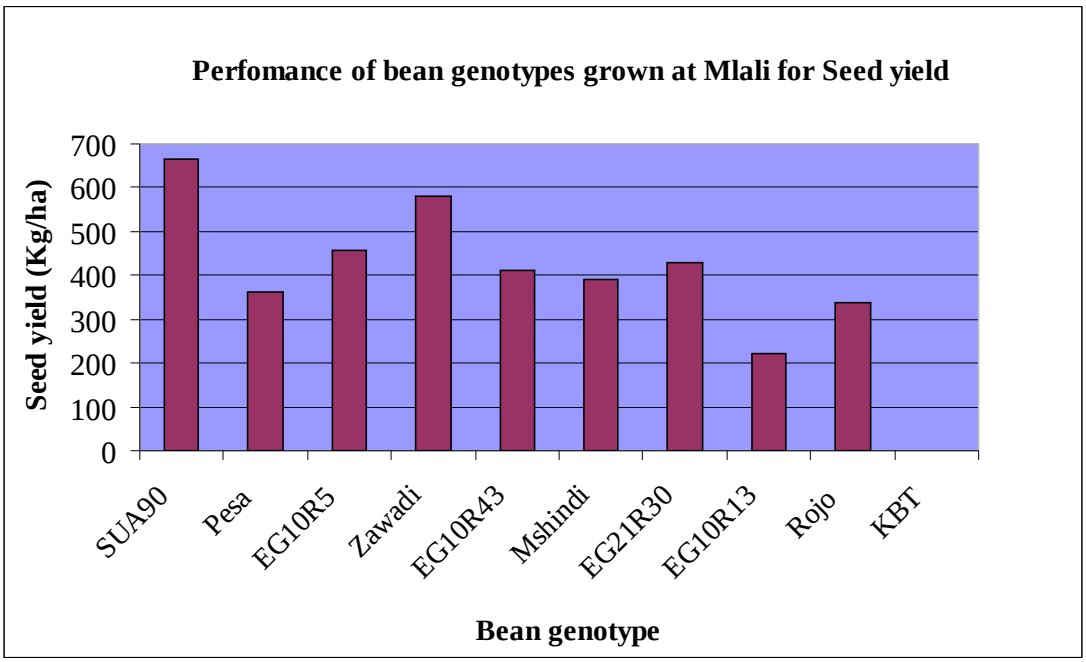

Figure 2: Performance of 10 bean genotypes grown at Mlali for Seed yield

Table 5: Performance of 10 common bean genotypes grown at Mlali

Genotype	Variable									
	Plant height (cm)	No. of internodes	Days to 50% flowering	Days to 80% maturity	Pods per plant	Seeds per pod	Pod length (cm)	Pod width (cm)	100 seed wt. (g)	Seed yield (kg/ha)
Rojo	31.1^{b}	20^{b}	32^{ab}	78^{b}	12^{abc}	4^{a}	11.1^{bcde}	3.0^{ab}	43.5^{abc}	336.7^{abc}
SUA90	33.2^{b}	21^{b}	30^{b}	78^{b}	15^{ab}	5^{a}	12.7^{ab}	2.78^{b}	31.3^{f}	663.3^{a}
Pesa	31.0^{b}	19^{b}	30^{b}	78^{b}	13^{ab}	5^{a}	10.9^{cde}	3.1^{ab}	42.7^{bcd}	363.3^{abc}
EG10R5	32.5^{b}	19^{b}	32^{ab}	78^{b}	12^{abc}	4^{a}	12.2^{abc}	3.0^{ab}	39.1^{cde}	456.7^{abc}
Zawadi	34.9^{b}	23^{b}	30^{b}	71^{c}	15^{ab}	5^{a}	13.4^{a}	3.0^{ab}	35.4^{ef}	580.0^{ab}
EG10R43	34.2^{b}	19^{b}	30^{b}	76^{bc}	7^{c}	5^{a}	11.8^{abcd}	3.0^{ab}	44.4^{ab}	410.0^{abc}
Mshindi	31.4^{b}	22^{b}	30^{b}	85^{a}	16^{a}	5^{a}	10.0^{e}	2.9^{b}	38.5^{de}	391.3^{abc}
EG21R30	31.1^{b}	21^{b}	33^{a}	85^{a}	13^{ab}	5^{a}	11.7^{bcd}	2.9^{b}	45.7^{ab}	430.0^{abc}
KBT	129.5^{a}	18^{b}	32^{ab}	79^{b}	16^{ab}	5^{a}	11.0^{cde}	3.2^{a}	47.7^{a}	663.3^{a}
EG10R13	24.4^{b}	32^{a}	33^{a}	78^{b}	11^{bc}	4^{a}	10.4^{de}	3.0^{ab}	42.2^{bcd}	223.3^{c}
Mean	41.3	21.3	31	78	13	5	11.5	3.0	41.0	451.8
SE±	96.1	15.3	1.6	13.5	8.8	0.4	1.0	0.0	7.2	3175.6
CV%	23.7	18.3	4.1	4.7	22.9	14.2	8.6	5.4	6.5	41.6
LSD(0.05)	16.8	6.7	2.2	6.3	5.1	1.1	1.7	0.3	4.6	96.7

Means followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 0.05$)

4.1.4: Performance of genotypes at Mgeta location

Performances of genotypes for different variables are shown in Table 6.

The result indicates that there were no significant differences among genotypes in terms of performance. Genotypes had a plant height ranging from 26.3cm (Pesa) to 33.9cm (EG10R43). The rest of the genotypes had plants heights between these values.

The number of internodes per plant was not significantly different among the genotypes; Pesa had the lowest number of internodes (15) while Lyamungu had the highest number with 25 internodes.

There were no significant differences in the number of days to 50% flowering among the evaluated genotypes. The days to 50% flowering ranged from 38 days (SUA 90, Pesa, EG10R5, and Zawadi) to 41days (EG21R30) with a mean of 39 days.

There were no significant differences among genotypes in terms of days to 80% maturity. Genotype EG21R30 and Rojo matured late (147 and 146 days respectively), while SUA90 was the earliest (89 days) to mature. The rest of the genotypes did not show any significant difference in the number of days required to attain 80% maturity.

Genotypes Lyamungu had the highest number of pods per plant (13) compared to other genotypes, while genotypes Pesa and EG10R43 had the lowest number of pods (4). The number of seeds per pod were not significantly different among the genotypes, the number of seeds per pod ranged from 1 to 5 (Rojo and EG10R13)

Pod length at Mgeta location was not significantly different ranging from 6.5 cm (Zawadi) to 11cm (Rojo, Mshindi and EG10R13). For pod width there were no

significant differences among the genotypes. Genotypes SUA90 (1.9cm), Pesa (1.7cm), and EG10R13 (1.7cm) had narrow pod width. The rest of the genotypes did not differ significantly among themselves.

There were no significant differences among the genotypes for 100 seed weight variable. Genotype EG10R43 had the smallest 100 seed weight of 18.1g while EG21R30 (58.3g), Rojo (53.1g), EG10R13 (50.2g) and Mshindi (43.9g) had a heavy 100 seed weight, the rest had medium 100 seed weight.

A genotype EG10R13 recorded the highest seed yield (633.3kg/ha) while Genotypes SUA90 (262.6kg/ha) and EG10R5 (245.2kg/ha) had seed yield above the mean (215.5kg/ha) while genotype Pesa had the lowest seed yield of 98.3kg/ha (Fig 3).

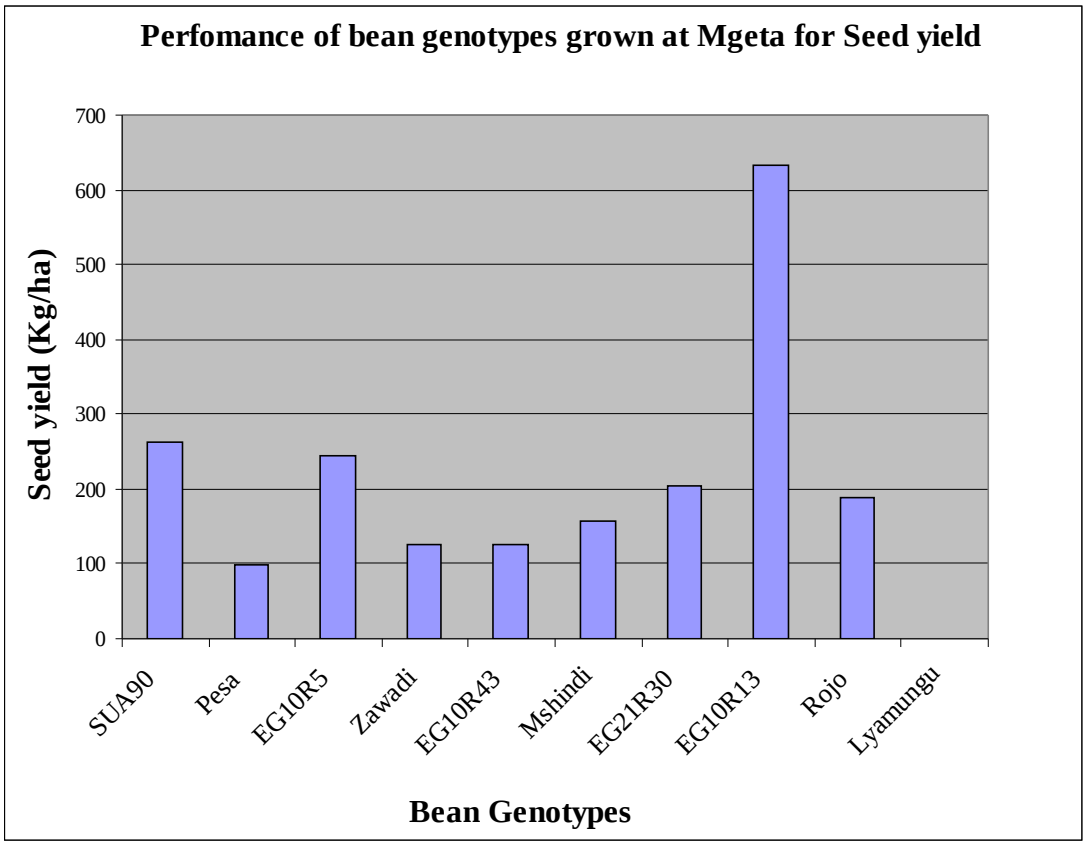

Figure 3: Performance of bean genotypes grown at Mgeta for Seed yield.

Table 6: Performance of 10 common bean genotypes grown at Mgeta

e	Variables									
	Plant Height (cm)	No of internodes	50% flowering	80% maturity	Pods Per plant	Seeds per pod	Pod length (cm)	Pod width (cm)	100 seed wt (g)	Seed yield (kg/ha)
	32.3ab	19ab	39a	146a	8b	5a	11.1a	3.1a	53.1ab	189.2b
	32.8ab	19ab	38a	89b	8b	3ab	9.2a	1.9ab	28.6ab	262.6b
	26.1b	15b	38a	132ab	4b	3ab	7.7a	1.7ab	30.1ab	98.3b
	26.9b	18ab	38a	131ab	7b	3ab	8.5a	3.0a	33.8ab	245.2b
	29.0ab	15b	38a	117ab	5b	4ab	6.5a	2.0a	40.7ab	125.4b
3	33.9a	20ab	39a	115ab	4b	1b	6.9a	1.1a	18.1b	125.9b
	27.5ab	17ab	40a	126ab	8b	4ab	11.1a	3.1a	44.0ab	156.1b
0	28.2ab	22ab	41a	147a	9b	4ab	10.8a	3.1a	58.3a	204.2b
3	26.8b	16ab	39a	129ab	8b	5a	11.1a	3.2a	50.3ab	633.3a
u	32ab	25a	39	125ab	13b	3ab	6.8a	1.7ab	29.8ab	112.4b
	29.6	19	39	126	7	3	9	2.4	38.7	215.5
	15.9	27.9	7.9	92	22.7	3.2	10.9	1.2	465.8	613.7
	13.6	28.5	7.2	24.1	66	52.8	36.9	45.8	55.8	98.1
5)	6.9	9.1	2.6	52	8.2	3.1	5.7	1.9	37	362.5

Means followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 0.05$)

4.1.5 Combined Performance of nine genotypes

This section looks at the data from the three locations analyzed in a combined ANOVA and the results obtained (Tables 7, 8 and 9).

Genotypes differed significantly on plant height at ($p \leq 0.001$), pods per plant ($p \leq 0.05$) significance level, days to 50% flowering at ($p \leq 0.05$) and Angular leaf spot severity at $p \leq 0.01$ significance level. Locations differed significantly for plant height, the number of internodes, days to 50% flowering, days to 80% maturity, pods/plant, seeds per pod, pod length, pod width, seed yield common bacterial blight and rust, all at $p \leq 0.001$ significance level. Genotype differed significantly $p \leq 0.05$ and $p \leq 0.01$ for variables pod width and angular leaf spot respectively. The genotypes had no significant differences, in 100 seed weight and also there were no significant differences for genotype x environment interaction (Tables 7 and 8) for this variable.

The genotypes differed significantly ($p \leq 0.001$) for their performance on plant height Genotype EG10R13 had the shortest plants (26.8cm) while EG10R43 had the tallest plant (36.0cm) followed by Zawadi (34.1cm) and SUA90 (33.8cm) (Table 9).

There were no significant differences for internodes among the genotypes tested, with the number ranging from 18 to 23 with mean of 21. Genotype EG10R13, Pesa, and SUA 90 had 23 internodes which was the highest, while Rojo had 18 the lowest internodes.

The results in Table 8 show that the combined analysis for the number of days to 50% flowering was significantly different ($p \leq 0.05$) among the genotypes. Genotypes EG10R13 took the longest time (36 days) to achieve 50% flowering, genotypes Pesa, SUA90, EG10R5, Mshindi and EG10R43 flowered earlier in 33 days.

It was observed that there was no significant difference in the number of days required to attain 80% maturity with mean of 93 days. Genotype SUA 90 and EG10R13 took the highest number of days (101 and 104 respectively) to attain maturity as seen in Table 8, while genotype Pesa reached maturity at the earliest time of 82 days.

Genotypes differed significantly ($p \leq 0.05$), in terms of the number of pods per plant; genotype EG10R13 (16) had the highest number of pods per plant, followed by EG21R30 (12) and Pesa (11). For seeds per pod ranged from 4 to 5, and all genotypes had mean seeds per pod of 4 seeds.

For combined EG10R13 genotype had a wider pod (3.8cm) followed by Rojo (3.0cm), Genotype with narrow/thin pods was EG10R43 (2.4cm). There was no significant difference for the rest of genotypes in terms of pod width. As for pod length, genotype Pesa had the longest pod compared to other genotypes and genotype EG10R5 had the shortest, other genotypes had pod length ranging from 9.2cm to 11.5cm.

As for 100 seed weight, genotype EG21R13 had a high 100 seed weight of 46.9g, where as SUA90 had a medium 100 seed weight of 28.7g. As for seed yield, genotype Pesa had the highest seed yield followed by EG10R13 (339.8kg/ha), EG10R43 (341.7kg/ha), Zawadi (323.3kg/ha) and SUA 90 (322.3kg/ha) which had above the mean (306.6kg/ha). Genotype Rojo had the lowest yield (143.2kg/ha), the rest of the genotypes did not differ significantly (Fig 4).

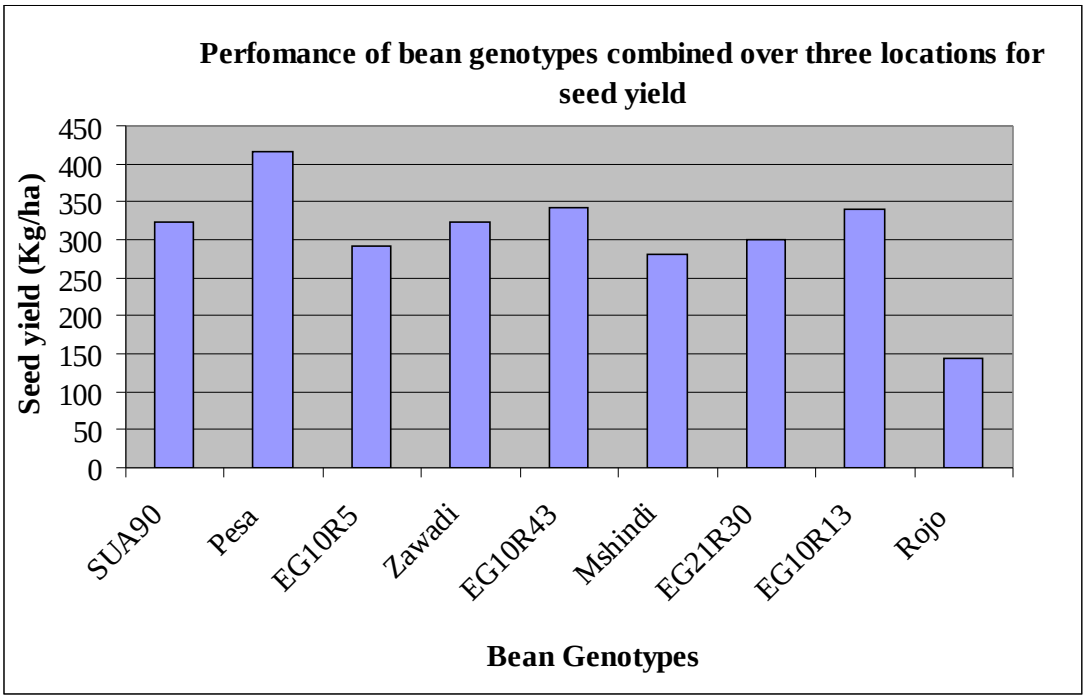

Figure 4: Performance of bean genotypes combined over three locations for Seed yield.

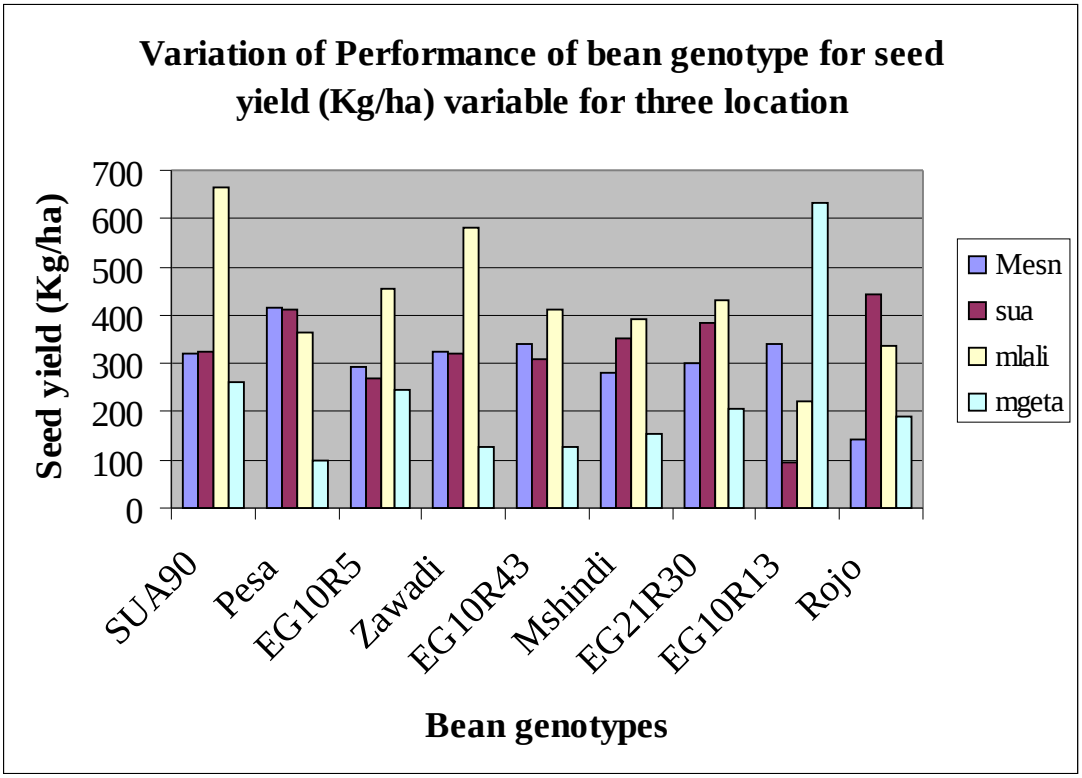

Figure 5: Performance variation of Seed yield for nine tested Bean genotypes over three locations

Table 7: Analysis of variance for agronomic studied variables

Source of variation	df	Plant Height (cm)	No. of internodes	Pod length	Pod width	50% flowering	80% maturity
Location	2	341.1***	331.49***	101.3***	7.42*	553.8***	20784.3***
Genotype	8	69.9***	30.4	10.26	1.61	9.64*	417.95
LxG	16	13.2	12.9	8.11	2.73	1.96	293.35
Error	52	15.2	19.13	6.0	2.33	4.42	341.5

Table 8: Analysis of variance for studied yield and diseases component

Source of variation	df	Pods per plant	Seeds per pod	Seed yield (kg/ha)	100 Seed Wt. (g)	CBB	ALS	Rust
Location	2	295.33***	14.4***	41290.9***	524.93	27.8***	17.6**	6.5** *
Genotype	8	28.3*	1.18	4312.51	292.11	0.6	1.8**	0.2
LxG	16	7.3	1.12	1977.64	162.72	0.7	0.7	0.2
Error	52	10.29	1.29	2453.22	166.84	0.7	0.6	0.2

* Significant at 0.05

** Significant at 0.01

*** Significant at 0.001

Table 9: Performance of agronomic\ vegetative variables on nine common bean genotypes combined over three locations (SUA, Mlali and Mgeta)

Genotype	Variables									
	Plant height (cm)	Number of internodes	Days to 50% flowering	Days to 80% maturity	Pods/ plant	Seeds/ pods	Pod length (cm)	Pod width (cm)	100 seed wgt. (g)	Seed yield (kg/ha)
SUA90	33.8^{abc}	23.0^{a}	34^{b}	101a	10^{ab}	4^{a}	11.5^{ab}	3.0^{ab}	43.6^{ab}	322.3^{a}
Pesa	31.1^{c}	23.0^{a}	33^{b}	82^{b}	11^{a}	4^{a}	12.8^{a}	2.5^{ab}	28.8^{c}	416.3^{ab}
EG10R5	31.1^{c}	19.2^{ab}	33^{b}	95^{ab}	9^{abc}	4^{a}	6.7^{b}	2.6^{ab}	36.5^{abc}	291.1^{a}
Zawadi	34.1^{abc}	19.1^{ab}	34^{b}	94^{ab}	9^{abc}	4^{a}	11.0^{ab}	2.9^{ab}	34.4^{bc}	323.3^{a}
EG10R43	36.0^{a}	20.2^{ab}	33^{b}	88^{ab}	9^{abc}	4^{a}	11.3^{ab}	2.6^{ab}	35.4^{abc}	341.7^{a}
Mshindi	31.6^{bc}	21.9^{ab}	33^{b}	88^{ab}	6.0^{c}	4^{a}	10.6^{ab}	2.4^{b}	32.6^{bc}	280.4^{ab}
EG21R30	31.6^{c}	20.9^{ba}	34^{ab}	95^{ab}	12^{a}	5^{a}	10.6^{ab}	2.9^{ab}	37.5^{abc}	300.1^{a}
EG10R13	26 .8^{d}	22.9^{a}	36^{a}	104^{a}	16^{a}	4^{a}	11.5^{a}	2.9^{ab}	46.9^{a}	339.8^{a}
Rojo	35.3^{ab}	18.3^{b}	34^{ab}	94^{ab}	8.0^{bc}	4^{a}	9.2^{b}	3.8^{a}	32.2^{bc}	143.2^{b}
Mean	32.4	20.9	34	93	10	4	10.9	2.9	36.4	306.6
SE±	15.2	19.1	4.4	341.5	1.3	1.3	6	2.3	166.8	2725.8
CV%	12.1	20.91	6.2	19.8	27.9	27.9	22.4	53	35.4	53.9
LSD(0.05)	2.1	2.4	1.14	10.1	0.6	0.6	2.3	0.8	7.1	90.2

Means followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 0.05$)

4.1.6 Location Performance of Genotypes

Table 10 below indicates the location of the performance of genotypes for the studied variable

Location differed significantly ($p \leq 0.001$) from each other for plant height; with Mgeta location having the shortest plants (29.6cm) than in other locations of SUA (43.0cm) and Mlali (41.3cm).

SUA location had the highest number of internodes (25) followed by Mlali (21) and then Mgeta (19). On the other hand the lowest number of pods per plant was observed at Mgeta (7) followed by SUA (10) then Mlali location having 13 pods.

Days to 50% flowering Mlali was the earliest to each (31 days) and followed by SUA (32 days), and Mgeta (39 days) which was relatively late.

Days to 80% maturity for the two locations SUA and Mlali were 77 and 78 days respectively, and did not differ significantly; however, Mgeta had the highest number of days to maturity (125) as shown in Table 9.

There were no significant differences among the studied locations in terms of the number of pods per plant, though Mlali location had the highest number of pods per plant followed by SUA and Mgeta location which had the lowest number of pods per plant.

The longest pod was found at SUA location with 12.4cm followed by Mlali location (11.6cm) then Mgeta (8.7cm). As for pod width, SUA location had the widest pods (3.3cm), while Mlali and Mgeta produced pods with width of 3.0cm and 2.4cm respectively.

There was no significance difference observed for 100 seed weight where at Mlali genotypes produced the largest seeds (41.3g) followed by Mgeta (38.7g) then SUA (32.7g) which had medium size as shown in Table 9.

The locations differed significantly ($p < 0.001$) in seed yield, where genotypes at Mlali yielded higher (451.7kg/ha) followed by SUA (330.1kg/ha), and Mgeta (215kg/ha).

Table 10: Combined Performance of 9 common bean genotypes for studied variables at SUA, Mlali and Mgeta

Location	Variables									
	Plant height (cm)	No of internodes	Days to 50% flowering	Days to 80% maturity	Pods/ plant	Seeds/ pod	Pod length (cm)	Pod width (cm)	Seed yield (kg/ha)	100 seed Wgt (g)
SUA	33.4	24	31	77	10	5	12.4	3.3	322.2	31.6
Mlali	31.5	21	31	78	13	5	11.6	2.9	428.3	40.3
Mgeta	29.4	20	39	125	6	3	8.7	2.4	169.1	37.4
Mean	31.7	21	34	93	10	4.1	10.9	2.9	306.6	36.4
SE±	15.2	19.2	4.4	341.5	10.3	1.3	6	2.3	27258	166.9
CV%	12.1	20.9	6.2	19.8	33.8	27.9	22.4	53	53.9	53.4
LSD(0.05)	2.1	2.2	1.1	10.1	1.8	0.6	1.3	0.8	90.2	7.1

Means followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 05$)

4.1.7 Diseases incidence severity reaction of 10 bean genotypes at SUA, Mlali and Mgeta

Some disease incidences of Common bean bacterial blight caused by *Xanthomonas phaseoli,* Angular leaf spot caused by *Phaseoisariopsis griseola* and Rust caused by *Uromyces appendiculatus* were found to be infecting bean plants at all locations from late vegetative stage to maturity.

The severity of Common bacterial blight at SUA location was not significantly different among the genotypes having the score range of 2.7 to 3 with Mshindi having a higher score; the rest all had the same score of 2.7. Infection by Angular leaf spot was significantly different among the studied genotypes with a score range of 3 to 4.7. Genotype EG21R30 had the highest severity scores (4.7) while EG10R13 had the lowest incidence of 3. The severity score of Rust disease was not significantly different among the genotypes; they had a score range of 2 to 2.3. Rojo and Mshindi had a higher score of 2.3 than the rest which had 2. At Mlali infection by Common bacterial blight was significantly different among the genotypes, genotype Pesa and EG10R13 had a score of 3.7, and genotype Rojo had the lowest incidence (2.0). The severity of Angular leaf spot recorded, genotype EG10R5 and EG10R43 as having a severity score of 3.0, genotype EG21R30 was the most severely attacked (5). Infection by Rust was not significantly different among the genotypes with EG21R30 having a score of 2.7 while the rest of the genotypes which had a severity score of 2.0.

Severity of Common bacterial blight was significantly different among the genotypes at Mgeta. Genotype EG10R5 had the highest severity (5.7) whereas genotypes Lyamungu (a local check) and EG10R43 had the least infection of 3.7. Infection by Angular leaf spot was significantly different among the genotypes, genotype Rojo, SUA90, EG10R5

and EG21R30 had the highest infection of 5.7, while the local genotype Lyamungu recorded lowest severity of 3.7. Rust was most severe in genotype Lyamungu (6) while the rest of the genotypes did not show significant differences in Rust severity. Beans at this location were also affected by powdery mildew with scores ranging from 2.3 to 4 and Ascochyta blight with scores ranging from 4.7 to 7.3. Ascochyta was a serious disease in this location.

Combined analysis for the three locations shows the common bacterial blight as being severe in genotype EG10R5 with a score of 3.9. The least severity attacked genotypes were Zawadi (3.2), Mshindi (3.3) and EG10R43 (3.1), on average genotype EG21R30 was most severely (5.1) affected by angular leaf spot, while EG10R13 was least attacked (3.7). Rust severity records show that there was no significant differences among the genotypes in the combined analysis on the studied genotypes having severity score of 2.7 (Mshindi) as the highest to 2.2 (Zawadi and EG10R5) as the least affected..

4.1.8 Location Disease Severity

Table 10 shows disease severity at three locations, where there were significant differences on common bacterial blight severity among locations whereby Mgeta had the highest score (4.5) followed by Mlali (3.1) while the lowest was SUA had the lowest (2.6).

In terms of angular leaf spot SUA had the lowest score (3.7) compared to Mlali (3.9) and the highest score was at Mgeta (5.1) location. Significant differences on rust severity was also observed between locations whereby Mgeta site had the highest score followed by Mlali (2.23), and SUA (2.1).

Table 11: Diseases incidence severity reaction over three locations (SUA, Mlali and Mgeta)

Genotype	Common bacterial blight				Angular Leaf Spot				Rust				ASC	PM
	SUA	Mlali	Mgeta	Mean	SUA	Mlali	Mgeta	Mean	SUA	Mlali	Mgeta	Mean	Mgeta	
Rojo	2.7a	2.0b	5.7a	3.5	4.0abc	4.0ab	5.7a	4.6	2.3a	2.0ba	3.3b	2.5	6.0	4.0
Mshindi	3.0a	3.0ab	4.0ab	3.3	4.0abc	4.0ab	5.7a	4.6	2.3a	2.0ba	3.7b	2.7	6.3	3.0
Zawadi	2.7a	3.0ab	4.0ab	3.2	3.3bc	4.3ab	4.7ab	4.1	2.0a	2.0b	2.7b	2.2	7.0	2.0
EG10R5	2.7a	3.3ab	5.7a	3.9	3.0c	3.0b	5.7a	3.9	2.0a	2.0b	2.7b	2.2	5.3	3.3
EG10RI3	2.7a	3.7a	4.3ab	3.6	3.0c	3.0b	5.0ab	3.7	2.0a	2.0b	3.0b	2.3	5.7	3.7
EG10R43	2.7a	3.0ab	3.7b	3.1	3.7abc	3.7ab	4.3b	3.9	2.0a	2.0b	3.0b	2.3	7.3	2.7
EG21R30	2.7a	3.0ab	5.0ab	3.6	4.7a	5.0a	5.7a	5.1	2.0a	2.7a	2.7b	2.5	5.7	2.0
SUA90	2.7a	3.0ab	5.0ab	3.6	4.3ab	4.3ab	4.7ab	4.4	2.0a	2.0b	2.7b	2.5	5.3	2.3
Pesa	2.7a	3..07a	4.7ab	3.7	3.7abc	4ab	5.7a	4.5	2.0a	2.0b	2.7b	2.5	5.3	3.0
Mean	2.6	3.1	4.5		3.7	4.7	5.1		2.1	2.06	3.2		5.8	2.9
SE±	0.28	0.51	1.2		0.5	0.6	0.8		0.1	0.03	0.5		1.5	1.3
CV	20.3	23.22	24		19.53	19.7	17.7		15.1	8.8	20.9		21	39
LSD	0.92	1.22	1.8		1.24	1.34	1.5		0.5	0.3	1.2		2.1	1.9

Means followed by the same letter(s) are not significantly different according to Mean separation by DMRT ($P \leq 0.05$)

Key:
ASC = for ascochyta blight
PM = for powdery mildew

4.1.9 Simple correlation Analysis

The correlation coefficients (r) between the studied variables on different variables on different genotypes grown at different locations are presented on Table 12-15.

4.1.9.1 SUA location

Plant height had a weak significant correlation (r = 0.387) with internodes number,
Days to 80% maturity strongly correlated (r = 0.558) with 50% flowering. While a weak significant correlation (r = 0.385) was observed between seeds per pod and internodes number. Again, the number of seeds per pod only correlated significantly with the pod length (r = 0.4447); strong significant correlation was as well recorded on 100 seed weight and yield (r = 0.612). A negative correlation was observed between 100 seed weight with pod length, on other hand negative correlation was between pod width with pod length, also seed yield with days to 50% flowering, and pod width (Table12).

4.1.9.2 Mlali location

The number of pods per plant (r = 0.633) and plant height (r = 0.772) were significantly correlated with internodes number; on the other hand days to 80% maturity had a weak correlation (r = 0.421) with 50% flowering. Pod width correlated significantly with days to 80% maturity (r = 0.446) and internodes number. Seeds per pod had a weak correlation (r = 0.384) with pod length while days to 80% maturity was significantly correlated with pod length (r = 0.529). Seed yield was significantly correlated with pod length (r = 0.5) and internodes number (r = 0.0542). While 100 seed weight was significantly correlated with days to 50% flowering (r = 0.514). 100 seed weight had a negative correlation with yield and a negative correlation with pods per plant; and seed yield had a negative correlation with days to 80% maturity (Table 13).

4.1.9.3 Mgeta location

Internodes number had a weak correlation with plant height (r = 0.388) and days to 50% flowering. Days to 80% maturity had a weak correlation (r = 0.377) with 50% flowering and internodes numbers (r = 0.442). But pods per plant had a strong correlation (r = 0.818) with internodes number and weak correlation (r = 0.37) with days to 80% maturity. Seeds per pod had a strong correlation with internodes number, days to 80% maturity, and pods per plant (r = 0.588, r = 0.676, and r = 0.576) respectively. Pod width was strongly correlated with the number of internodes (r = 0.596), days to 80% maturity (r = 0.688), pods per plant (r = 0.583), seeds per pod (r = 0.877), and pod length (r = 0.816). Also pod length had a weak significant correlation with days to 50% flowering (r = 0.401). Yield had a strong significant correlation with internodes number, pods per plant, pod length and pod width (r = 0.584, r = 0.578 and r = 0.62, r = 0.527) respectively.

A 100 seed weight was significantly correlated with the number of internodes (r = 0.614), days to 80% maturity (r = 0.715), pods per plant (r = 0.522), seeds per pod (r = 0.926), pod length (r = 0.695), and pod width (r = 0.816), yield (r = 0.484), whereby weak significant correlation was observed with days to 50% flowering (r = 0.377). Also there was a weak negative correlation between pod length and days to 80% maturity, and between seeds per pod and days to 80% maturity (Table 14). Rust disease severity was significantly correlated with pods per plant (r = 0.592), yield (r = 0.508) and weak correlation with pod length (r = 0.361) (Table 14).

4.1.9.4 Combined correlation for three locations

For combined analysis for the three locations the number of internodes was significantly correlated with plant height (r =0.679), while days to 50% flowering was significantly

correlated with plant height (r = 0.387) and internodes number (r = 0.288). Days to 80% maturity correlated with plant height (r = 0.254) and days to 50% flowering (r = 0.774). There was a positive and significant correlation between pods per plant and plant height (r = 0.321), internodes number (r = 0.541), day to 50 flowering (r = 0.424) and days to 80% maturity (r = 0.266).

Significance correlation was observed between seeds per pod and plant height (r = 0.340), internodes number (r = 0.561), days to 50% flowering (r = 0.349), and pods per plant (r = 0.598). Pod length was significantly correlated with plant height (r = 0.375), internodes number (r = 0.618), days to 50% flowering (r = 0.385), pods per plant (r = 0.534) and seeds per pod (r = 0.723). While pod width correlated with plant height (r = 0.338), pods per plant (r = 0.384), seeds per pod (r = 465) and pod length (r = 0.355). Yield correlated with plant height (r = 0.394), internodes number (r = 0.467), days to 50% flowering (r = 0.462), days to 80% maturity (r = 0.250), pods per plant (r = 0.713), seeds per pod (r = 0.524) and pod length (r = 0.525). Also there was a negative correlation among variables as indicated on Table 15.

A 100 seed weight correlated with seeds per pod (r = 0.649), pod width (r = 0.305), pod per plant (r = 0.343), pod length (r = 0.312) weak correlation was observed with internodes number (r = 0.219) (Table 15).

Table 12: Simple correlation coefficient between different variables for 10 common bean genotypes at SUA

	1	2	3	4	5	6	7	8	9	10	11	12
lant height												
nternodes	0.387*											
0% flowering	0.16	-0.015										
0% maturity	-0.063	0.07	0.558** *									
ods/plant	-0.023	0.341	0.435*	0.351								
eeds/pod	-0.056	0.385*	-0.185	-0.058	0.125							
od length	-0.118	0.218	-0.178	0.323	-0.088	0.447*						
od width	-0.039	0.089	0.308	0.197	0.356	0.172	-0.309					
ield	0.296	0.369*	-0.005	0.092	0.522	0.24	0.053	-0.209				
00 Seed Wt.	0.63	0.34	0.235	0.068	0.327	0.05	-0.167	0.053	0.612***			
BB	-0.281	-0.27	-0.294	-0.039	0.368*	-0.02	0.03	-0.267	-0.238	-0.255		
LS	-0.163	0.084	0.147	0.425	-0.044	-0.029	0.227	0.422*	0.173	0.012	0.416	
UST	0.28	0.372*	-9.253	-0.147	0.143	0.052	-0.103	-0.074	0.199	0.034	0.023	-0.156

* Significant at 0.05

** Significant at 0.01

*** Significant at 0.001

Table 13: Simple correlation coefficient between different variables for 10 common bean genotypes at Mlali

	1	2	3	4	5	6	7	8	9	10	11	12
ant height												
o of internodes	0.772***											
0% flowering	0.362	0.276										
0% maturity	-0.03	-0.032	0.421*									
ods per plant	0.33	0.633***	0.089	0.056								
eeds per pod	-0.023	0.308	-0.293	-0.193	0.244							
od length	-0.038	0.269	0.1	0.529**	0.23	0.384*						
od width	0.439	0.422*	0.162	0.446*	0.141	0.164	0.311					
eld	0.427	0.542**	0.036	-0.298	0.489	0.197	0.5**	0.166				
00 S /weight	0.437	0.276	0.514**	0.32	-0.139	0.191	-0.27	0.457	-0.089			
BB	-0.056	-0.129	-0.301	-0.238	0.001	0.134	-0.011	0.206	-0.035	-0.068		
LS	0.263	0.308	0.004	0.009	0.311	0.181	0.263	0.096	0.298	0.088	0.56	
UST	0.08	0.008	0.482**	0.511	0.041	0.064	0.026	-0.264	0.019	0.251	-0.208	0.316

* Significant at 0.05

** Significant at 0.01

*** Significant at 0.001

Table 14: Simple correlation coefficient between different variables for 10 common bean genotypes at Mgeta

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	plant height														
2	No of internode	0.388*													
3	50% flowering	-0.088	0.368*												
4	80% maturity	-0.086	0.442*	0.377*											
5	Pods per plant	0.225	0.818***	0.217	0.37*										
6	Seeds per pod	0.214	0.588**	0.332	0.676***	0.576**									
7	Pod length	0.07	0.644***	0.374*	0.654***	0.655***	0.797***								
8	Pod width	0.025	0.596***	0.401*	0.688***	0.583***	0.877***	0.816***							
9	Yield	0.295	0.584***	-0.001	0.322	0.687***	0.578***	0.62***	0.527**						
10	100 SW	0.206	0.614***	0.377*	0.715***	0.522***	0.926***	0.695***	0.816***	0.484**					
11	CBB	0.145	0.295	-0.019	0.265	0.175	0.445	0.338	0.356	0.167	0.142*				
12	ALS	-0.049	0.043	0.09	0.254	-0.074	0.337	0.303	0.319	0.171	0.312	0.714***			
13	RUST	0.051	0.331	0.219	0.173	0.592***	0.263	0.361*	0.305	0.508**	0.175	-0.233	0.332		
14	ASC	0.268	-0.339	-0.214	0.561***	-0.356	0.427*	0.543**	0.578***	0.485**	0.378*	-0.075	0.125	-0.313	
15	PM	0.056	0.068	0.028	0,305	0.036	0.186	0.221	0.144	-0.064	0.124	0.212	0.282	0.029	0.095

Table 15: Simple correlation coefficient between different variables for 9 common bean genotypes combined for 3 locations

	1	2	3	4	5	6	7	8	9	10	11	12
height												
	0.679**											
f internodes	*											
	0.387**											
flowering	*	0.288**										
			0.774**									
maturity	0.254*	-0.178	*									
		0.541**	0.424**									
s per plant	0.321**	*	*	0.266*								
		0.561**	0.349**		0.598**							
s per pod	0.340**	*	*	-0.026	*							
	0.375**	0.618**			0.534**	0.723**						
ength	*	*	0.385**	-0.141	*	*						
					0.384**	0.465**	0.355**					
width	0.123	0.338**	-0.078	-0.001	*	*	*					
	0.394**	0.467**	0.462**		0.713**	0.524**	0.525**					
l	*	*	*	0.250*	*	*	*	0.142				
						0.649**		0.305**	0.266			
eed wgt	0.004	0.219*	0.177	0.467	0.343**	*	0.312**	*	*			
	0.354**		0.562**	0.632**						0.308*		
	*	0.288**	*	*	0.259*	-0.082	0.227*	-0.135	-0.191	*		
	0.229*	-0.146	0.576**	0.598**	0.223*	-0.071	-0.098	-0.215	-0.141	0.272*	0.686***	

			*	*								
			0.689**	0.644**					0.272			0.531**
T	0.272*	0.238*	*	*	0.275**	0.230*	-0.212	-0.131	*	0.082	0.446***	*

* Significant at 0.05

** Significant at 0.01

*** Significant at 0.001

4.1.9.4: Stability parameters for variables studied

The result indicates that Rojo genotype had taller plant with a negative b- value and a high positive variance of deviation. All genotypes had a negative b-value below the unity but Pesa had 0 variance of deviation. Zawadi, Mshindi, and EG21R30 had a variance of deviation around a unity (Table 16 and 17).

According to Finlay and Wilkison (1963), varieties with b value around 1 have n average response. When an average response is associated with high yield, varieties are specifically adapted to high yielding environments and are optimally responding to inputs. If they are associated with low yield, the varieties are specifically adapted to low yielding environments b>1 implies high sensitivity to environmental change.

The results show that for a number of internodes, genotype Pesa had a high positive b-value having a variance of deviation of 0 as shown in Tables 16 and 17. Other genotypes had b-value far from a unit and 0 variance of deviation. EG10R5 and EG10R13 had a low variance of deviation and few numbers of internodes per plant. Rojo had a high mean number of internodes having b-value far below from a unit which also means having a high variance of deviation.

For days to 50% flowering (Tables 16 and 17), none of the genotypes had b-value or variance of deviation around unity, where the values for b and a variance of deviation ranged between 3.5-4.5 and 6-28 respectively. The relationship between mean days to 80% maturity and stability parameters shows that none of the genotypes had low b-value or low variance of deviation (Tables 16 and 17).

For pods per plant the results in Tables 16 and 17 shows that Pesa had high mean pods per plant with low b-value, and EG10R43 having a low number of pods per plant with a low b-value than a unit and a low variance of deviation. EG10R43 had low pods per plant with a low b-value than a unit and a low variance of deviation.

The stability parameters for seeds per pod, genotype EG10R43 had a high number of seeds per pod and had b-value far above a unit with positive variance of deviation above the unit. Genotype Rojo had few mean seeds per pod but had b value around a unity and small variance of deviation. Genotype EG10R5 had a high number of seeds per pod, b value 1 and 0 variance of deviation as indicated in Tables 16 and 17.

For pod length genotype, SUA90 had long pods but had a high positive b value with a low variance of deviation. Genotypes Rojo and EG21R30 had long pods with b value around a unity and a low variance of deviation (Tables 16 and 17).

Stability parameters for pod width as indicated in Tables 16 and 17 show that, Pesa had thick pods with b value around a unit having a low variance of deviation, but EG10R43 had b value around a unit and variance of deviation above the unit, with thick pods.

For seed yield, a higher yielder was SUA 90 (416 Kg/ha) followed by Zawadi (341.7kg/ha), EG21R30 (339.3kg/ha), EG10R5 (323.3 kg/ha) and Rojo (322.3kg/ha) all of which were greater than mean, EG10R13 had a low yield (143.2 kg/ha) All these seed yields had high b value and variance of deviation (Tables 16 and 17).

Tables 16 and 17 show that for 100 seed weight, EG10R43 and Pesa had large seed size, having a low b value and a high variance of deviation. Genotype SUA 90, EG10R5 and EG10R13 had a medium seed size and b value around 1 except EG10R13 which had b value of 2.59, but all had a high variance of deviation. The rest of the genotypes had a small seed size with a high b value and a low variance of deviation

Table 16: b-values for stability parameters for 9 genotypes combined over three locations (SUA, Mlali and Mgeta)

Genotype	b-values for means of									
	Plant height	No of internodes	Days to 50% flowering	Days to 80% maturity	Pods/plant	Seeds /pod	Pod length (cm)	Pod width (cm)	Seed yield (kg/ha)	100 seed Wt (g)
Rojo	-5.1	5.5	4	34.5	-1.5	0.5	-0.6	0.08	37.83	9.49
SUA90	-1.2	-4.5	3.5	5	-1.0	-1.0	-3.7	0.47	9.21	1.16
Pesa	-4.9	4.0	4	28.5	-3.5	-0.5	-1.5	0.66	46.73	3.3
EG10R5	-3.4	-1.5	3.5	121	-1.0	-1.0	-1.8	0.08	3.46	1.71
Zawadi	-4.6	-3.5	3.5	21	-1.5	-0.5	-3.7	0.45	29.05	5.27
EG10R43	-3.0	-3.5	4.5	19.5	-2.0	-2.0	-3.1	0.99	27.16	8.7
Mshindi	-4.2	-3.5	3.5	24	-1.5	-0.5	0.3	0.16	29.25	6.92
EG21R30	-3.6	-2.0	3.5	33	-1.5	0	-0.6	0.18	26.7	11.2
EG10R13	-1.2	-2.5	3.5	24	-3.0	-0.5	-1.8	0.72	2.6	2.59

Table 17: Variance of deviation for stability parameters for 9 genotypes combined over three locations (SUA, Mlali and Mgeta

Genotype	Variance of deviation for means of									
	Plant height	No of internodes	Days to 50% flowering	Days to 80% maturity	Pods Plant	Seeds pod	Pod length	Pod width	Seed yield	100 seed weight (g)
Rojo	26.8	13.5	6.0	748.2	4.5	0.2	0.2	0.004	31	0.01
SUA90	0.48	4.2	13.5	24	24	0.7	0.1	0.13	8178	9.91
Pesa	0.0	0.0	10.67	433.5	20.2	1.5	2.2	0.29	788.6	57.29
EG10R5	3.1	0.2	4.17	8740	6.0	0.0	2.4	0.01	2386	32.76
Zawadi	1.0	13.5	13.5	416.7	48.2	0.2	6.9	0.24	7724	0.01
EG10R43	4.8	13.5	13.5	228.2	0.7	2.7	2.1	0.52	2209	206.2
Mshindi	0.7	1.5	28.17	294	28.17	0.2	0.6	0.01	1070	1.4
EG21R30	0.3	6.0	13.5	560	4.2	0.7	0.1	0.0	1170	1.34
EG10R13	8.9	0.2	8.17	322.7	16.7	0.2	2.0	0.23	836.9	150

4.2: Discussion

4.2.1 Performance of genotypes in three locations

Genotypes differed significantly on plant height, pods per plant, days to 50% flowering and angular leaf spot severity. Similar results on some vegetative and yield components on maize were reported by Ngowi (2002). This trend is due to genetic difference of the genotypes used, for these genotypes were derived from a bean population with a wide genetic base. Environment differences (location, replanting and limited moisture) also contributed to these differences, because they cause the genotypes to perform differently when they are grown under different environments (Gardener, 1988).

The performance of genotypes at Mlali was better compared to that of the other locations, because of differences in planting time. At Mgeta and SUA, replanting was done a month after Mlali because the first seedlings were destroyed by rain. Planting at Mlali was done in the month of April which received the highest amount of rainfall per month. Planting in the other two locations was done a month later when the rains had decreased (Appendix 1). This was the main factor that contributed to the difference in performance of these genotypes across the locations. Late planting contributed to the low yields given by the genotypes. These yields were below the genotypes yield potential.

The results reveal that for combined analysis, the general performance of genotypes was good for all the studied variables at all the sites, with the exception of genotype EG10R13 while plant height and days to 80% maturity were shorter and took more days compared to other genotypes. Hence, it is recommended that these be grown in all three sites. The results also reveal significant effect of diseases severity for combined analysis;

genotypes EG10R5 and EG21R30 succumbed more than others to common bacterial blight, and angular leaf spot respectively. For combined analysis the number of days to 50% flowering and the number of days to 80% maturity were shorter at SUA and Mlali site compared to the same phenomenon at Mgeta due to the effect of temperature. The effect of temperature on flowering has been reported early by Yoshida (1981), who observed that there is sensitivity to temperature below 30°C, and that flowering is influenced by an increase in temperature. Flowering is accelerated by an increase in temperature which facilitates nodes development hence earlier flowering and maturity the presence of genetic differences in flowering duration among genotypes varied due to perhaps differences in temperature. Similar results on genotypic sensitivity on temperature changes have been reported by (Monteith and Scott, 1982). Increasing temperature above the coolest limit up to 20°C to 25ºC for temperate crops, and 25°C to 37ºC for tropical crops accelerates development, (Monteith and Scott, 1982; Moaghan *et al*,. 2002).

Soil moisture differences among the three sites as depicted by the amount of rainfall received (Appendix 1) and the time of planting were the probable physiological factors that influenced flowering and maturity duration thus affecting plant growth and development. Genotype sensitivity and response varied due to difference in soil moisture regimes. Similar results have been reported by Setimela (1997), who observed that maize genotypes responded differently to drought at various growth stages. The effect of low soil moisture and low temperatures have also been observed by scientists working on other cereal crops like rice (Ohashi *et al.*, 2000; Vergara, 1976) who found a differential decrease in the growth and development and consequently flowering duration when temperatures are low.

The results of this study from ANOVA show significant differences among genotypes for all the studied variable across locations, except for 100 seeds weight. The performance of genotypes was different due to differences in their genetic constitution, As Beeker and Leon (1988) and Brancourt-Hulmel *et al.,* (1997), note genetic constitution, has a bearing on the extent of G x E interaction. In this study the effects associated with location were highly significant in determining differential genotype responses. In other words, the location component of variance was larger than the genotype component for all variables except for 100 seed weight (non significant); In the genotype component of variance, the trait, and plant height were highly significant. Similar results for seed yield are reported by Polignano *et al.,* (2009) on his study on grass pea. These non-interactions indicate that from a statistical point of view, the relative performance among genotypes is the same from location to location. This indicates that genetic variation for all variables existed among the genotypes except for 100 seed weight and that the selection should be effective for these traits in the improvement of future work. For 100 seeds weight, there was no interaction between location and genotypes indicating that the lines behaved similarly in all locations.

Significant ($p \leq 0.001$) interaction was observed for location and genotype on variable plant height, which indicates that genotypes and location had a major effect-on the plant height trait. The same result was obtained by Ohashi *et al.* (2000), on the effect of low temperatures and insufficient soil moisture on plant height reduction in rice.

In the combined three location analysis, there were significant differences for number of internodes per plant among the evaluated genotypes which implies that the environment

plays a major role in influencing the performance of common bean genotypes. Hence, under favourable conditions (such as adequate moisture, good nutrient availability and ideal temperature), a common bean plant elongates more by producing more branches hence more nodes.

For the number of pods per plant, the results show highly significant differences for location and significant differences for genotypes implying that the number of pods harvested varied according due to differences in both genotypes and the environment (Table 8). Tryphone (2008), obtained similar results in his work on diversity of common bean (Phaseolus vulgaris L.) varieties in iron and zinc contents from collections in major growing areas of Tanzania.

This study shows that location had a strong influence on the number of seeds per pod, and pod length, which showed highly significant differences; and pod width (which showed significant differences). Among locations, genotypes varied significantly on most of the studied variables, this suggests that the three environments were not similar Genotype x Location interaction was not significant though, this was probably due to in planting seedlings at different times. Despite the fact that the number of seed per pod was genotype-specific, differences in moisture at around pod filling at the three sites due to differences in the time of plating could have led to differential leaf senescence, which in turn might have caused the reduction pod size with reduced seed numbers from one location to another (Ngowi, 2002). Also genetic variability in the tested genotypes is likely because the genotypes used have all been derived from common bean populations with a wide genetic base.

The findings suggest that there were no significant differences between genotypes on seed size (100 seed weight). The differential response of genotypes of the seed size over locations implies that environmental factors were not the same. For 100 seed weight, G x E interaction was not significant as compared to genotype and location differences respectively). Similar results were reported by, Tryphone (2008). The location differences could be attributed to differences in the times of planting, soil and climatic conditions, planting at SUA and Mgeta was done in May and june respectively, a month after Mlali. At this time of the yea,r the rains had declined considerably (Appedix 1). Similarly Matsushime (1980) who worked on rice noted that higher grain weight can be obtained when crops are not stressed by moisture and nutrient availability near grain filling stage.

As far as seed yield is concerned, the combined ANOVA (Table 8) shows no significant G x E interactions except but location had an effect on seed yield. This indicates that in this study, location played a major role in influencing most traits or yield components measured. The performance of genotypes was good at medium and low altitude, and their performance relative to each other was not the same as genotype changed their rank across the environments, though the general seed yield was not good this is because of rainfall distribution during growing period. Altogether bean yield is a product of several yield components including the number of pods/plant, seeds/pod and seed weight. These components are generally the product of sequential development processes (Heinrich *et al.*, 1983).

Disease severity was higher at Mgeta for the three major diseases, additional diseases *i.e. Ascochyta* and powdery mildew were noted at Mgeta site only. *Ascochyta* disease was so severe for most genotypes leading to the reduction in seed yield. The high

altitude at Mgeta provides a conducive environment for these diseases as indicated by Wortmann *et al.,* (1998). Therefore, it is important to synchronize planting time to periods of low infection rates or use pesticides in order to combat the disease.

4.2.2 Relationship among traits

The results from this study indicate positive correlations between yield and the number of pods per plant, plant height and 100 seed weight. These results agree with those of Nienhuis and Singh (1985) and those of Adams (1973) who found that yield was positively correlated with number of pods per plant. These traits are indicators for yield, hence could be selected simultaneously in breeding programs. High correlations were also observed between number of days to 50% flowering and the number of days to 80% maturity. These results agree with those of Mduruma and Nchimbi (1994); Cerna and Bearver (1990) who observed a positive correlation between days to flowering and days to 80% maturity indicating a possibility of simultaneous selection for both traits.

The results from this study indicate a positive correlation between yield and plant height implying that as the plant height increases, the yield tend to increase. Again a significant positive correlation between yield and days to 50% flowering implies that later flowering beans result into high yields because under favourable conditions, bean plant produces more branches resulting into more nodes per plant hence more pods per plant and therefore high yields. Kuruvadi and Escobar (1993) obtained the the same results of the association between yield and pods/plant in common bean. The same result was also obtained by Weber and Moorthy (1952) on grain yield which was highly significant and positively associated with pods/plant and seed weight. Johnson *et al.* (1955b) reportedof there being positive and significant correlations between yield and seed weight in

soybeans. Correlation between pods per plant and plant height with internodes number at Mlali indicates that as internodes number increases there is an increase in pods per plant and plant height. Significant correlations were also observed between days to 80% maturity with pods/plant, plant height with pods/plant, plant height with seed yield and pods with seed yield all of which were consistently positive and significant across locations implying that these traits have stable relations and can be selected for improvement simultaneously in breeding programmes. Thus, the selections for pods/plant, seed/pod, and seed weight individually or simultaneously should increase yielding ability of the genotypes. Other relations like days to 50% flowering with plant height, pods/plant with days to 50% flowering, seed yield with days to 50% flowering, plant height with days to 80% maturity and days to 80% maturity with 100 seed weight were specific to locations and thus such associations depend the on environment.

4.2.3 Stability of genotypes

Finlay and Wilkison (1963) stated that varieties with b values around 1 have an average response. When an average response is associated with high yield, varieties are specifically adapted to high yielding environments and are optimally responding to inputs. If they are associated with low yield, the varieties are specifically adapted to low yielding environments. When b>1 it implies that the varieties have high sensitivity to environmental change. Eberhart and Russell (1966) proposed an assessment of cultivar response to environmental changes using a linear regression coefficient and the variance of the regression deviations. Therefore, in this case a desirable stable variety is the one with mean yield higher than the average of all the cultivars under test and a regression coefficient around unity and a small deviation from a regression possibly around zero. Genotype SUA 90, Rojo, EG10R5, Zawadi and EG21R30 had a high seed yield but

none had a b value and a variance of regression of around unit and zero respectively. This implies that these genotypes are unstable and should be grown only under favourable environments. Similar observations were made by Paulo (2000) on his study on yield stability in maize *(Zea mays* L.) and correlation among the parameters. Other genotypes had low yield than the average that means they are unstable and are adapted to low yielding environments.

The results show that for a number of internodes, genotype Pesa was stable and adapted to favourable growth environments. Other genotypes had a b-value far from a unit and 0 variance of deviation. EG10R5 and EG10R13 had low a variance of deviation, negative b value and few numbers of internodes per plant which indicates that they are stable and adapted to unfavourable environment. Rojo had a high mean number of internodes having a b-value far below a unit meaning it also has a high variance of deviation indicating that it is unstable and. adapted to unfavourable environments

For days to 50% flowering, none of the genotypes had a b-value or a variance of deviation around unit, all genotypes had a high b value and a high variance of deviation. Therefore, the genotypes were unstable as they were adapted to unfavourable environment.

The relationship between mean days to 80% maturity and stability parameters shows that no genotype had a low b value or low variance of deviation. Therefore, the genotypes were unstable and adapted to unfavourable environment for this variable.

For pods per plant, the results show that Pesa had a high mean pods per plant with a low b-value, and EG10R43 having low pods per plant with low b-value than a unit and low variance of deviation. EG10R43 had a low pods per plant with low b-value than a unit and a low variance of deviation.

The estimate of stability parameters for mean seeds per pod indicates that genotype EG10R43 had a high number of seeds per pod, stable and adapted to favourable growth condition, genotype Rojo and EG10R5 had few mean seeds per pod, stable and had an average adaptation for this variable. For pod length genotype Rojo, SUA 90 and EG21R30 had long pods, stable and adapted to unfavourable environment. Pesa and EG10R43 had thick pods, and the estimation of stability parameters indicates that these pods have an average adaptation and are stable and unstable respectively. For seed yield all genotypes are adapted to favourable environment and are unstable as they had a high b value and a high variance of deviation.

For 100 seed weight, EG10R43 and Pesa had large seed size, was unstable and adapted to unfavourable condition. Genotype SUA 90, EG10R5 and EG10R13 were unstable had an average adaptation but EG10R13 adapted to favourable condition. The rest of the genotypes had small seed size and were unstable and adapted to favourable growth condition.

4.2.4 Disease severity

Severity variations on the diseases observed at single sites and from combined analysis were expected as the genotypes are genetically different and the differences in location may have caused the may cause genotypes to behave differently when they are grown

under different environments (Gardener, 1988). This is probably due to environmental changes (soil nutrient availability, moisture and temperature (Wortmann *et al*., 1998).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1: CONCLUSION

Genotypes showed variation on the studied variables though there was no significant difference for genotype x environment interaction which indicates that the lines behaved similarly in the tested locations. The variation observed was due to environment effect on studied locations. The performance of genotypes at Mlali was better than that of other locations, this is due to difference on planting period where at other locations planting was done one month after that of Mlali. Differences in soil moisture among three sites as shown by the amount of rainfall received was another factor that physiologically varied the performance of genotypes across the location. Therefore, location played a major role in influencing the performance of bean genotypes evaluated across three locations also the genotypes showed significant differences in their performance. From a combined analysis, genotype Pesa (416kg/ha) had the highest seed yield followed by EG10R13 (339.83), EG10R43 (341.67kg/ha), Zawadi (323.25kg/ha) and SUA 90 (322.25kg/ha) as had yield above the mean (306.55kg/ha), thus can grown in all sites regardless environmental condition .However, these yields had b value greater than a unit and high a variance of deviation that means they are unstable and can be grown only under favourable environments and respond to input.s

Genotypes performed better for some variables such as yield at their location for example EG10R13 (633.3kg/ha) at Mgeta, Kablankent (661.7kg/ha), (400kg/ha) at Mlali and SUA respectively. Across the locations, SUA 90 performed better with 416kg/ha; other genotypes that performed above the average mean were Rojo, EG10R5, EG21R30

and Zawadi. Though general production was low this was due to rain distribution which was not good during growing season.

This study also reveals a significant positive correlation between yield and days to 50% flowering which implies that later flowering beans results into high yields, as under favourable condition bean plant produce more branches resulting into more nodes per plant hence more pods per plant and therefore high yield.

The results from this study show that diseases Common Bacterial Blight caused by *Xanthomonas phaseoli*, Angular Leaf Spot caused by *Phaseoisariopsis griseola* and Rust caused by *Uromyces appendiculatus* were found to be infecting bean plants in all the locations from late vegetative stage to maturity at different severity score. However, at Mgeta the severity was high for these diseases and others like Ascochyta blight and Powdery Mildew. This trend might be attributed to low temperature and high humidity.

Genotype Rojo and EG10R43 can be grown in all sites without being much affected by Common Bacterial Blight. Genotype EG10R13 also can be grown at all sites as it seems to be least attacked by Angular Leaf Spot at all locations. Genotypes Zawadi, EG10R5, SUA 90 and Pesa were least infected by rust at all locations thus they can be grown at all locations. These genotypes can be crossed with Lyamungu a local variety from Mgeta which had intermediate severity so as to have resistant genotype to rust.

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The results from this study show that some genotypes had good attributes of one or two stability parameters but lack others in various variables including yield. Thus crossing of the two genotypes could result to segregates with performance of attributes suggested for

example; EG21R30 had large seed size, and can be crossed with SUA 90 with small seeds size to have medium seed size.

5.2 Recommendations

Genotype SUA 90, Rojo, EG10R5, Zawadi and EG21R30 with high mean yield and low G x E interaction (widely adapted genotypes) are recommended because they have demonstrated their ability to express high yield potential in favourable environmental conditions.

Genotypes differed for disease reaction at each location, thus determination for pathogenic races will define the important races in the different bean growing areas and such information is necessary in determining broad resistance

A combination of desirable traits were not centred in a single genotype but were distributed over several genotypes. Hybridization between genotypes with higher grain yield and superior lines for yield components could result in desirable recombination in the progeny.

Since these results were for one season for the genotypes, it is suggested that another study be carried for two or more seasons for location x year, season x year and year x year interaction so as to further verify the obtained results.

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APPENDICIES

Appendix 1: Morogoro Maximum, Minimum Temperature and rainfall data for a period beginning from January to September 2008

month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
maxtemp^{0}C	33.2	30.7	31.1	28.5	28.7	27.2	27.2	28.7	30.7
min	22.7	21.5	21.5	20.8	18.4	15.7	15.8	16.6	17
rain (mm)	15.4	77.5	138.7	298.1	27.7	14.9	2.9	3.5	8.9

Appendix 2: Soil physical and chemical characteristics taken at 0−15 cm depth before planting at Mlali, Mgeta and SUA

Location	Mlali		Mgeta		SUA	
Soil property	Results	Remarks	Results	Remarks	Results	Remarks
Sand	68.10 %	high	76%	High	26%	Low
Silt	13.00 %	low	8%	Low	14%	Low
Clay	18.90 %	low	16%	Low	60%	High
pH: H2O	7.44	Moderate alkalinity	6%	Moderate acidity	5.2	Moderate acidity
Textural class		Sandy loam		Sandy loam		Clay

Appendix 3: Estimate of stability parameters of plant height for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean plant height	b	b-1	SE_b	S^2d	R^2 %
Rojo	45.5	-5.1	5.8	3.6	26.8	65.8
SUA90	36.3	-1.2	34.2	0.5	0.48	86.5
Pesa	40.9	-4.9	109.3	0	0	100
EG10R5	37.9	-3.4	13.9	1.3	3.1	88
Zawadi	43.3	-4.6	27.8	0.7	1	97.6
EG10R43	42.0	-3.0	12.5	1.6	4.8	79.1
Mshindi	40.0	-4.2	100.3	0.18	0.7	99.8
EG21R30	38.8	-3.6	46.1	0.4	0.3	98.8
EG10R13	29.2	-1.2	6.4	2.1	8.9	25
Mean	39.3					

Appendix 4: Estimate of stability parameters of number of internodes per plant for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotypes	Mean number of internodes	b	b-1	SE_b	S^2d	R^2 %
Rojo	34.0	5.5	6.1	2.6	13.5	61.8
SUA90	31.7	-4.5	10.16	1.4	4.2	90.7
Pesa	27.0	4.0	5.0	0	0	100
EG10R5	22.33	-1.5	35.8	0.6	0.2	96.4
Zawadi	27.0	-3.5	4.8	2.6	13.5	64.5
EG10R43	29.0	-3.5	5.6	2.6	13.5	64.5
Mshindi	28.0	-3.5	14.9	0.8	1.5	94.2
EG21R30	27.0	-2.0	7.2	1.7	6.0	57.1
EG10R13	23.3	-2.5	37.4	0.29	0.2	98.7
Mean	27.7					

Appendix 5: Estimate of stability parameters of days to 50% flowering for 9 genotypes three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean 50% days	b	b-1	SE_b	S^2d	R^2 %
Rojo	26.0	4.0	3	1.73	6.0	84.2
SUA90	26.0	3.5	2.5	2.6	13.5	64.5
Pesa	24.7	4.0	3.0	2.311	10.67	75.0
EG10R5	26.7	3.5	2.5	1.44	4.17	85.5
Zawadi	26.0	3.5	2.5	2.6	13.5	64.5
EG10R43	24.0	4.5	3.5	2.6	13.5	75.0
Mshindi	27.3	3.5	2.5	3.75	28.17	46.5
EG21R30	29.0	3.5	2.5	2.6	13.5	64.5
EG10R13	27.3	3.5	2.5	2.02	8.17	75.0
Mean	26.33					

Appendix 6: Estimate of stability parameters of days to 80% maturity for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean 80% maturity	b	b-1	SE_b	S^2d	R^2 %
Rojo	31.3	34.5	33.5	19.34	748.2	76.1
SUA90	72.0	5.0	4.0	3.46	24.0	67.6
Pesa	38.0	28.5	27.5	14.72	433.5	78.9
EG10R5	87.0	121	120	66.11	8740.0	76.9
Zawadi	45.7	21.0	20.0	14.43	416.7	67.9
EG10R43	49.3	19.5	18.5	10.68	228.2	76.9
Mshindi	47.0	24.0	23.0	12.12	294.0	79.7
EG21R30	38.3	33.0	32.0	16.74	560.0	79.5
EG10R13	45.7	24.0	23.0	12.7	322.7	78.1
Mean	45.91					

Appendix 7: Estimate of stability parameters of pods per plant for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean pods per plant	b	b-1	SE_b	S^2d	R^2 %
Rojo	13.3	-1.5	4.3	1.4	4.5	51.9
SUA90	13.0	-1.0	1.7	3.4	24.0	7.7
Pesa	16.3	-3.5	2.4	3.2	20.2	54.9
EG10R5	11.0	-1.0	2.9	1.7	6.0	25.0
Zawadi	12.3	-1.5	1.2	4.9	48.2	8.5
EG10R43	10.3	-2.0	8.1	0.6	0.7	92.3
Mshindi	14.7	-1.5	1.8	3.8	28.17	13.8
EG21R30	14.3	-1.5	4.6	1.4	4.2	51.9
EG10R13	13.7	-3.0	2.2	2.9	16.7	51.9
Mean	13.11					

Appendix 8: Estimate of stability parameters of seeds per pod for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean seeds per pod	b	b-1	SE_b	S^2d	R^2 %
Rojo	3.3	0.5	5.4	0.3	0.2	75
SUA90	6.3	-1.0	5.1	0.6	0.7	75
Pesa	5.0	-0.5	2.7	0.9	1.5	25
EG10R5	6.0	-1.0	0.0	0.0	0.0	100
Zawadi	5.7	-0.5	9.1	0.3	0.2	75
EG10R43	7.67	-2.0	3.1	1.2	2.7	75
Mshindi	5.67	-0.5	9.1	0.3	0.2	75
EG21R30	4.3	0	3.5	0.6	0.7	0
EG10R13	4.67	-0.5	7.5	0.3	0.2	75
Mean	5.4					

Appendix 9: **Estimate of stability parameters of pod length for 9 genotypes in** three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean pod length	b	b-1	SE_b	S^2d	R^2 %
Rojo	12.7	-0.6	18.27	0.3	0.2	77.5
SUA90	20.3	-3.7	62.6	0.2	0.1	99.8
Pesa	12.6	-1.5	5.6	1.0	2.2	66.1
EG10R5	14.6	-1.8	6.2	1.1	2.4	73.8
Zawadi	18.74	-3.7	4.7	1.9	6.9	80.2
EG10R43	16.9	-3.1	7.6	1.0	2.1	90.3
Mshindi	10.1	0.3	8.6	0.5	0.6	17.5
EG21R30	12.8	-0.6	37.9	0.2	0.1	94.4
EG10R13	12.8	-1.8	5.9	1.0	2.0	76.4
Mean	14.61					

Appendix 10: Estimate of stability parameters of pod width for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean pod width	b	b-1	SE_b	S^2d	R^2 %
Rojo	2.85	0.08	0.92	0.05	0.004	75.0
SUA90	3.41	0.47	1.47	0.26	0.13	76.6
Pesa	3.94	0.66	1.66	0.38	0.29	75.0
EG10R5	2.77	0.08	0.92	0.05	0.01	75.0
Zawadi	3.53	0.45	1.45	0.35	0.24	61.9
EG10R43	4.35	0.99	1.99	0.5	0.52	79.1
Mshindi	2.62	0.16	0.84	0.05	0.01	90.5
EG21R30	2.53	0.18	0.82	0.02	0	98.7
EG10R13	4.0	0.72	1.72	0.34	0.23	81.8
Mean	3.3					

Appendix 11: Estimate of stability parameters of seed yield for 9 genotypes in three combined locations (SUA, Mlali and Mgeta)

Genotype	Mean yield	b	b-1	SE_b	S^2d	R^2 %
Rojo	322.25	37.83	38.83	3.94	31	98.9
SUA90	416.29	9.21	10.21	63.92	8178	2.0
Pesa	291.07	46.73	43.73	19.22	788.6	85.5
EG10R5	323.25	3.46	4.46	34.54	2386	1.0
Zawadi	341.67	29.05	30.05	62.15	7724	17.9
EG10R43	280.41	27.16	28.16	33.24	2209	40.1
Mshindi	300.12	29.25	30.25	23.13	1070	61.5
EG21R30	339.83	26.7	27.7	24.19	1170	55.0
EG10R13	143.2	2.6	1.6	20.46	836.9	1.6
Mean	306.55					

Appendix 12: Estimate of stability parameters of 100 seed weight (g) for 9genotypes in three combined locations (SUA, Mlali and Mgeta:

Genotype	Mean seed weight (g)	b	b-1	SE_b	S^2d	R^2 %
Rojo	24.6	9.49	8.49	0.66	0.01	100
SUA90	26.4	1.16	0.16	2.23	9.91	21.2
Pesa	43.1	3.3	4.3	5.35	57.29	27.29
EG10R5	31.0	1.71	0.71	4.05	32.76	15.1
Zawadi	24.9	5.27	4.27	0.06	0.01	100
EG10R43	50.1	8.7	9.7	10.15	206.2	42.4
Mshindi	23.7	6.92	5.92	0.84	1.4	98.6

EG21R30	24.4	11.2	10.2	0.82	1.34	99.5
EG10R13	27.0	2.59	1.59	8.67	150.0	8.2
Mean	30.58					